Corporate Yield Spreads: Default Risk or Liquidity? New Evidence from the Credit Default Swap Market

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ABSTRACT

We use the information in credit default swaps to obtain direct measures of the size of the default and nondefault components in corporate spreads. We find that the majority of the corporate spread is due to default risk. This result holds for all rating categories and is robust to the definition of the riskless curve. We also find that the nondefault component is time varying and strongly related to measures of bond-specific illiquidity as well as to macroeconomic measures of bond market liquidity.

HOW DO FINANCIAL MARKETS VALUE CORPORATE DEBT? What portion of corporate yield spreads is directly attributable to default risk? How much of the spread stems from other factors such as liquidity and taxes? These issues are of fundamental importance from an investment perspective since corporate debt outstanding in the United States now approaches $5 trillion, making it one of the largest asset classes in the financial markets. These issues are also of key importance from a corporate finance perspective because the presence of nondefault components in corporate spreads could directly affect capital structure decisions as well as the timing of debt and equity issuances.

A number of articles have studied the determinants of corporate yield spreads. Important examples include Jones, Mason, and Rosenfeld (1984), Longstaff and Schwartz (1995a), Duffie and Singleton (1997), Duffee (1999), Elton et al. (2001), Collin-Dufresne, Goldstein, and Martin (2001), Delianedis and Geske (2001), Eom, Helwege, and Huang (2004), Huang and Huang (2003), Collin-Dufresne, Goldstein, and Helwege (2003), Liu, Longstaff, and Mandell (2004), and many others. Previously, however, researchers have been limited by having only bond data available to them in their efforts to identify the components of corporate spreads.

In the past several years, credit derivatives have begun trading actively in financial markets. By their nature, these innovative contracts provide researchers with a near-ideal way of directly measuring the size of the default component in corporate spreads. Credit derivatives are rapidly becoming one of the most successful financial innovations of the past decade. The British Bankers' Association estimates that from a total notional amount of $180 billion in 1997, the credit derivatives market grew more than tenfold to $2.0 trillion by the end of 2002. Furthermore, the British Bankers' Association forecasts that the total notional amount of credit derivatives will reach $4.8 trillion by the end of 2004.

This paper uses the information in credit default swap premia to provide direct measures of the size of the default and nondefault components in corporate yield spreads. Credit default swaps are the most common type of credit derivative. In a credit default swap, the party buying protection pays the seller a fixed premium each period until either default occurs or the swap contract matures. In return, if the underlying firm defaults on its debt, the protection seller is obligated to buy back from the buyer the defaulted bond at its par value. Thus, a credit default swap is similar to an insurance contract that compensates the buyer for losses arising from a default. A key aspect of our study is the use of an extensive data set on credit default swap premia and corporate bond prices provided to us by the Global Credit Derivatives desk at Citigroup. This proprietary data set include weekly market quotations for a broad cross-section of firms actively traded in the credit derivatives market.

In measuring the size of the default component, we use two approaches. First, we use the credit default swap premium directly as a measure of the default component in corporate spreads. As shown by Duffie and Liu (2001), however, this widely used model-independent approach can be biased. Accordingly, we also use a reduced-form model approach to measure the size of the default component. Specifically, we develop closed-form expressions for corporate bond prices and credit default swap premia within the familiar Duffie and Singleton (1997, 1999) framework. In this reduced-form model, corporate bond cash flows are discounted at an adjusted rate that includes a liquidity or convenience yield process. This feature allows the model to capture any liquidity or other nondefault-related components in corporate bond prices. For each firm in the sample, we fit the model jointly to credit default swap premia and a cross-section of corporate bond prices with maturities straddling the 5-year horizon of the credit default swaps in the sample. Once estimated, the default component is given directly from the closed-form expression for corporate bond prices. We illustrate these approaches with a detailed case study of Enron. The analysis is then extended to include all firms in the sample. To ensure that the results are robust to alternative specifications of the riskless rate, we report results using the Treasury, Refcorp, and swap curves to calculate corporate spreads.

We find that the default component accounts for the majority of the corporate spread across all credit ratings. In particular, calculating spreads relative to the Treasury curve, the default component represents 51% of the spread for AAA/AA-rated bonds, 56% for A-rated bonds, 71% for BBB-rated bonds, and

83% for BB-rated bonds. The percentages are even higher when the other curves are used to calculate spreads.

These results contrast with those in Jones et al. (1984), Elton et al. (2001), Delianedis and Geske (2001), Huang and Huang (2003), and others who report that default risk accounts for only a small percentage of the spread for investment-grade bonds. However, Elton et al. find that spreads include an important risk premium in addition to compensation for the expected default loss. Since the credit default swap premium measures the risk-neutral default component (expected default loss plus credit risk premium), our results may in fact be consistent with those of Elton et al. Furthermore, both Delianedis and Geske and Huang and Huang show that under some parameterizations, results paralleling ours can be obtained from a structural model, though this requires either larger jump sizes or larger credit risk premia than in typical calibrations.[1] Finally, Eom et al. (2004) show that some structural models can actually overestimate corporate spreads. Thus, our results may prove useful in identifying which structural models and calibrations best explain the pricing of corporate debt.

On the other hand, our results indicate that the default component does not account for the entire corporate credit spread. Using the Treasury curve to calculate spreads, we find evidence of a significant nondefault component for every firm in the sample. This nondefault component ranges from about 20–100 basis points. Similarly, using the Refcorp and swap curves, we find evidence of a significant nondefault component for 96% and 75% of the firms in the sample, respectively.

To test whether the nondefault component is related to taxes or the illiquidity of corporate bonds, we regress the average value of the nondefault component on the coupon rate and various measures of individual corporate bond illiquidity. We find only weak evidence that the nondefault component is related to the differential state tax treatment given to Treasury and corporate bonds. In contrast, the nondefault component is strongly related to measures of individual corporate bond illiquidity such as the size of the bid–ask spread and the principal amount outstanding. We also explore the time-series properties of the average nondefault component by regressing weekly changes in its value on lagged changes and measures of Treasury richness or specialness and overall bond market liquidity. The average nondefault component is strongly mean reverting and is directly related to measures of Treasury bond richness and marketwide measures of liquidity such as flows into money market mutual funds and the amount of new corporate debt issued. These results indicate that there are important individual corporate bond and marketwide liquidity dimensions in spreads.

The literature on credit derivatives is growing rapidly. Important theoretical work in the area includes Jarrow and Turnbull (1995, 2000), Longstaff and Schwartz (1995a, 1995b), Das (1995), Das and Tufano (1996), Duffie (1998,

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[1] However, recent work by Pan (2002), Collin-Dufresne et al. (2003), and Liu et al. (2004), suggests that the market price of jump-related risks such as default is surprisingly high in some markets.

1999), Lando (1998), Duffie and Singleton (1999), Hull and White (2000, 2001), Das and Sundaram (2000), Jarrow and Yildirim (2002), Acharya, Das, and Sundaram (2002), Das, Sundaram, and Sundaresan (2003), and many others. There are also several recent empirical studies of the pricing of credit default swaps, including Cossin et al. (2002), Zhang (2003), Blanco et al. (2003), Houweling and Vorst (2004), Norden and Weber (2004), Hull, Predescu, and White (2004), and Berndt et al. (2004). This paper differs from these others in that we use the information in credit default swap premia to study the components of corporate yield spreads.

The remainder of this paper is organized as follows. Section I provides a brief introduction to credit default swaps and the credit derivatives market. Section II describes how the default component of corporate spreads is identified from credit default swap and corporate bond data. Section III presents a case study of Enron. Section IV presents the empirical estimates of the size of the default component in corporate spreads. Section V examines the properties of the nondefault component of the spread. Section VI summarizes the results and makes concluding remarks.

I. Credit Default Swaps

Credit derivatives are contingent claims with payoffs that are linked to the creditworthiness of a given firm or sovereign entity. The purpose of these instruments is to allow market participants to trade the risk associated with certain debt-related events. Credit derivatives widely used in practice include total return swaps, spread options, and credit default swaps.[2] In this paper, we focus exclusively on the latter since they are the predominant type of credit derivative trading in the market.[3]

The simplest example of a single-name credit default swap contract can be illustrated as follows. The first party to the contract, the protection buyer, wishes to insure against the possibility of default on a bond issued by a particular company. The company that has issued the bond is called the reference entity. The bond itself is designated the reference obligation. The second party to the contract, the protection seller, is willing to bear the risk associated with default by the reference entity. In the event of a default by the reference entity, the protection seller agrees to buy the reference issue at its face value from the protection buyer. In return, the protection seller receives a periodic fee from the protection buyer. This fee, typically quoted in basis points per $100 notional amount of the reference obligation, is called the default swap premium. In the event of default, the contract is settled (exchange of the bond and the face value) and the protection buyer discontinues the periodic payment. If a default does not occur over the life of the contract, then the contract expires at its maturity date.

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[2] Credit default swaps on a portfolio of bonds, sometimes called portfolio credit default swaps, also exist. For example, see Fitch, Duff, and Phelps (2001).

[3] The British Bankers' Association (2002) reports that single-name credit default swaps are the most popular type of credit derivative, representing nearly 50% of the credit-derivatives market.

As a specific example, suppose that on January 23, 2002, a protection buyer wishes to buy 5 years of protection against the default of the Worldcom 7.75% bond maturing April 1, 2007. The buyer owns 10,000 of these bonds, each having a face value of $1,000. Thus, the notional value of the buyer's position is $10,000,000. The buyer contracts to buy full protection for the face value of the debt via a single-name credit default swap with a 169 basis point premium. Thus, the buyer pays a premium of $A/360 \times 169$, or approximately 42.25 basis points per quarter for protection, where A denotes the actual number of days during a quarter. This translates into a quarterly payment of $A/360 \times \$10,000,000 \times 0.0169 = A/360 \times \$169,000$. If there is a default, then the buyer delivers the 10,000 Worldcom bonds to the protection seller and receives a payment of $10,000,000. If the credit event occurs between default swap premium payments, then at final settlement, the protection buyer must also pay to the protection seller that part of the quarterly default swap premium that has accrued since the most recent default swap premium payment.[4] Credit events that typically trigger a credit default swap include bankruptcy, failure to pay, default, acceleration, a repudiation or moratorium, or a restructuring.

In the most general credit default swap contract, the parties may agree that any of a set of bonds or loans may be delivered in the case of a physical settlement (as opposed to cash settlement, to be discussed below). In this case, the reference issue serves as a benchmark against which other possible deliverable bonds or loans might be considered eligible. In any case, the deliverable obligations are usually specified in the contract. It is also possible, however, that a reference obligation may not be specified, in which case, any senior unsecured obligation of the reference entity may be delivered. Alternatively, cash settlement, rather than physical settlement, may be specified in the contract. The cash settlement amount would either be the difference between the notional and market value of the reference issue (which could be ascertained by polling bond dealers), or a predetermined fraction of the notional amount. Note that because the protection buyer generally has a choice of the bond or loan to deliver in the event of default, a credit default swap could include a delivery option similar to that in Treasury note and bond futures contracts.[5]

Since credit default swaps are over-the-counter contracts, the maturity is negotiable and maturities from a few months to 10 years or more are possible, although 5 years is the most common horizon. In this paper, we focus on credit default swaps for corporates and financials with a 5-year horizon. The notional amount of credit default swaps ranges from a few million to more than a billion dollars, with the average being in the range of $25–$50 million (J.P. Morgan (2000)). A wide range of institutions participates in the credit derivatives market. Banks, security houses, and hedge funds dominate the protection buyers' market, with banks representing about 50% of the demand. On the protection sellers' side, banks and insurance companies dominate (British Bankers' Association (2002)).

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[4] Worldcom filed for bankruptcy on July 21, 2002.

[5] For an in-depth discussion of this feature, see Mithal (2002).

II. Measuring the Default Component

In this section, we describe the two approaches used to measure the size of the default component in corporate yield spreads. To be clear about definitions, corporate bond yield spreads will always be calculated as the yield on a corporate bond minus the yield on a riskless bond with the identical coupon rate and maturity date. Thus, we compare the yields on risky and riskless bonds with identical promised cash flows.[6]

In the first approach, we follow the widely used industry practice of assuming that the credit default swap premium equals the default component for the firm's bonds. Comparing the credit default swap premium for a 5-year contract directly with the corporate spread for a 5-year bond provides a simple model-independent measure of the percentage size of the default component.

Although straightforward to implement, it is important to stress that this approach generally produces a biased measure of the default component. As shown by Duffie (1999), the credit default swap premium should equal the spread between corporate and riskless floating-rate notes. Duffie and Liu (2001), however, show that the spread between corporate and riskless fixed-coupon bonds is generally not equal to the spread between corporate and riskless floating-rate notes. As we will show, the difference between fixed-rate and floating-rate spreads can be as much as 5–10 basis points or more in our sample. In general, the effect of the bias is to underestimate the size of the default component in investment-grade bonds, and vice versa for below-investment-grade bonds. This bias can be avoided by using an explicit credit model to make the adjustment from floating-rate to fixed-rate spreads. Accordingly, in our second approach, we develop a simple closed-form model for valuing credit-sensitive contracts and securities within the well-known reduced-form framework of Duffie (1998), Lando (1998), Duffie and Singleton (1997, 1999), and others. Once fitted to the data, the model can then be used to provide direct estimates of the default component of the spread implied by credit default swap premia.

Following Duffie and Singleton (1997), let r_t denote the riskless rate, λ_t the intensity of the Poisson process governing default, and γ_t a convenience yield or liquidity process that will be used to capture the extra return investors may require, above and beyond compensation for credit risk, from holding corporate rather than riskless securities. Each of the processes r_t, λ_t, and γ_t is stochastic, although we assume that they evolve independently of each other. This assumption greatly simplifies the model, but has little effect on the empirical results. As in Lando (1998), we make the assumption that a bondholder recovers a fraction $1 - w$ of the par value of the bond in the event of default.

Given the independence assumption, we do not actually need to specify the risk-neutral dynamics of the riskless rate to solve for credit default swap premia and corporate bond prices. We require only that these dynamics be such that

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[6] This feature is important since this allows us to measure the pure effect of default risk on yields. If the coupon and maturity are not held constant, the yield spread measure can confound the effects of default risk with term structure effects.

the value of a riskless zero-coupon bond $D(T)$ with maturity T be given by the usual expression,

$$D(T) = E\left[\exp\left(- \int_0^T r_t \, dt \right) \right]. \tag{1}$$

To specify the risk-neutral dynamics of the intensity process λ_t, we assume that

$$d\lambda = (\alpha - \beta\lambda) \, dt + \sigma \sqrt{\lambda} \, dZ_\lambda, \tag{2}$$

where α, β, and σ are positive constants, and Z_λ is a standard Brownian motion. These dynamics allow for both mean reversion and conditional heteroskedasticity in corporate spreads, and guarantee that the intensity process is always nonnegative. For the risk-neutral dynamics of the liquidity process γ_t, we assume that

$$d\gamma = \eta \, dZ_\gamma, \tag{3}$$

where η is a positive constant and Z_γ is also a standard Brownian motion. These dynamics allow the liquidity process to take on both positive and negative values.[7]

Following Duffie (1998), Lando (1998), Duffie and Singleton (1999), and others, it is now straightforward to represent the values of corporate bonds and the premium and protection legs of a credit default swap as simple expectations under the risk-neutral measure. Let c denote the coupon rate for a corporate bond, which for expositional simplicity is assumed to pay coupons continuously. The price of this corporate bond $CB(c, w, T)$ can be expressed as

$$\begin{aligned}
CB(c, w, T) = \; & E\left[c \int_0^T \exp\left(- \int_0^t r_s + \lambda_s + \gamma_s \, ds \right) dt \right] \\
& + E\left[\exp\left(- \int_0^T r_t + \lambda_t + \gamma_t \, dt \right) \right] \\
& + E\left[(1 - w) \int_0^T \lambda_t \exp\left(- \int_0^t r_s + \lambda_s + \gamma_s \, ds \right) dt \right].
\end{aligned} \tag{4}$$

The first term in this expression is the present value of the coupons promised by the bond, the second term is the present value of the promised principal payment, and the third term is the present value of recovery payments in the event of a default. Observe that in each term, corporate cash flows are discounted at the adjusted discount rate $r_t + \lambda_t + \gamma_t$.

Turning now to the valuation of the credit default swap, it is important to recall that swaps are contracts, not securities. This distinction is important because the contractual nature of credit default swaps makes them far less sensitive to liquidity or convenience yield effects. First, securities are in fixed supply.

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[7] We also explore alternative specifications for γ_t that allow for a mean-reverting drift. These specifications generally do not perform better than equation (3), and often do worse because of parameter identification problems.

In contrast, the notional amount of credit default swaps can be arbitrarily large. This means that the types of supply and demand pressures that may affect corporate bonds are much less likely to influence credit default swaps. Second, the generic or fungible nature of contractual cash flows means that credit default swaps cannot become "special" in the way that securities such as Treasury bonds or popular stocks may.[8] Third, since new credit default swaps can always be created, these contracts are much less susceptible to being "squeezed" than the underlying corporate bonds. Fourth, since credit default swaps resemble insurance contracts, many investors who buy credit protection may intend to do so for a fixed horizon and, hence, may not generally plan to unwind their position earlier. Fifth, even if an investor wants to liquidate a credit default swap position, it may be less costly to simply enter into a new swap in the opposite direction than to try to sell his current position. Thus, the liquidity of his current position is less relevant given his ability to replicate swap cash flows through other contracts. Sixth, it can sometimes be difficult and costly to short corporate bonds. In contrast, it is generally as easy to sell protection as it is to buy protection in credit default swap markets. Finally, Blanco, Brennan, and Marsh (2003) find that credit derivative markets are more liquid than corporate bond markets in the sense that new information is impounded into credit default swap premia more rapidly than into corporate bond prices.

Because of these considerations, we assume that the convenience yield or illiquidity process γ_t is applicable to the cash flows from corporate bonds, but not to cash flows from credit default swap contracts. Alternatively, γ_t can also be viewed as the differential convenience yield between corporate securities and credit derivative contracts.[9]

Let s denote the premium paid by the buyer of default protection. Assuming that the premium is paid continuously, the present value of the premium leg of a credit default swap $P(s, T)$ can now be expressed as

$$P(s, T) = E\left[s \int_0^T \exp\left(-\int_0^t r_s + \lambda_s \, ds \right) dt \right]. \tag{5}$$

Similarly, the value of the protection leg of a credit default swap $PR(w, T)$ can be expressed as

$$PR(w, T) = E\left[w \int_0^T \lambda_t \exp\left(-\int_0^t r_s + \lambda_s \, ds \right) dt \right]. \tag{6}$$

Setting the values of the two legs of the credit default swap equal to each other and solving for the premium gives

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[8] For example, see Duffie (1996), Duffie, Garleanu, Pederson (2002), and Geczy, Musto, and Reed (2002).

[9] Thus, if credit default swaps include a liquidity component, then γ_t might underestimate the size of the nondefault component in corporate bonds. We are grateful to the referee for this observation.

$$s = \frac{E\left[w \int_0^T \lambda_t \exp\left(-\int_0^t r_s + \lambda_s \, ds\right) dt\right]}{E\left[\int_0^T \exp\left(-\int_0^t r_s + \lambda_s \, ds\right) dt\right]}. \tag{7}$$

If λ_t is not stochastic, the premium is simply λw. Even when λ_t is stochastic, however, the premium can be interpreted as a present-value-weighted average of $\lambda_t w$. In general, because of the negative correlation between λ_t and $\exp(-\int_0^t \lambda_s \, ds)$, the premium should be less than the expected average value of λ_t times w.

Given the square-root dynamics for the intensity process λ_t and the Gaussian dynamics for the liquidity process γ_t, standard results such as those in Duffie, Pan, and Singleton (2000) make it straightforward to derive closed-form solutions for the expectations in equations (4) and (7). Appendix A shows that the value of a corporate bond is given by

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\begin{aligned}
CB(c, w, T) = c &\int_0^T A(t) \exp\left(B(t)\lambda\right) C(t) \, D(t) e^{-\gamma t} \, dt \\
&+ A(T) \exp\left(B(T)\lambda\right) C(T) \, D(T) e^{-\gamma T} \\
&+ (1 - w) \int_0^T \exp\left(B(t)\lambda\right) C(t) \, D(t) (G(t) + H(t)\lambda) e^{-\gamma t} \, dt, \quad (8)
\end{aligned}
$$

where λ and γ denote the current (or time-zero) values of the intensity and liquidity processes, respectively, and where

$$A(t) = \exp\left(\frac{\alpha(\beta + \phi)}{\sigma^2} t\right) \left(\frac{1 - \kappa}{1 - \kappa e^{\phi t}}\right)^{\frac{2\alpha}{\sigma^2}},$$

$$B(t) = \frac{\beta - \phi}{\sigma^2} + \frac{2\phi}{\sigma^2(1 - \kappa e^{\phi t})},$$

$$C(t) = \exp\left(\frac{\eta^2 t^3}{6}\right),$$

$$G(t) = \frac{\alpha}{\phi}(e^{\phi t} - 1) \exp\left(\frac{\alpha(\beta + \phi)}{\sigma^2} t\right) \left(\frac{1 - \kappa}{1 - \kappa e^{\phi t}}\right)^{\frac{2\alpha}{\sigma^2} + 1},$$

$$H(t) = \exp\left(\frac{\alpha(\beta + \phi) + \phi\sigma^2}{\sigma^2} t\right) \left(\frac{1 - \kappa}{1 - \kappa e^{\phi t}}\right)^{\frac{2\alpha}{\sigma^2} + 2},$$

$$\phi = \sqrt{2\sigma^2 + \beta^2},$$

and

$$\kappa = (\beta + \phi)/(\beta - \phi).$$

Similarly, Appendix A shows that the credit default swap premium is given by

$$s = \frac{w \int_0^T \exp(B(t)\lambda)D(t)(G(t) + H(t)\lambda)\,dt}{\int_0^T A(t)\exp(B(t)\lambda)D(t)\,dt}. \tag{9}$$

With these closed-form solutions, our empirical approach will be to fit the model to match simultaneously the credit default swap premium and the prices of corporate bonds with maturities straddling the 5-year maturity of the credit default swap.

III. The Enron Case Study

Before applying this approach to the entire sample, it is helpful to first illustrate the methodology via a case study of Enron during the year leading up to its eventual default and Chapter 11 bankruptcy filing on December 2, 2001. Two primary types of Enron data are used in this case study: Credit default swap premia and corporate bond yields.

The credit default swap data used in this case study consist of bid and ask quotations for 5-year credit default swaps on Enron during the period from December 5, 2000 to October 22, 2001. Quotations are obtained on days when there is some level of participation in the market as evidenced either through trades or by active market-making by a dealer. For Enron, we select 31 observations during the sample period, corresponding to roughly a weekly frequency, based on the availability of data on corporate bond yields and credit default swap premia. As the point estimate of the credit default swap premium, we use the midpoint of the bid and ask quotations. The data are provided to us by the Global Credit Derivatives desk at Citigroup. We note, however, that the data set includes quotations from a variety of credit derivatives dealers. Thus, quotations should be representative of the entire credit derivatives market.

Since the credit default swaps in the sample have a 5-year horizon, it would be ideal if there were always a matching 5-year bond available at each observation date from which the corporate spread could be determined. In reality, there are no Enron bonds that exactly match the 5-year maturity of the credit default swaps for any of the observation dates in the sample. Even if there were, the possibility of noise or measurement error in the bond price data would introduce volatility into the estimate of the default probability. To address these two problems, we adopt the following straightforward, and hopefully more robust, approach. Rather than focusing on a specific Enron bond, we use data from a set of bonds with maturities that bracket the 5-year horizon of the credit default swap. The process used to identify these bonds is described in Appendix B. This process results in a set of eight Enron bonds with maturities ranging from June 2003 to October 2007.[10] These eight bonds are all fixed-rate senior unsecured

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[10] The maturity dates of the credit default swaps associated with the first and last dates in the sample are December 5, 2005 and October 22, 2006. Thus, this set of bonds has maturities that bracket the maturity dates of the credit default swap quotes in the sample.

dollar-denominated debt obligations of Enron and do not have any embedded options. Only bonds that are registered with the Securities and Exchange Commission (SEC) are included in the set. The coupon rates for these bonds range from 6.625% to 9.875%. We refer to this set of bonds as the bracketing set. The bond yield data are also obtained from a proprietary corporate bond database provided by Citigroup. Given the well-documented measurement problems associated with corporate bond data, we conduct a number of robustness checks using data for the bonds collected from the Bloomberg system to verify that our data are reliable.

Before turning to the estimation of the default component, we first need to identify a riskless discount function $D(T)$ for each observation date. To ensure that the results are robust to alternative definitions of the riskless rate, we use three different curves to generate the riskless discount function: The Treasury, Refcorp, and swap curves. We use the Treasury curve since it is the standard benchmark riskless curve in most empirical tests in finance. The use of the Refcorp curve is motivated by a recent paper by Longstaff (2004) that shows that Refcorp bonds have the same default risk as Treasury bonds, but not the same liquidity or specialness of Treasury bonds. Thus, the Refcorp curve may provide a more accurate measure of the riskless curve than the Treasury curve. Finally, we use the swap curve since this curve is widely used by practitioners to discount cash flows in fixed income derivatives markets. As shown by Duffie and Singleton (1997) and Liu et al. (2004), however, the swap curve includes both credit and default components.

For the Treasury curve, we collect data for the constant maturity 6-month, 1-year, 2-year, 3-year, 5-year, 7-year, and 10-year rates from the Federal Reserve. We then use a standard cubic spline algorithm to interpolate these par rates at semiannual intervals. These par rates are then bootstrapped to provide a discount curve at semiannual intervals. To obtain the value of the discount function at other maturities, we use a straightforward linear interpolation of the corresponding forward rates. For the Refcorp curve, we collect 3-month, 6-month, 1-year, 2-year, 3-year, 5-year, 7-year, and 10-year zero-coupon yields directly from the Bloomberg system, which uses a bootstrap algorithm very similar to that described above. We then use the same approach of linearly interpolating forward rates to obtain the discount function for other maturities. Finally, we collect constant maturity 3-month, 6-month, 1-year, 2-year, 3-year, 5-year, 7-year, and 10-year swap rates from the Bloomberg system and follow the same algorithm as that described above for the Treasury curve to obtain swap discount functions. In each case, we collect data for a 10-year horizon since all of the corporate bonds in our sample have a maturity of 10 years or less.

To compute the corporate spread, we use the following procedure. For each corporate bond in the bracketing set, we solve for the yield on a riskless bond with the same maturity date and coupon rate. Subtracting this riskless yield from the yield on the corporate bond gives the yield spread for that particular corporate bond. To obtain a 5-year-horizon yield spread for the firm, we regress the yield spreads for the individual bonds in the bracketing set on their
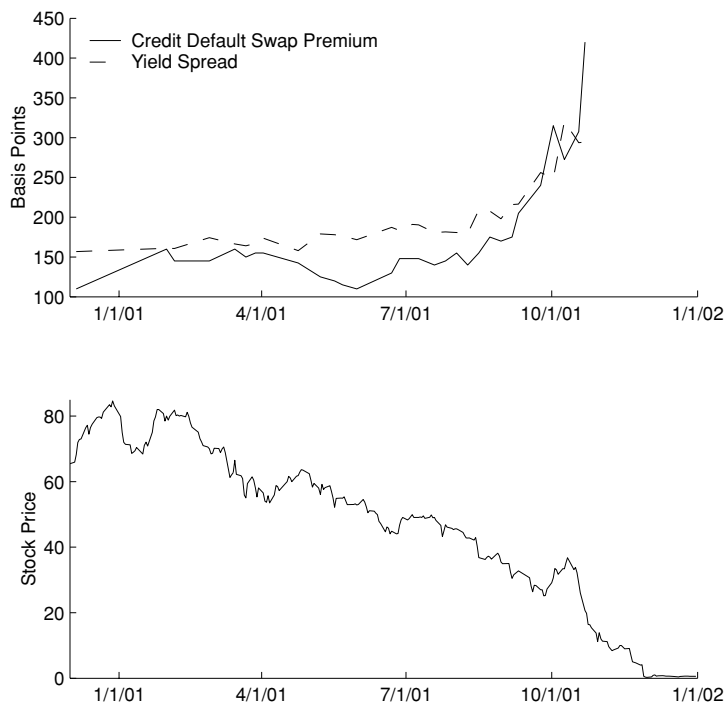
Figure 1. Time-series plot of Enron's credit default swap premium, yield spread over Treasury, and stock price. The top plot shows the time series of Enron's credit default swap premium and the yield spread over Treasury. The bottom plot shows the times series of Enron's stock price.

maturities. We then use the fitted value of the regression at a 5-year horizon as the estimate of the corporate spread for the firm. Figure 1 plots the yield spread, the credit default swap premium, and the stock price for Enron during the sample period. Recall that in the model-independent approach, the credit default swap premium is used as the estimate of the default component of the corporate spread. As shown, the credit default swap premium frequently diverges from the corporate yield spread.

To estimate the parameters for the intensity and liquidity processes, we do the following. First, we pick trial values for the parameters α, β, σ, and η. For each of the 31 observation dates, we have the 5-year credit default swap premium and yields for a subset (ranging from 3 to 8, and averaging 4) of the Enron bonds in the bracketing set described above. Given the parameters and for each date, we solve for the value of λ_t that matches exactly with the value of the credit default swap premium and for the value of γ_t that results in the best root-mean-square fit of the model to the bond yields for that date.[11] We repeat this process

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[11] In doing this, we fit the market bond and credit default swap data to discrete versions of equations (8) and (9) that match the actual semiannual timing of coupon payments and the quarterly timing of swap premia (rather than assuming that cash flows are paid continuously).

for all 31 observation dates and compute the root-mean-squared error over all of the 31 observation dates. We then pick another trial value of the parameters, and repeat the entire process. Convergence occurs by searching over parameter values until the global minimum value of the overall root-mean-squared error is obtained.[12] Throughout this procedure, we hold the recovery percentage w constant at 50%.[13] However, the estimation results are virtually identical when other values of w are used.

This estimation approach has several key advantages. Foremost among these is that by fitting to a cross-section of bonds with maturities that bracket that of the credit default swap, we minimize the effect of any measurement error in individual bond prices on the results. In essence, by using a cross-section of bonds, we attempt to "average out" the effects of idiosyncratic pricing errors in individual bonds. Nonetheless, λ_t by design captures the default risk of the firm because its value is chosen to fit the credit default swap premium exactly, while γ_t is chosen to fit the bond prices as well as possible. Thus, γ_t captures the nondefault yield spread associated with bonds in the bracketing set (relative to the credit default swap).

This process results in estimates of the four parameters α, β, σ, and η of the risk-neutral dynamics as well as for the values of λ_t and γ_t for each of the 31 observation dates in the sample. The overall root-mean-squared error from the fitting procedure ranges from about 10 to 17 basis points, depending on which discounting curve is used. These fitting errors are relatively small given the large variation in Enron spreads during the sample period.[14]

The top panel of Figure 2 plots the implied values of the intensity process λ_t for each of the 31 observation dates. As shown, the implied default intensities are almost the same for each of the three discounting curves. The implied default intensity rises slowly from a level of about 150 basis points at the end of 2000 to about 250 basis points near the end of August 2001. Around the second week of October 2001, however, the implied default intensity increases rapidly to more than 800 basis points. Table I provides a chronology of some of the events leading up to Enron's bankruptcy. The chronology shows that the first indications of major financial problems at Enron surfaced in the press around October 16, 2001. Enron's debt was downgraded by Standard and Poor's to B− on November 28, 2001, and to CC on November 30, 2001. Enron filed for bankruptcy and defaulted on its debt on December 2, 2001. Note that the last observation in our sample is dated October 22, 2001.

The middle panel of Figure 2 plots the implied values of the liquidity process γ_t. The average value of the liquidity process is 8.1 basis points when the Treasury curve is used, −27.0 basis points when the Refcorp curve is used, and −66.4 basis points when the swap curve is used. The average values of γ_t when

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[12] As a further identification condition, we require that the estimated values of σ and η be consistent with the volatilities of changes in the estimated λ_t and γ_t values.

[13] A 50% recovery rate is consistent with the median value for senior unsecured bonds reported in Duffie and Singleton (1999).

[14] We also estimate the parameters using a specification in which we fit to the prices of the bonds, rather than the yields of the bonds. The results are nearly identical to those reported.
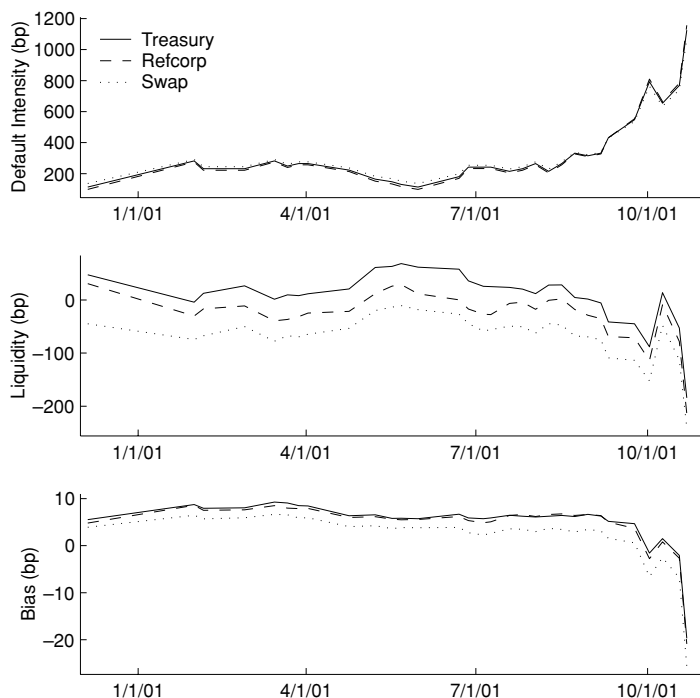
Figure 2. Time-series plot of Enron's intensity process, liquidity process, and the difference between the default component and the credit default swap premium. The top plot shows the intensity process in basis points for each of the riskless curves. The middle plot shows the liquidity process in basis points for each of the riskless curves. The bottom plot shows the difference between the default component and the credit default swap premium in basis points, which is the bias caused by using the credit default swap premium as a measure of the default component of the yield spread.

the Refcorp and swap curves are used are both highly statistically significant (different from 0). The liquidity process is fairly constant throughout most of the sample period, but declines rapidly as the implied probability of a default begins to increase in August 2001 (but not one-to-one with the increase in λ_t).

Once the model is estimated, we can solve directly for the components of the corporate spread. Specifically, the nondefault component equals the difference between the actual yield on the bond and the liquidity-adjusted yield, which is the model-implied yield for a bond with the same coupon and maturity but without the liquidity component. This liquidity-adjusted yield is given directly by substituting the appropriate fitted parameters into equation (8) (for details, see Appendix A). The default component is then given by simply subtracting the nondefault component from the corporate spread. To solve for the default component in the 5-year-horizon yield for a firm, we follow the same regression approach described earlier for yield spreads in that we regress the default components for the bonds in the bracketing set on the maturities of the bonds, and we use the 5-year fitted value as the default component for the firm. To

Table I
Chronology of Enron Events

31 Jul, 2001	Enron CFO Fastow ends ownership and management ties with certain limited partnerships.
14 Aug, 2001	Enron CEO Skilling resigns.
5 Sep, 2001	Closing stock price of $32.36 sets up potential default on $915 million note issued by Enron limited partnership.
16 Oct, 2001	Enron takes $1 billion charge and books $618 million third-quarter loss. Limited partnerships contribute to losses.
17 Oct, 2001	Enron confirms shrinking equity by $1.2 billion through share repurchase in transaction tied to CFO Fastow investment vehicle.
19 Oct, 2001	*Wall Street Journal* reports that CFO Fastow made millions from limited partnerships on which Enron incurred losses.
22 Oct, 2001	Enron reports being contacted by SEC regarding limited partnerships.
24 Oct, 2001	*Wall Street Journal* reports that Enron may need to issue stock to cover obligations of limited partnerships.
25 Oct, 2001	Enron draws down $3 billion credit line.
29 Oct, 2001	Moody's downgrades Enron from Baa1 to Baa2.
31 Oct, 2001	SEC formally launches investigation of Enron's limited partnerships.
1 Nov, 2001	Standard and Poor's downgrades Enron from BBB+ to BBB.
6 Nov, 2001	*Wall Street Journal* reports that Enron seeking $2 billion from private-equity and power-trading firms.
8 Nov, 2001	*Wall Street Journal* reports that Dynergy and Enron are discussing a merger. Enron restates earnings.
9 Nov, 2001	Moody's downgrades Enron to Baa3. Standard and Poor's downgrades Enron to BBB−. Dynergy announces $8.85 billion merger.
19 Nov, 2001	Enron announces earnings warning. $690 million note becomes demand obligation.
28 Nov, 2001	Moody's downgrades Enron to B2. Standard and Poor's downgrades Enron to B−. Dynergy walks away from Enron merger.
30 Nov, 2001	Standard and Poor's downgrades Enron to CC.
2 Dec, 2001	Enron files for Chapter 11 bankruptcy, sues Dynergy.

simplify the exposition, we will refer to the default component for an individual bond and the 5-year-horizon default component for a firm simply as the default component whenever the context is clear. We adopt the same convention in discussing the nondefault components or yield spreads for individual bonds or firms.

The bottom panel of Figure 2 shows that there is a nontrivial difference between the default component for Enron and the credit default swap premium. On average, the default component is about 6 basis points higher than the credit default swap premium. While this may not be large relative to the average size of the default component, it is nontrivial relative to the average size of the nondefault component which is only 8.1 basis points. Furthermore, there is also a significant amount of time variation in the bias. In particular, the credit default swap premium is a downward biased estimate of the default component during the early part of the sample when spreads are tighter, but becomes an upward biased estimate as Enron approaches bankruptcy. These results
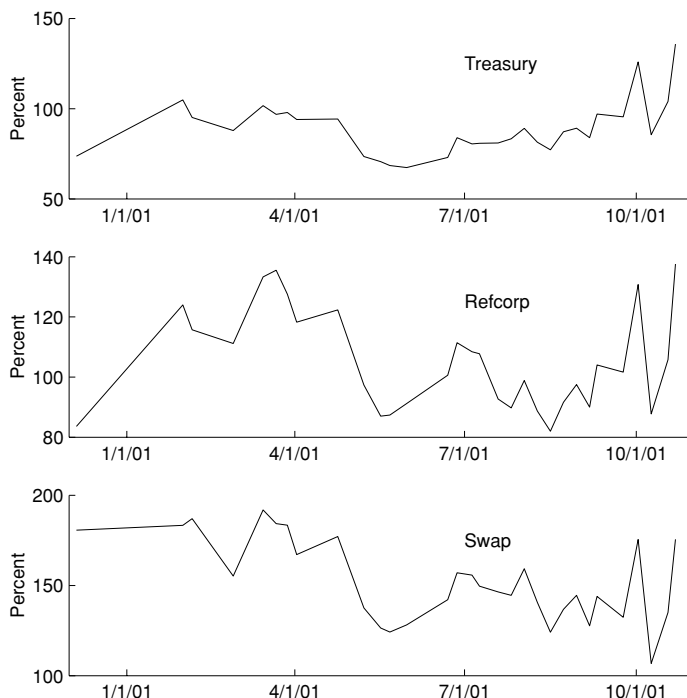
Figure 3. Time-series plot of the fraction of the yield spread due to default for Enron. The three plots show the fraction of Enron's yield spread due to the default component for each of the riskless curves.

indicate that it is important to use a model-based approach in estimating the components of the corporate spread.

The top panel of Figure 3 plots the default component as a percentage of the total spread when the Treasury curve is used. On average, default accounts for 90% of the spread. However, there is significant time variation in this default proportion. The default proportion is around 75% at the beginning of the sample period, but then rises to nearly 100% for much of the first half of the period. The default proportion then declines to about 70%–80% in the summer, and finally rises to more than 90% as Enron begins to approach financial distress. The middle and bottom panels of Figure 3 plot the percentages using the Refcorp and swap curves.[15]

IV. The Default Component

Having illustrated our approach with Enron, we now extend the analysis to a large sample of firms using an extensive data set provided by Citigroup.

[15] It is important to acknowledge that our empirical approach of using a bracketing set of bonds does not eliminate all measurement error. This may partially explain why some of the percentages shown in Figure 3 for the size of the default component (particularly for the cases in which the Treasury and Refcorp curves are used) are in excess of 100.

This data set includes credit default swap premia for 5-year contracts and corresponding corporate bond prices for 68 firms actively traded in the credit-derivatives market during the March 2001 to October 2002 period.[16] Details of how the data set is constructed are described in Appendix B.

To estimate the size of the default component for each firm, we follow the same process as for Enron in collecting data for bonds with maturities bracketing the 5-year horizon of the credit default swaps as well as meeting the other criteria described in Appendix B. The set of bonds included in the sample for each firm is again referred to as the bracketing set. The number of bonds in the bracketing set varies by firm. The minimum number of bonds used is 2 and the maximum number of bonds is 18. Since not all bonds have price data for every date for which we have credit default swap data, the average number of bonds used to estimate the default component on a particular date can be less than the total number of bonds in the bracketing set.

As a preliminary analysis, Table II reports the ratio of the default component for the firms in the sample to the total yield spread when the model-independent approximation is used. Specifically, we report the ratio of the credit default swap premium to the total spread for each firm. The results are reported separately for each of the three curves used as the riskless discounting curve. In each panel, we also report the average credit default swap premium and average total corporate spread along with the ratio. The asterisk next to a ratio indicates that the ratio is statistically different from 1.00.

As shown, the ratio of the credit default swap premium to the total corporate spread varies widely across firms. As discussed earlier, the size of the default component for investment-grade bonds tends to be higher than reported in previous studies. On the other hand, the size of the default component for the BB-rated bonds is much closer to that reported in earlier articles such as Huang and Huang (2003). To be specific, when the Treasury curve is used as the riskless curve, the percentage of the total spread explained by the model-independent estimate of the default component is 49% for AAA/AA-rated bonds, 53% for A-rated bonds, 68% for BBB-rated bonds, and 84% for below-investment-grade bonds. The corresponding ratios are all higher when the Refcorp or swap curves are used as the riskless curve.[17]

We next repeat the process described in the previous section to estimate the risk-neutral parameters and values of λ_t and γ_t for each of the firms in the sample. Table III reports the average values of the two processes for each firm, along with the fraction that the average value of λ_t represents of the average value of $\lambda_t + \gamma_t$. This fraction can be viewed as a measure of the instantaneous default component, or the proportion of the spread on short-term bonds due entirely to default risk. Again, the asterisk next to a fraction denotes that the fraction is statistically different from 1. Note that, by definition, finding that the fraction is statistically different from 1 implies that the average value of γ_t is different from

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[16] The data for Enron are from December 2000 to October 2001.

[17] The rating reported for each firm is the rating on the last date of the sample period for that firm.

Table II

Ratio of Credit Default Swap Premium to Total Corporate Spread

This table reports the average credit default swap premium (CDS), the average yield spread (Sprd) over the indicated benchmark riskless curve (Treasury, Refcorp, or swap), and the ratio of the two. Ratios denoted with an asterisk are significantly different from 1 at the 5% level based on a test of the difference between the credit default swap premia and the spreads; N denotes the number of observations.

Rating	Firm	Treasury Curve			Refcorp Curve			Swap Curve			
		CDS	Sprd	Ratio	CDS	Sprd	Ratio	CDS	Sprd	Ratio	N
AAA	GE Capital	46.8	92.0	0.51*	46.8	73.4	0.64*	46.8	31.8	1.47*	69
AA	Citigroup	40.9	106.8	0.38*	40.9	88.3	0.46*	40.9	46.1	0.89*	70
AA	Dupont	38.2	74.2	0.51*	38.2	60.4	0.63*	38.2	22.5	1.70*	52
AA	Merrill Lynch	66.7	130.9	0.51*	66.7	112.5	0.59*	66.7	71.1	0.94*	70
AA	Morgan Stanley	55.5	133.8	0.41*	55.5	112.8	0.49*	55.5	73.7	0.75*	70
AA	SBC	81.7	113.0	0.72*	81.7	100.0	0.82*	81.7	58.3	1.40*	52
AA	Wal-Mart	23.5	74.4	0.32*	23.5	54.0	0.44*	23.5	14.8	1.59*	70
A	AON	80.2	188.3	0.43*	80.2	167.5	0.48*	80.2	125.1	0.64*	42
A	Alcoa	40.6	110.5	0.37*	40.6	92.2	0.44*	40.6	53.4	0.76*	52
A	Bank One	44.4	116.1	0.38*	44.4	100.5	0.44*	44.4	60.2	0.74*	52
A	Bank of America	39.2	109.6	0.36*	39.2	90.9	0.43*	39.2	49.8	0.79*	70
A	Bear Stearns	74.0	163.1	0.45*	74.0	143.3	0.52*	74.0	103.3	0.72*	70
A	Boeing	59.4	127.9	0.46*	59.4	108.1	0.55*	59.4	71.9	0.82*	70
A	CIT Group	208.7	251.5	0.83*	208.7	237.6	0.88*	208.7	196.5	1.06*	47
A	Caterpillar	48.6	158.8	0.31*	48.6	134.5	0.36*	48.6	90.2	0.54*	70
A	Con Edison	48.1	129.7	0.37*	48.1	115.5	0.42*	48.1	74.4	0.65*	52
A	Conoco	66.4	123.7	0.54*	66.4	110.5	0.60*	66.4	72.0	0.92*	52
A	Countrywide Cr.	88.2	144.5	0.61*	88.2	130.3	0.68*	88.2	91.2	0.97	52
A	Deere	68.0	143.5	0.47*	68.0	123.3	0.55*	68.0	86.9	0.78*	69
A	Dow Chemical	98.0	158.1	0.62*	98.0	143.3	0.68*	98.0	105.7	0.93*	52
A	Duke Capital	85.1	144.7	0.59*	85.1	128.5	0.66*	85.1	90.6	0.94	39
A	Goldman Sachs	60.1	142.9	0.42*	60.1	121.1	0.50*	60.1	82.4	0.73*	70
A	Hewlett Packard	111.4	166.8	0.67*	111.4	152.1	0.73*	111.4	111.2	1.00	42
A	Household Fin.	171.4	210.6	0.81*	171.4	196.2	0.87*	171.4	154.2	1.11*	58
A	IBM	54.7	93.1	0.59*	54.7	77.8	0.70*	54.7	35.6	1.54*	70
A	JP Morgan Chase	54.8	132.8	0.41*	54.8	114.9	0.48*	54.8	74.2	0.74*	70
A	Lehman Brothers	75.4	153.0	0.49*	75.4	133.1	0.57*	75.4	94.2	0.80*	70
A	Nordstrom	130.7	239.4	0.55*	130.7	225.5	0.58*	130.7	184.8	0.71*	52
A	Philip Morris	106.5	162.4	0.66*	106.5	143.7	0.74*	106.5	102.2	1.04	70
A	Rohm&Haas	50.4	121.2	0.42*	50.4	108.0	0.47*	50.4	72.3	0.70*	52
A	Sears-Roebuck	101.1	177.8	0.57*	101.1	157.6	0.64*	101.1	120.5	0.84*	70
A	United Tech.	50.3	104.0	0.48*	50.3	87.2	0.58*	50.3	49.7	1.01	52
A	Viacom	74.9	147.1	0.51*	74.9	122.8	0.61*	74.9	86.9	0.86*	71
BBB	AT&T	270.5	321.2	0.84*	270.5	304.3	0.89*	270.5	262.9	1.03	69
BBB	Abitibi	250.8	316.6	0.79*	250.8	304.0	0.83*	250.8	261.7	0.96*	52
BBB	Albertson's	74.2	165.4	0.45*	74.2	142.8	0.52*	74.2	106.8	0.69*	70
BBB	Amerada Hess	81.1	150.7	0.54*	81.1	135.2	0.60*	81.1	98.0	0.83*	52
BBB	Daimler Chrysler	133.5	200.7	0.67*	133.5	179.1	0.75*	133.5	139.8	0.96*	73
BBB	Delphi Automotive	137.9	219.5	0.63*	137.9	204.1	0.68*	137.9	164.8	0.84*	61
BBB	Enron	173.6	197.5	0.88*	173.6	170.2	1.02	173.6	117.9	1.47*	31
BBB	Federated	103.1	174.6	0.59*	103.1	166.0	0.62*	103.1	127.4	0.81*	52
BBB	Fedex	73.3	176.9	0.41*	73.3	160.4	0.46*	73.3	124.5	0.59*	52

Table II—*Continued*

Rating	Firm	Treasury Curve			Refcorp Curve			Swap Curve			N
		CDS	Sprd	Ratio	CDS	Sprd	Ratio	CDS	Sprd	Ratio	
BBB	Ford Motor Credit	204.3	258.2	0.79*	204.3	238.1	0.86*	204.3	197.7	1.03	71
BBB	GMAC	154.9	213.2	0.73*	154.9	194.4	0.80*	154.9	152.7	1.01	71
BBB	Hilton Hotels	299.1	372.7	0.80*	299.1	363.8	0.82*	299.1	321.2	0.93*	52
BBB	Ingersoll-Rand	76.8	178.1	0.43*	76.8	154.6	0.50*	76.8	110.0	0.70*	52
BBB	Int. Paper	95.0	177.6	0.53*	95.0	158.1	0.60*	95.0	116.5	0.82*	70
BBB	Lockheed Martin	76.4	139.8	0.55*	76.4	117.8	0.65*	76.4	83.8	0.91*	69
BBB	MBNA	171.9	252.7	0.68*	171.9	241.1	0.71*	171.9	198.5	0.87*	52
BBB	MGM Mirage	278.1	359.7	0.77*	278.1	347.5	0.80*	278.1	305.1	0.91*	51
BBB	Marriot	128.8	237.7	0.54*	128.8	223.3	0.58*	128.8	185.4	0.69*	52
BBB	Motorola	288.9	348.6	0.83*	288.9	335.0	0.86*	288.9	290.4	0.99	70
BBB	Norfolk Southern	79.3	143.3	0.55*	79.3	128.5	0.62*	79.3	89.3	0.89*	52
BBB	Occidental	78.4	165.5	0.47*	78.4	150.3	0.52*	78.4	110.8	0.71*	52
BBB	Park Place Ent.	283.0	403.0	0.70*	283.0	388.7	0.73*	283.0	348.0	0.81*	52
BBB	Qwest Capital	240.1	271.8	0.88*	240.1	252.0	0.95	240.1	209.3	1.15*	16
BBB	Raytheon	153.5	189.4	0.81*	153.5	169.1	0.91*	153.5	133.0	1.15*	70
BBB	Sprint	140.0	204.3	0.69*	140.0	177.1	0.79*	140.0	140.0	1.00	33
BBB	Sun Microsystems	186.7	262.3	0.71*	186.7	247.3	0.76*	186.7	210.0	0.89*	52
BBB	TRW	158.8	244.3	0.65*	158.8	224.2	0.71*	158.8	185.0	0.86*	70
BBB	The Gap	107.8	213.1	0.51*	107.8	191.7	0.56*	107.8	153.7	0.70*	19
BBB	Union Pacific	75.1	134.4	0.56*	75.1	122.2	0.61*	75.1	81.3	0.92*	52
BBB	Visteon	187.5	268.4	0.70*	187.5	244.6	0.77*	187.5	206.0	0.91*	71
BBB	Walt Disney	80.4	140.6	0.57*	80.4	120.7	0.67*	80.4	77.0	1.04	70
BBB	Worldcom	162.0	235.4	0.69*	162.0	205.1	0.79*	162.0	168.0	0.96*	33
BB	Capital One	266.2	349.4	0.76*	266.2	328.2	0.81*	266.2	284.6	0.94	30
BB	Georgia Pacific	461.0	472.7	0.98	461.0	460.9	1.00	461.0	417.8	1.10*	52
BB	Goodyear	346.0	461.4	0.75*	346.0	444.7	0.78*	346.0	401.6	0.86*	68
Average	AAA/AA	50.5	103.6	0.49*	50.5	85.9	0.59*	50.5	45.5	1.11	65
Average	A	80.4	150.8	0.53*	80.4	133.3	0.60*	80.4	93.8	0.86*	59
Average	BBB	156.4	229.3	0.68*	156.4	211.3	0.74*	156.4	171.1	0.91*	55
Average	BB	357.7	427.8	0.84*	357.7	411.3	0.87	357.7	368.0	0.97	50

0. Thus, Table III implies that the average value of γ_t is different from 0 for virtually every firm in the sample.[18]

Table III shows that the instantaneous default component tends to be a larger percentage of the total spread than is the case in Table II. When the Treasury curve is used as the riskless curve, the proportion of the instantaneous spread explained by default is 62% for AAA/AA-rated bonds, 63% for A-rated bonds, 79% for BBB-rated bonds, and 89% for the BB-rated bonds. Again, the percentages are higher when the Refcorp and swap curves are used as the riskless curve.

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[18] We note also that the in-sample correlations for changes in r_t, λ_t, and γ_t show that these variables are not completely independent. In particular, when the Refcorp curve is used, the correlations between changes in r_t and in the average values of λ_t and γ_t are -0.28 and -0.03, while the correlation between changes in the average values of λ_t and γ_t is -0.38.

Table III

Fraction of the Instantaneous Spread Explained by the Default Intensity

This table reports the average values of the implied default intensity process (lambda) and the liquidity process (gamma), and the fraction lambda/(lambda + gamma), where the indicated curves are used as the benchmark riskless curve (Treasury, Refcorp, and swap). Fractions denoted with an asterisk are significantly different from 1 based on a *t*-test for the hypothesis that gamma equals 0 (finding that gamma is nonzero implies that the ratio of lambda to the sum lambda + gamma is not equal to 1); *N* denotes the number of observations.

Rating	Firm	Treasury Curve			Refcorp Curve			Swap Curve			N
		Lambda	Gamma	Fraction	Lambda	Gamma	Fraction	Lambda	Gamma	Fraction	
AAA	GE Capital	77.0	43.6	0.64*	77.1	25.0	0.75*	77.1	−16.3	1.27*	69
AA	Citigroup	42.4	63.4	0.40*	42.5	46.3	0.48*	42.1	4.0	0.91*	70
AA	Dupont	35.4	32.1	0.52*	35.5	20.2	0.64*	37.6	−16.9	1.82*	52
AA	Merrill Lynch	76.4	58.2	0.57*	76.1	40.8	0.65*	76.2	0.2	1.00	70
AA	Morgan Stanley	52.4	72.1	0.42*	52.0	53.4	0.49*	52.2	14.4	0.78*	70
AA	SBC	233.3	17.7	0.93*	209.6	8.6	0.96	207.7	−30.3	1.17*	52
AA	Wal-Mart	13.7	44.0	0.24*	13.8	26.6	0.34*	13.9	10.6	4.25*	70
A	AON	119.3	100.7	0.54*	147.5	81.9	0.64*	164.6	42.8	0.79*	42
A	Alcoa	44.5	69.7	0.39*	44.5	51.2	0.47*	44.3	13.4	0.77*	52
A	Bank One	32.9	71.5	0.31*	32.9	55.6	0.37*	33.1	16.7	0.67*	52
A	Bank of America	28.0	69.9	0.29*	28.1	53.2	0.35*	27.8	11.7	0.70*	70
A	Bear Stearns	59.6	84.9	0.41*	47.2	67.0	0.41*	69.3	26.3	0.72*	70
A	Boeing	100.4	68.8	0.59*	100.5	50.6	0.67*	100.0	14.2	0.88*	70
A	CIT Group	534.0	52.2	0.91*	533.3	39.5	0.93*	530.1	−0.7	1.00	47
A	Caterpillar	44.8	70.4	0.39*	44.7	50.9	0.47*	44.4	15.2	0.74*	70
A	Con Edison	42.3	82.7	0.34*	42.2	68.4	0.38*	42.4	29.1	0.59*	52
A	Conoco	42.8	56.0	0.43*	53.9	43.2	0.56*	63.6	5.0	0.93*	52
A	Countrywide Cr.	118.6	57.3	0.67*	118.6	44.1	0.73*	118.3	6.5	0.95*	52
A	Deere	74.0	75.2	0.50*	73.6	57.6	0.56*	82.6	20.0	0.81*	69
A	Dow Chemical	147.6	66.8	0.69*	151.4	52.5	0.74*	147.2	15.4	0.91*	52
A	Duke Capital	110.6	57.0	0.66*	119.9	40.9	0.75*	127.3	3.7	0.97	39
A	Goldman Sachs	61.6	85.4	0.42*	61.2	64.6	0.49*	61.4	25.3	0.71*	70
A	Hewlett Packard	222.5	53.5	0.81*	231.4	39.7	0.85*	241.2	−0.3	1.00	42
A	Household Fin.	411.9	44.2	0.90*	411.5	31.3	0.93*	408.2	−9.7	1.02	58
A	IBM	49.8	32.1	0.61*	49.9	17.9	0.74*	50.0	−25.2	2.02*	70
A	JP Morgan Chase	70.3	79.4	0.47*	69.9	62.7	0.53*	69.9	21.6	0.76*	70
A	Lehman Brothers	50.0	74.5	0.40*	50.1	56.2	0.47*	60.6	16.9	0.78*	70
A	Nordstrom	163.8	110.3	0.60*	163.9	97.6	0.63*	163.9	57.8	0.74*	52
A	Philip Morris	116.0	51.9	0.69*	123.2	32.9	0.79*	132.6	−6.5	1.05	70
A	Rohm&Haas	36.0	71.6	0.33*	41.0	59.5	0.41*	49.3	23.6	0.68*	52
A	Sears-Roebuck	235.6	75.7	0.76*	235.0	57.1	0.80*	233.6	20.9	0.92*	70

A	United Tech.	35.6	53.6	0.40*	44.8	36.8	0.55*	45.0	−0.2	1.00	52
A	Viacom	90.4	69.3	0.57*	90.2	46.6	0.66*	122.4	9.6	0.93*	71
BBB	AT&T	708.8	81.8	0.90*	707.3	67.0	0.91*	706.5	25.1	0.97*	69
BBB	Abitibi	398.7	79.3	0.83*	381.7	66.2	0.85*	375.0	26.3	0.93*	52
BBB	Albertson's	111.3	87.0	0.56*	122.5	65.6	0.65*	132.4	29.2	0.82*	70
BBB	Amerada Hess	78.8	68.2	0.54*	98.2	52.6	0.65*	100.1	16.1	0.86*	52
BBB	Daimler Chrysler	184.1	61.9	0.75*	190.7	40.9	0.82*	191.0	2.8	0.99	73
BBB	Delphi Automotive	236.6	88.9	0.73*	248.5	74.4	0.77*	261.1	35.0	0.88*	61
BBB	Enron	325.6	8.1	0.98	320.6	−27.0	1.09*	331.8	−66.4	1.25*	31
BBB	Federated	145.3	78.3	0.65*	178.2	68.8	0.72*	177.8	32.4	0.85*	52
BBB	Fedex	120.8	100.4	0.55*	157.0	83.2	0.65*	153.2	48.0	0.76*	52
BBB	Ford Motor Credit	523.4	62.1	0.89*	522.9	44.3	0.92*	519.1	4.2	0.99	71
BBB	GMAC	297.1	51.9	0.85*	297.2	34.1	0.90*	296.2	−6.5	1.02	71
BBB	Hilton Hotels	464.2	94.4	0.83*	462.6	78.2	0.86*	460.7	40.5	0.92*	52
BBB	Ingersoll-Rand	47.4	76.0	0.38*	47.3	64.2	0.42*	55.7	30.2	0.65*	52
BBB	Int. Paper	133.6	76.2	0.64*	114.6	59.5	0.66*	123.1	17.9	0.87*	70
BBB	Lockheed Martin	135.4	56.7	0.70*	111.0	38.3	0.74*	183.1	1.7	0.99	69
BBB	MBNA	264.8	75.8	0.78*	264.1	64.9	0.80*	261.3	23.1	0.92*	52
BBB	MGM Mirage	401.3	84.5	0.83*	287.8	72.0	0.80*	342.9	32.2	0.91*	51
BBB	Marriot	185.0	108.5	0.63*	218.9	92.6	0.70*	218.9	56.0	0.80*	52
BBB	Motorola	503.3	92.6	0.84*	502.9	75.5	0.87*	500.1	34.1	0.94*	70
BBB	Norfolk Southern	106.1	60.3	0.64*	128.2	45.6	0.74*	115.1	7.5	0.94*	52
BBB	Occidental	158.6	81.4	0.66*	147.8	67.5	0.69*	151.9	28.5	0.84*	52
BBB	Park Place Ent.	636.0	115.1	0.85*	622.3	101.4	0.86*	613.7	62.7	0.91*	52
BBB	Qwest Capital	582.4	31.5	0.95*	546.6	13.5	0.98	570.7	−28.1	1.05*	16
BBB	Raytheon	274.9	33.0	0.89*	286.0	13.6	0.95*	317.3	−23.5	1.08*	70
BBB	Sprint	285.3	75.3	0.79*	284.6	48.7	0.85*	285.6	11.2	0.96	33
BBB	Sun Microsystems	263.0	72.2	0.78*	263.4	58.7	0.82*	277.4	21.5	0.93	52
BBB	TRW	260.4	82.8	0.76*	252.4	64.7	0.80*	283.5	24.7	0.92*	70
BBB	The Gap	180.8	75.1	0.71*	180.7	49.2	0.79*	180.3	22.5	0.89*	19
BBB	Union Pacific	228.6	54.7	0.81*	226.2	43.1	0.84*	266.5	2.5	0.99	52
BBB	Visteon	352.5	89.6	0.80*	351.9	66.8	0.84*	351.1	28.5	0.92*	71
BBB	Walt Disney	136.7	50.8	0.73*	136.6	31.7	0.81*	143.0	−5.8	1.04*	70
BBB	Worldcom	201.9	70.4	0.74*	184.9	42.3	0.81*	256.8	2.9	0.99	33
BB	Capital One	447.1	82.6	0.84*	446.8	66.9	0.87*	446.4	26.2	0.94*	30
BB	Georgia Pacific	1545.2	139.0	0.92*	1542.3	125.5	0.92*	1526.6	85.6	0.95*	52
BB	Goodyear	898.9	130.1	0.87*	898.0	114.8	0.89*	894.1	74.0	0.92*	68
Average	AAA/AA	75.8	47.3	0.62*	72.3	31.6	0.70*	72.4	−7.9	1.12	65
Average	A	117.0	68.6	0.63*	119.6	52.3	0.70*	124.3	13.6	0.90*	59
Average	BBB	279.2	72.6	0.79*	276.4	55.1	0.83*	287.6	16.8	0.94*	55
Average	BB	963.7	117.2	0.89*	962.4	102.4	0.90*	955.7	61.9	0.94*	50

Table IV reports the model-based estimates of the size of the default component in the yield spread for the firms in the sample. As shown, the proportion of the spread explained by default risk averages more than 50% across all credit rating categories and choices of the riskless curve. When the Treasury curve

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Table IV

Ratio of Default Component to Total Corporate Spread

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This table reports the average default component (Dflt), the average yield spread (Sprd) over the indicated benchmark riskless curve (Treasury, Refcorp, and swap), and the ratio of the two. Ratios denoted with an asterisk are significantly different from 1 at the 5% level based on a test of the difference between the default components and the spreads; N denotes the number of observations.

Rating	Firm	Treasury Curve			Refcorp Curve			Swap Curve			N
		Dflt	Sprd	Ratio	Dflt	Sprd	Ratio	Dflt	Sprd	Ratio	
AAA	GE Capital	49.6	92.0	0.54*	49.4	73.4	0.67*	49.1	31.8	1.54*	69
AA	Citigroup	43.0	106.8	0.40*	43.0	88.3	0.49*	42.7	46.1	0.92*	70
AA	Dupont	40.2	74.2	0.54*	40.1	60.4	0.66*	40.0	22.5	1.78*	52
AA	Merrill Lynch	70.0	130.9	0.53*	69.9	112.5	0.62*	69.4	71.1	0.98	70
AA	Morgan Stanley	58.2	133.8	0.44*	58.0	112.8	0.51*	57.7	73.7	0.78*	70
AA	SBC	87.6	113.0	0.78*	86.7	100.0	0.87*	85.7	58.3	1.47*	52
AA	Wal-Mart	24.6	74.4	0.33*	24.5	54.0	0.45*	24.4	14.8	1.65*	70
A	AON	86.4	188.3	0.46*	86.2	167.5	0.51*	85.7	125.1	0.69*	42
A	Alcoa	42.8	110.5	0.39*	42.6	92.2	0.46*	42.3	53.4	0.79*	52
A	Bank One	46.9	116.1	0.40*	46.8	100.5	0.47*	46.6	60.2	0.77*	52
A	Bank of America	41.1	109.6	0.37*	41.0	90.9	0.45*	40.8	49.8	0.82*	70
A	Bear Stearns	78.0	163.1	0.48*	77.5	143.3	0.54*	77.6	103.3	0.75*	70
A	Boeing	61.8	127.9	0.48*	61.5	108.1	0.57*	61.0	71.9	0.85*	70
A	CIT Group	215.3	251.5	0.86*	214.4	237.6	0.90*	212.2	196.5	1.08*	47
A	Caterpillar	54.5	158.8	0.34*	54.4	134.5	0.40*	54.1	90.2	0.60*	70
A	Con Edison	50.6	129.7	0.39*	50.5	115.5	0.44*	50.2	74.4	0.67*	52
A	Conoco	68.2	123.7	0.55*	68.4	110.5	0.62*	68.3	72.0	0.95	52
A	Countrywide Cr.	91.1	144.5	0.63*	90.8	130.3	0.70*	90.1	91.2	0.99	52
A	Deere	69.6	143.5	0.49*	69.3	123.3	0.56*	69.1	86.9	0.80*	69
A	Dow Chemical	100.3	158.1	0.63*	99.9	143.3	0.70*	99.2	105.7	0.94	52
A	Duke Capital	88.9	144.7	0.61*	88.8	128.5	0.69*	88.6	90.6	0.98	39
A	Goldman Sachs	63.3	142.9	0.44*	63.0	121.1	0.52*	62.7	82.4	0.76*	70
A	Hewlett Packard	115.4	166.8	0.69*	115.0	152.1	0.76*	113.8	111.2	1.02	42
A	Household Fin.	178.5	210.6	0.85*	177.9	196.2	0.91*	175.9	154.2	1.14*	58
A	IBM	57.2	93.1	0.61*	57.2	77.8	0.74*	56.9	35.6	1.60*	70
A	JP Morgan Chase	57.3	132.8	0.43*	57.2	114.9	0.50*	56.8	74.2	0.77*	70
A	Lehman Brothers	78.3	153.0	0.51*	78.1	133.1	0.59*	78.0	94.2	0.83*	70
A	Nordstrom	136.0	239.4	0.57*	135.8	225.5	0.60*	134.6	184.8	0.73*	52
A	Philip Morris	112.7	162.4	0.69*	112.7	143.7	0.78*	112.0	102.2	1.10*	70
A	Rohm&Haas	51.5	121.2	0.43*	51.7	108.0	0.48*	51.8	72.3	0.72*	52
A	Sears-Roebuck	109.4	177.8	0.62*	109.0	157.6	0.69*	107.8	120.5	0.89*	70
A	United Tech.	52.0	104.0	0.50*	52.1	87.2	0.60*	51.8	49.7	1.04	52
A	Viacom	78.4	147.1	0.53*	78.0	122.8	0.63*	78.7	86.9	0.91*	71
BBB	AT&T	271.6	321.2	0.85*	270.5	304.3	0.89*	267.6	262.9	1.02	69
BBB	Abitibi	258.9	316.6	0.82*	258.1	304.0	0.85*	255.7	261.7	0.98	52
BBB	Albertson's	78.4	165.4	0.47*	78.5	142.8	0.55*	78.2	106.8	0.73*	70

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(*continued*)

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Table IV—*Continued*

Rating	Firm	Treasury Curve			Refcorp Curve			Swap Curve			
		Dflt	Sprd	Ratio	Dflt	Sprd	Ratio	Dflt	Sprd	Ratio	N
BBB	Amerada Hess	83.6	150.7	0.56*	84.0	135.2	0.62*	83.5	98.0	0.85*	52
BBB	Daimler Chrysler	139.4	200.7	0.69*	139.2	179.1	0.78*	138.1	139.8	0.99	73
BBB	Delphi Automotive	143.1	219.5	0.65*	143.0	204.1	0.70*	141.9	164.8	0.86*	61
BBB	Enron	178.7	197.5	0.90*	178.3	170.2	1.05	175.7	117.9	1.49*	31
BBB	Federated	105.5	174.6	0.60*	106.7	166.0	0.64*	105.8	127.4	0.83*	52
BBB	Fedex	77.6	176.9	0.44*	78.5	160.4	0.49*	77.8	124.5	0.62*	52
BBB	Ford Motor Credit	214.8	258.2	0.83*	214.0	238.1	0.90*	211.6	197.7	1.07*	71
BBB	GMAC	160.1	213.2	0.75*	159.7	194.4	0.82*	158.0	152.7	1.03*	71
BBB	Hilton Hotels	309.8	372.7	0.83*	310.0	363.8	0.85*	306.9	321.2	0.96*	52
BBB	Ingersoll-Rand	83.1	178.1	0.47*	82.9	154.6	0.54*	82.3	110.0	0.75*	52
BBB	Int. Paper	102.8	177.6	0.58*	102.3	158.1	0.65*	101.7	116.5	0.87*	70
BBB	Lockheed Martin	82.7	139.8	0.59*	80.9	117.8	0.69*	83.8	83.8	1.00	69
BBB	MBNA	180.0	252.7	0.71*	179.7	241.1	0.75*	178.0	198.5	0.90*	52
BBB	MGM Mirage	286.3	359.7	0.80*	285.6	347.5	0.82*	283.4	305.1	0.93*	51
BBB	Marriot	135.7	237.7	0.57*	136.4	223.3	0.61*	135.5	185.4	0.73*	52
BBB	Motorola	288.0	348.6	0.83*	288.0	335.0	0.86*	284.5	290.4	0.98	70
BBB	Norfolk Southern	84.3	143.3	0.59*	84.7	128.5	0.66*	83.8	89.3	0.94*	52
BBB	Occidental	85.6	165.5	0.52*	85.0	150.3	0.57*	84.5	110.8	0.76*	52
BBB	Park Place Ent.	302.2	403.0	0.75*	301.1	388.7	0.77*	298.2	348.0	0.86*	52
BBB	Qwest Capital	250.4	271.8	0.92*	249.1	252.0	0.99	246.5	209.3	1.18*	16
BBB	Raytheon	159.7	189.4	0.84*	159.4	169.1	0.94*	159.4	133.0	1.20*	70
BBB	Sprint	147.8	204.3	0.72*	147.2	177.1	0.83*	145.3	140.0	1.04	33
BBB	Sun Microsystems	193.0	262.3	0.74*	192.3	247.3	0.78*	191.6	210.0	0.91	52
BBB	TRW	167.0	244.3	0.68*	166.3	224.2	0.74*	165.6	185.0	0.90*	70
BBB	The Gap	111.9	213.1	0.52*	112.0	191.7	0.58*	110.6	153.7	0.72*	19
BBB	Union Pacific	81.8	134.4	0.61*	81.5	122.2	0.67*	81.4	81.3	1.00	52
BBB	Visteon	201.8	268.4	0.75*	200.7	244.6	0.82*	199.1	206.0	0.97	71
BBB	Walt Disney	84.9	140.6	0.60*	84.7	120.7	0.70*	83.8	77.0	1.09*	70
BBB	Worldcom	166.8	235.4	0.71*	165.4	205.1	0.81*	166.7	168.0	0.99	33
BB	Capital One	264.4	349.4	0.76*	263.3	328.2	0.80*	260.2	284.6	0.91*	30
BB	Georgia Pacific	446.8	472.7	0.95*	445.4	460.9	0.97	439.9	417.8	1.05*	52
BB	Goodyear	356.8	461.4	0.77*	355.6	444.7	0.80*	351.1	401.6	0.87*	68
Average	AAA/AA	53.3	103.6	0.51*	53.1	85.9	0.62*	52.7	45.5	1.16	65
Average	A	84.0	150.8	0.56*	83.8	133.3	0.63*	83.3	93.8	0.89*	59
Average	BBB	163.0	229.3	0.71*	162.7	211.3	0.77*	161.4	171.1	0.94*	55
Average	BB	356.0	427.8	0.83*	354.8	411.3	0.86*	350.4	368.0	0.95	50

is used as the riskless curve, the average size of the default component ranges from 51% for AAA/AA-rated bonds to 83% for BB-rated bonds. When the Refcorp curve is used, the corresponding percentages range from 62% to 86%. Interestingly, when the swap curve is used as the riskless curve, the proportion due to default is 116% for AAA/AA-rated bonds, 89% for A-rated bonds, 94% for BBB-rated bonds, and 95% for BB-rated bonds. Intuitively, the reason why the swap curve implies default components greater than 100% of the corporate spread in some cases is that the swap curve probably includes a credit component itself. Thus, firms with higher credit ratings than those in the basket of 16 banks

used in the official LIBOR fixing tend to have negative values for the liquidity process γ_t, which, in turn, implies a negative nondefault component.

Although not shown, we also examine the percentage of the variation in corporate spreads explained by the default component. This is done by regressing the time series of the yield spread for each firm on the estimated default component for that firm. The R^2s from these regressions, using the Treasury curve, average 0.37 for the AAA/AA-rated bonds, 0.43 for the A-rated bonds, 0.57 for the BBB-rated bonds, and 0.62 for the BB-rated bonds. The results using the Refcorp and swap curves are very similar or slightly higher. Overall, the average R^2 across all firms is about 0.51. Thus, the default component represents the majority of the corporate spread not only in size, but also generally in terms of the percentage of time-series variation explained.

Comparing the size of the default component in Table IV with that from the model-independent estimate reported in Table II again shows that the model-independent approach is biased. When the Treasury curve is used as the riskless curve, the difference between the estimated default components in Tables IV and II is 2.8 basis points for AAA/AA-rated bonds, 3.6 basis points for A-rated bonds, 6.6 basis points for BBB-rated bonds, and −1.7 basis points for BB-rated bonds.[19] Failing to correctly account for this bias could potentially have unfortunate effects in drawing inferences about the size and statistical properties of the default and nondefault components of corporate spreads.

Although Table IV shows that the majority of the corporate yield spread is due to default risk, Table IV also shows that default risk does not explain all of the corporate spread. When the Treasury curve is used as the riskless curve, we find that the default component is reliably smaller than the total spread for each of the 68 firms in the sample. When the Refcorp and swap curves are used as the riskless curve, 96% and 75% of the ratios are significantly different from 1.00, respectively. Thus, our results about the existence of a significant nondefault component are robust to the choice of the riskless discounting curve.

One important issue to consider is whether our results underestimate the size of the default component because of the effects of counterparty credit risk. If there is a risk that the party selling credit protection might enter into financial distress itself and thereby be unable to meet its contractual obligations, then the value of the promised protection is obviously not worth as much to the buyer. In this situation, the premium that the buyer would be willing to pay would be correspondingly less. To keep things as simple as possible in exploring this issue, assume that with probability p the protection seller is unable to meet his contractual obligations. Furthermore, assume that the default by the protection seller is independent of default on the underlying reference obligation. In this simple case, the value of the protection leg is now only worth $(1 - p)$ times the value given in equation (6). In turn, this means that the protection buyer would only be willing to pay $(1 - p)s$, where s is the value given in equation (7). Given

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[19] Seven of the firms in the sample have absolute biases in excess of 10 basis points, and the model-independent approach underestimates the size of the default component for all but one of the investment-grade firms.

this, it is now easy to answer the question: How large would the probability of counterparty default need to be to conclude that the corporate spread is entirely due to default risk? The answer is 1.00 minus the default component ratio shown in Table IV. For example, using the Treasury curve, the average ratio for AAA/AA-rated bonds is 0.51. Thus, the probability of a counterparty default would need to be 0.49, or 49%, for the yield spread of these bonds to be due entirely to default risk. This is orders of magnitude larger than any realistic estimate of the default risk of the large investment-grade firms selling credit protection even over a 5-year horizon. Similar conclusions follow for the other ratings categories in the sample. Finally, the fact that the size of the nondefault component varies across ratings categories also argues against the nondefault component being due to counterparty credit risk. If the nondefault component were due to counterparty credit risk, there would be more uniformity in its size. This follows since the set of counterparties selling protection is likely to be very similar across all of the firms in the sample. In summary, counterparty credit risk is unlikely to account for much of the nondefault component of spreads.

Another issue to consider is whether the larger estimates of the default component we find are due to illiquidity in the credit derivatives market. The answer to this is clearly "no" since the most likely effect of illiquidity, if any, in the credit derivatives market would actually be to understate the size of the default component. To see this, consider a market in which corporate bonds trade at a discount to their fair value because of their illiquidity. In this market, the protection leg of a credit default swap would likely be worth less than its theoretical value because, similar to the cash flows from a bond, it is a credit-sensitive cash flow. In contrast, the premium leg of the credit default swap is a completely generic fixed annuity similar to that for any interest rate swap. Thus, since both legs of a credit default swap have to have the same value at the inception of the swap (the zero net-present-value condition for swaps), the premium that a protection buyer would be willing to pay would need to be less since the value of the illiquidity-impaired protection leg is less. This means that if there is any illiquidity component in credit default swap premia, then we may be underestimating the size of the default component. Thus, finding that the majority of corporate spreads is due to default risk is likely not an artifact of the effects, if any, of illiquidity on credit default swap premia.[20]

V. The Nondefault Component

In this section, we examine the properties of the nondefault component of the spread, which is given by simply subtracting the default component of the

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[20] As another robustness check, we reestimate the default component using the assumption that $w = 1$ rather than $w = 0.50$. The results are virtually the same as those reported here. Intuitively, the reason why the results are not sensitive to the assumption about recovery is that w is used symmetrically in the bond price and credit default swap premium; the effects of w largely wash out in the calibration procedure. Another way of seeing this is to note that a portfolio consisting of a corporate bond and credit protection is very nearly the same as a riskless bond irrespective of the assumptions made about recovery.
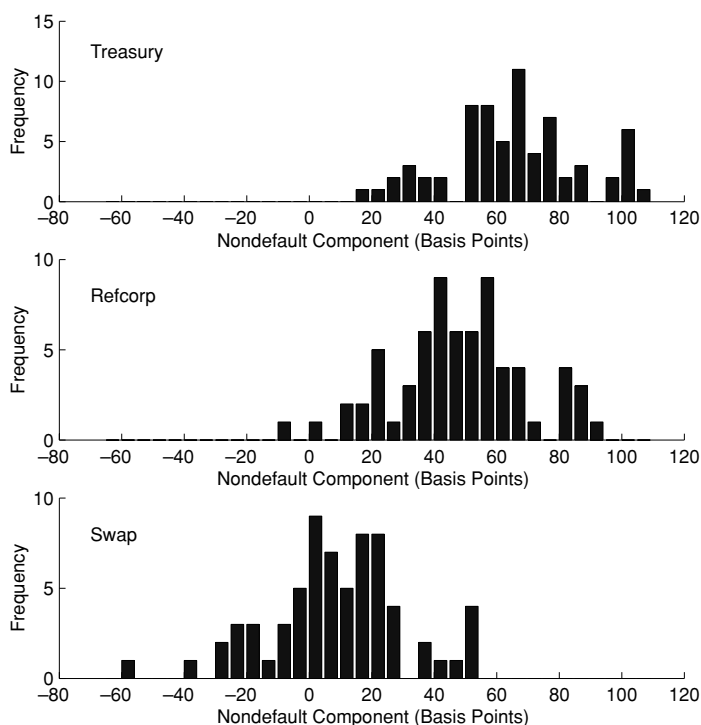
Figure 4. Distribution of time-series-averaged nondefault components. The three plots show the distribution across firms of the time-series average of the nondefault component of the yield spread for the different riskless curves.

spread from the total spread. The average nondefault component for each firm can be obtained directly from Table IV by subtracting the default component in each panel from the corresponding corporate spread.

Figure 4 plots histograms of the average nondefault component for each firm in the sample. As shown, there is considerable cross-sectional variation in the nondefault components. Using the Treasury curve, the nondefault components range from 18.8 to 104.5 basis points, with a mean of 65.0. Using the Refcorp curve, the nondefault components range from −8.1 to 89.8 basis points with a mean of 47.7. Similarly, using the swap curve, the nondefault components range from −57.8 to 50.5 basis points with a mean of 8.6. These nondefault components are significantly different from 0 for virtually every firm in the sample.[21]

Figure 5 plots the average default and nondefault components by rating category. As shown, both the average default and nondefault components increase as the rating category declines. However, the plots show that the rating-related variation in the default component is much stronger than for the nondefault

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[21] As discussed earlier, if the CDS premium includes a small liquidity component, then the actual size of the nondefault component in corporate bonds could actually be slightly higher than these estimates.
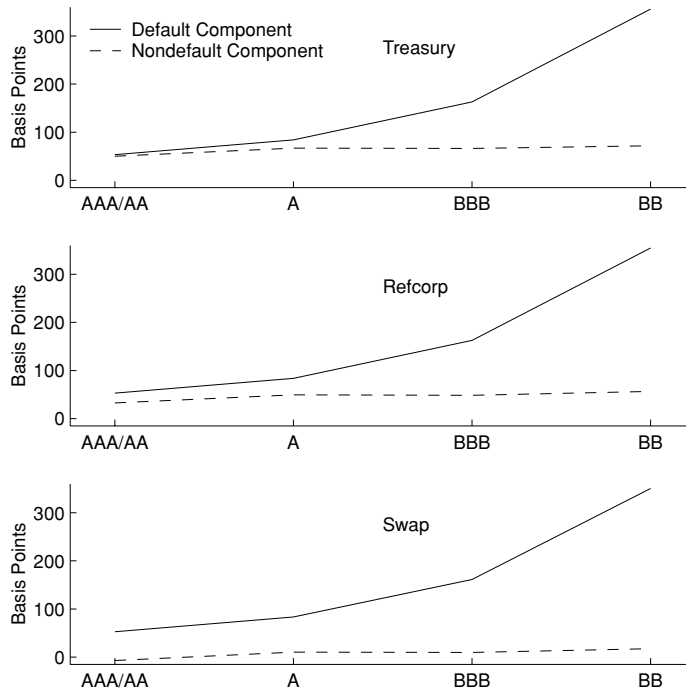
Figure 5. Plot of spread components versus ending rating. The three plots show the default and nondefault components of the yield spread, calculated by averaging over firms with a given ending credit rating.

component. For example, when the Treasury curve is used, the default component ranges from 53.3 basis points to 356.0 basis points, while the nondefault component ranges from 50.3 to 71.8 basis points. Thus, compared to the default component, the nondefault component is nearly constant across rating categories.

Many previous studies have found evidence of nondefault components in corporate spreads. Important examples include Jones et al. (1984), Duffie and Singleton (1997), Duffee (1999), Elton et al. (2001), Delianedis and Geske (2001), Collin-Dufresne et al. (2001), Huang and Huang (2003), Eom et al. (2004), and Liu et al. (2004). Typically, these studies find evidence that the nondefault component is related to tax or liquidity factors. Motivated by this, we explore the determinants of the nondefault component from both a cross-sectional and time-series perspective using a number of tax and liquidity-related explanatory variables.

A. Cross-Sectional Analysis

We focus first on the cross-sectional variation in the time-series averages of the nondefault component. Our approach in doing this is to regress the nondefault component for individual bonds on a number of explanatory variables suggested by theoretical considerations.

One important feature that could drive a wedge between the yields on corporate and Treasury bonds is that interest on Treasury bonds is exempt from state and local income taxes, while interest on corporate bonds is not. Note, however, that this asymmetry does not apply to the spread between corporate and Refcorp bonds, or corporate bonds and swaps. In a recent paper, Elton et al. (2001) argue that the asymmetry in taxation between corporates and Treasuries might explain a significant portion of the yield spread between corporates and Treasuries. Since credit default swaps are purely contractual in nature, the premium should reflect only the actual risk of default on the underlying bonds. Thus, if the spread between corporates and Treasuries includes a tax-related component in addition to the default-related component, then this portion of the spread should not be incorporated into the credit default swap premium. Of course, the size of any tax-related component in corporate spreads will depend on the marginal state and local tax rate of the marginal investor in the corporate bond market. The recent trend toward greater participation in the corporate bond markets by pension, retirement, 401k, and other tax-exempt investors, however, raises the possibility that the marginal state and local tax rate could be very small or even zero.[22] Note that any tax-related component in yield spreads would be linked to bond-specific features such as the coupon rate of the corporate bond.[23]

To test for tax effects, we use the coupon rate of the bonds as an explanatory variable. The intuition for using this variable is that an investor with a marginal tax rate of τ would need to receive a pre-tax coupon of $c/(1-\tau)$ to have an after-tax coupon of c. Thus, the markup in the coupon to compensate for the additional state and local taxes incurred by corporate bonds should be roughly proportional to the coupon rate of the bonds. By including the coupon rate in the regression, we allow for the possibility that the spread includes a tax-related component.

Another possible determinant of the nondefault component is the illiquidity of individual corporate bonds relative to the benchmark riskless curve. For example, if corporate bonds are less liquid than Treasury or Refcorp bonds and priced accordingly, then corporate spreads could also include a liquidity component. Thus, the liquidity of the corporate bonds (or lack thereof relative to the bonds defining the riskless curve used to estimate the $D(T)$ function) should not affect the cost of credit protection in the credit default swap market.[24]

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[22] Sarig and Warga (1989) and Delianedis and Geske (2001) report that market participants view tax-exempt pension funds as the dominant players in the corporate bond markets.

[23] The effects of taxation on the credit default swap premium itself have not been studied in the literature. We conjecture, however, that any effect would be small. The reason for this is that the market is currently limited to large institutions rather than individuals, and that for most of these institutions, cash flows and mark-to-market gains and losses from swaps are taxed as ordinary income. Furthermore, the tax treatment of both legs of a credit default swap is the same; there is no tax asymmetry driving a wedge between the values of the premium and protection legs of the swap.

[24] Empirical studies documenting the presence of liquidity-related premia in Treasury bond prices include Amihud and Mendelson (1991), Kamara (1994), and Longstaff (2004).

To test whether cross-sectional differences in the nondefault component reflect the relative illiquidity of individual bonds, we regress the nondefault component for each bond in the sample on a number of liquidity proxies for these bonds. In doing this, it is important to acknowledge that liquidity is a concept that is sometimes difficult even to define, much less to quantify. Accordingly, our approach focuses on proxies that reflect different interpretations of liquidity and are based on available data. Unfortunately, measures of trading activity or volume are not available to us. Also, we do not have measures of the "specialness" or costs of shorting individual corporate bonds. As shown in Duffie (1996), these costs often mirror the relative liquidity of securities.[25]

The first proxy is the average bid–ask spread (in basis points) of the corporate bonds in the bracketing set. The bid–ask spread for each bond is calculated by taking the time-series average of the daily bid–ask spread reported by Bloomberg. These average bid–ask spreads range from about 4 basis points to more than 15 basis points.[26]

The second proxy attempts to measure the general availability of the bond issue in the market. In particular, we use the notional amount outstanding of each bond as a proxy for the bond's liquidity.

The third proxy is the age of the bond. This proxy parallels the notion of on-the-run and off-the-run bonds in Treasury markets. There is extensive evidence that on-the-run Treasury bonds are much more liquid than off-the-run Treasury bonds. If there is a similar effect in the corporate bond market, then older bonds may be less liquid than more recently issued bonds.

The fourth proxy is the time to maturity of the bond. The intuition for this variable is that there may be maturity clienteles for corporate bonds. Thus, it is possible, for example, that shorter-maturity corporate bonds may be more liquid than longer-maturity bonds. If so, then the difference in maturities across bonds may be related to cross-sectional differences in the nondefault component.

The fifth proxy is a dummy variable for bonds issued by financial firms. Since financial firms are presumably more connected to the capital markets, their securities may enjoy greater liquidity than the securities of other firms.[27]

The sixth and final proxy for bond-specific illiquidity is a dummy variable for bonds issued by highly rated firms (i.e., firms with a credit rating of AAA or AA). The intuition for this proxy is that there may be a "flight-to-quality" premium in highly rated bonds because they may be more marketable during a market panic or crisis. If so, then their liquidity may be more comparable to that of Treasury bonds. In turn, this implies that there might be a smaller nondefault component in the spread of AAA/AA-rated bonds.

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[25] To provide some perspective, we contacted several securities dealers about the costs of shorting corporate bonds. For liquid corporate bonds, the cost of shorting is only on the order of five basis points. We note, however, that in rare cases (typically related to firms in financial distress) corporate bonds can trade special by as much as 50–75 basis points for brief periods of time.

[26] Bid–ask spreads are calculated for bonds with Bloomberg "generic" prices, signifying a consensus among market participants regarding the value of the bond. So-called "fair value" prices, where a bond is priced by Bloomberg using matrix-pricing techniques, are not used in the calculation of the overall bid–ask spread.

[27] Ford Motor Credit and GMAC are treated as financial firms in this analysis.

Table V

**Regression of Nondefault Component of the Spread on Tax
and Liquidity Proxies**

This table reports the results from regressing the average nondefault component of the spread in basis points for each bond on the bond's percentage coupon rate, average bid–ask spread in basis points, the principal amount in $100 millions, age in years, time to maturity in years, and dummy variables for financial firms and AAA/AA-rated firms. The t-statistics are based on the Newey–West estimate of the covariance matrix.

Nondefault component $= \beta_0 + \beta_1 \text{Coupon} + \beta_2 \text{Bid/Ask Spread} + \beta_3 \text{Principal Amt} + \beta_4 \text{Age}$

$+ \beta_5 \text{Maturity} + \beta_6 \text{Financial} + \beta_7 \text{AAA/AA rating} + \epsilon$

Variable	Treasury Curve		Refcorp Curve		Swap Curve	
	β Coefficient	t-Statistic	β Coefficient	t-Statistic	β Coefficient	t-Statistic
Intercept	5.576	0.48	3.190	0.27	−33.913	−2.93
Coupon	5.441	3.35	3.178	1.90	3.637	2.19
Bid–Ask Spread	0.369	1.96	0.510	2.47	0.549	2.77
Principal Amt	−0.622	−3.16	−0.706	−3.67	−0.691	−3.81
Age	−0.336	−0.47	−0.623	−0.77	−0.777	−1.00
Maturity	2.947	3.25	2.860	3.10	2.055	2.46
Financial	12.399	2.40	12.867	2.67	10.938	2.32
AAA/AA Rating	−13.242	−2.17	−12.024	−2.19	−12.630	−2.29
	$R^2 = 0.234$	$N = 356$	$R^2 = 0.212$	$N = 356$	$R^2 = 0.210$	$N = 356$

Table V reports the results from the regression of the nondefault component for each bond in the sample on the tax and liquidity variables. As shown, the coupon rate of the bond is significant at the 5% level for the Treasury and swap curves, and significant at the 10% level for the Refcorp curve. The regression coefficient for the Treasury regression is 5.441, which is easily in the range of realistic marginal state income rates.[28] While it may be tempting to interpret this as evidence consistent with the tax hypothesis, the results for the other curves are not so easy to interpret. In particular, the tax difference described above applies only to corporate bonds versus Treasuries. In contrast, the state tax treatment of Refcorp bonds and swaps is essentially the same as that of corporate bonds. Thus, it is difficult to interpret the significant coefficients for the coupon rate in the Refcorp and swap regressions as a tax effect. In fact, these significant coefficients may simply be capturing the fact that higher-coupon bonds may be less popular or less liquid than other bonds.[29] If so, only the difference between the regression coefficient in the Treasury regression and the regression coefficients in the other regression may be unambiguously interpreted as a tax effect. Subtracting 3.178 or 3.637 from 5.441 implies that the actual marginal state tax rate incorporated into the prices of these bonds may only be on the order of 1–2%.

[28] The top marginal state income tax rate ranges from 0% for a number of states to 9.3% for California and 10.4% for New York.

[29] We are grateful to the referee for pointing out this possibility.

Turning to the measures of corporate bond illiquidity, Table V also shows that the average bid–ask spread of the corporate bonds is significantly positively related to the nondefault component in all three regressions. Thus, as the liquidity of the corporate bonds decreases, the size of the nondefault component increases. This is consistent with the hypothesis that less liquid bonds tend to have a larger liquidity component embedded within their yield spreads, and that this component is not included in market credit default swap premia. The principal amount of the bond outstanding is significantly negatively related to the nondefault component in each regression. These results are also consistent with a liquidity interpretation. In particular, the nondefault component is smaller for bonds with larger issue sizes, which are presumably more liquid or easy to find in the financial markets.

The coefficient for the age of the bond is not significant in any of the three regressions reported in Table V. This may be evidence against the existence of an on-the-run effect in the corporate bond market. It is important to raise the caveat, however, that the age of the bonds in the sample ranges from about 1 year to more than 10 years; newly issued or on-the-run issues are rare in the sample. Thus, the bonds in the sample may simply all be off-the-run bonds. In this case, it may be unsurprising that we find no cross-sectional effects. In contrast, there is a strong positive relation between the nondefault component and the time to maturity of the bond. Thus, these results are consistent with the interpretation that longer-maturity bonds are less liquid than shorter-maturity bonds.

Both of the dummy variables are significant. Surprisingly, the coefficient for the financial dummy variable is positive in sign. This suggests that there is an additional 11–13 basis points in the nondefault component of financial firms. This is not consistent with the hypothesis that debt issued by financial firms is more liquid or more readily marketable than debt for other firms. On the other hand, these results do indicate that there are industry effects in the nondefault component of corporate spreads. The regression coefficient for the AAA/AA dummy variable is significant and negative, and is about -12 or -13 basis points. This is supportive of the presence of a small but significant "flight-to-quality" or "flight-to-liquidity" premium in the prices of the highest-rated corporate bonds.

B. Time-Series Analysis

Turning now to the time-series properties of the nondefault component, we observe that there are two ways in which a liquidity component in corporate spreads could arise. The first is through the idiosyncratic illiquidity of individual corporate bonds. The effect of this would be to create cross-sectional variation in the nondefault component across bonds. The regression results in Table V are consistent with the presence of bond-specific illiquidity components in corporate spreads. The second way is if Treasury (or Refcorp or other benchmark) bonds trade at a premium because of their unique role in financial markets as highly liquid or marketable havens during turbulent periods (for
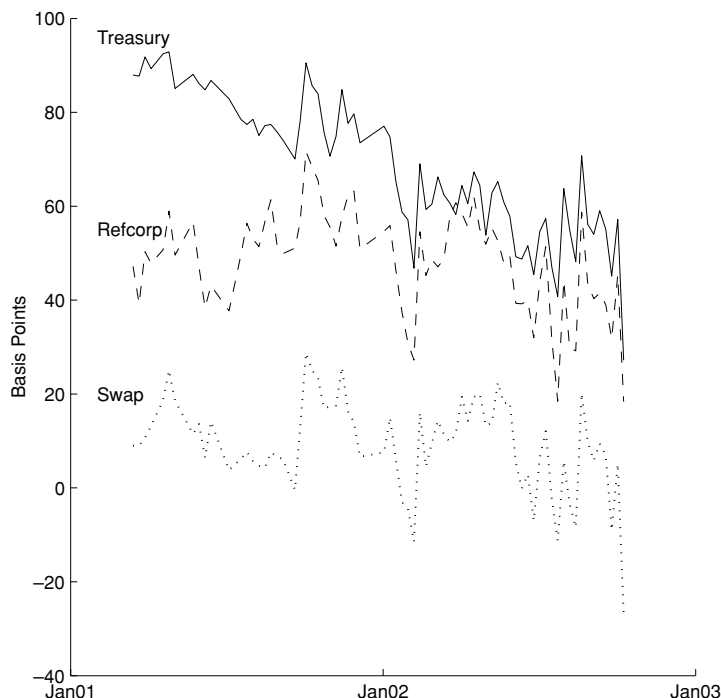
Figure 6. Time-series plot of the average nondefault spread. The plot shows the time series of the nondefault spread averaged over firms for each of the riskless curves.

example, during flights to quality or liquidity). In this case, corporate spreads will contain a common Treasury liquidity component. The effect of this Treasury-specific richness or liquidity would be to increase the measured spread for all corporate bonds. Thus, this effect would show up only in the common time-series variation in the nondefault components, not in the cross-section of the nondefault components.

To test whether there is variation in the nondefault component arising from changes or systematic shocks to marketwide liquidity measures, we average the nondefault component over firms and regress weekly changes in this measure on changes in several macroeconomic measures of Treasury and corporate bond market liquidity. Figure 6 plots the time series of the average nondefault component. The first measure is motivated by recent work by Longstaff (2004), who finds that liquidity spreads in the Refcorp market are related to flows into money market mutual funds. Accordingly, we obtain weekly changes in total money market mutual fund assets from the Federal Reserve Board and include the sum of the two previous weekly changes as an explanatory variable. The intuition for this variable is that money market mutual funds represent a hedge against flights to quality or liquidity. A sudden increase in the amount of funds flowing into money market mutual funds may be associated with a

general lack of liquidity in more-risky markets such as the corporate bond market. This systematic liquidity shock would appear as a general widening in the spreads between all corporate bonds and Treasury or other benchmark bonds.

The second measure is the weekly dollar amount of corporate (including agency) debt issued in the fixed income markets. This measure is obtained from the Bloomberg system. If there is a large inflow of new debt in the market, the liquidity of older corporate bonds may be impaired. This would translate into a widening in the nondefault component for the bonds in our sample. Again, this variable measures marketwide liquidity rather than bond-specific illiquidity.

The third measure is the difference in the yield of the current on-the-run 5-year Treasury bond and the average yield of generic off-the-run Treasury bonds. As the on-the-run yield, we use the constant maturity 5-year Treasury rate calculated by the Federal Reserve from benchmark on-the-run issues. The off-the-run yield is the 5-year generic Treasury rate reported in the Bloomberg system and which is based on the yields of nonbenchmark Treasury bonds. The spread between on-the-run and off-the-run bonds reflects the specialness or liquidity of Treasury bonds (see Duffie (1996)). This spread is also related to the financing advantage of on-the-run Treasury bonds in the special repo market (see Jordan and Jordan (1997), Buraschi and Menini (2002), and Krishnamurthy (2002)).

Table VI reports the results from regressing the weekly changes in the average nondefault component on the three proxies as well as the lagged change in the nondefault component. As shown, the coefficient for the lagged change in the nondefault component is negative and highly significant. This demonstrates

Table VI
Regression of Changes in Average Nondefault Component
of the Spread on Bond Market Liquidity Measures

This table reports the results from regressing weekly changes in the average nondefault component in basis points on the previous change, changes in total money market mutual fund assets in $ billions, the total amount of agency and corporate debt issued in $ millions, and the difference between yields on off-the-run and on-the-run Treasury bonds in basis points.

$$\Delta \text{Nondefault Component} = \beta_0 + \beta_1 \text{Lagged } \Delta \text{ Nondefault Component} + \beta_2 \Delta \text{MMMF Assets}$$

$$+ \beta_3 \text{Debt Issuance} + \beta_4 \text{On/Off the Run Spread} + \epsilon$$

Variable	Treasury Curve		Refcorp Curve		Swap Curve	
	β Coefficient	t-Statistic	β Coefficient	t-Statistic	β Coefficient	t-Statistic
Intercept	−4.515	−1.58	−4.734	−1.39	−6.374	−1.97
Lagged Δ Nondefault Component	−0.478	−4.01	−0.305	−2.62	−0.389	−3.26
Δ MMMF Assets	0.295	2.33	0.266	1.75	0.301	2.09
Debt Issuance	0.116	1.35	0.144	1.40	0.190	1.95
On/Off the Run Spread	0.519	0.24	0.573	2.15	0.444	1.76
	$R^2 = 0.240$	$N = 71$	$R^2 = 0.201$	$N = 71$	$R^2 = 0.236$	$N = 71$

that the nondefault component is both time varying and mean reverting. Furthermore, the magnitude of the regression coefficients suggests that the speed of mean reversion is very rapid; that is, shocks to the nondefault component tend to dissipate within a few weeks or months.

The coefficient for the change in money market mutual fund assets is positive and significant at the 5% level for the Treasury and swap regressions, and positive and significant at the 10% level for the Refcorp regression. Thus, as money flows into defensive money market positions, the nondefault component of corporate spreads increases. This is consistent with the interpretation of the nondefault component as a liquidity-related component.

The amount of debt issued has a positive sign but is not significant at conventional levels in the Treasury and Refcorp regressions. For the swap regression, however, the amount of debt is positively and significantly related to the nondefault component. This supports the view that as the market absorbs new debt, existing issues become less liquid.

The coefficient for the on-the-run/off-the-run spread is positive and significant at the 5% and 10% levels, respectively, for the Refcorp and swap regressions. This provides direct evidence that as the richness or extreme liquidity of Treasury bonds increases, the average nondefault component of all corporate bonds increases. This again supports the hypothesis that an important portion of the nondefault component of corporate spreads is due to the liquidity of the Treasury bonds.

C. Discussion

Taken together, the cross-sectional and time-series results indicate that the nondefault component of corporate bond spreads is strongly related to a number of liquidity measures. Bond-specific illiquidity measures are important in explaining cross-sectional differences, while marketwide or macroeconomic measures of liquidity explain a sizable portion of the common variation in all corporate spreads. This evidence of strong marketwide components in corporate spreads is clearly consistent with the evidence in Collin-Dufresne et al. (2001) about the commonalities in corporate spreads. In fact, they argue that the presence of an aggregate liquidity factor in bond markets may explain most of the movements of credit spreads. Similarly, Duffie and Singleton (1997), Delianedis and Geske (2001), Liu et al. (2004), and Longstaff (2004) find consistent evidence that time variation in corporate spreads is related to systematic liquidity shocks. Finally, Pastor and Stambaugh (2003), Wang (2003), Acharya and Pederson (2003), and others find evidence that variation in liquidity is a risk that is priced in equity markets.

VI. Conclusion

In this paper, we use the information in credit default swaps to provide direct evidence about the size of the default and nondefault components in corporate spreads. An important feature of our analysis is the use of an extensive data

set on credit default swap premia and the corresponding corporate bond prices provided to us by the Global Credit Derivatives desk at Citigroup.

The results indicate that the default component represents the majority of corporate spreads. Even for the highest-rated investment-grade firms in the sample, default risk accounts for more than 50% of the total corporate spread. These results complement and extend previous work by suggesting that the market price of credit risk may be larger than implied by some structural models. Alternatively, market-implied risk-neutral estimates of jump risk may be larger than estimates based on historical data.

We also find evidence of a significant nondefault component in corporate spreads. This result is robust to the choice of the riskless curve. We find that the nondefault component is time varying and mean reverts rapidly. The nondefault component of spreads is strongly related to measures of bond-specific illiquidity such as the bid–ask spread and the outstanding principal amount. In addition, changes in the nondefault component are related to measures of Treasury richness such as the on-the-run/off-the-run spread as well as to measures of the overall liquidity of fixed income markets such as the flows into money market mutual funds. In contrast, there is only weak support for the hypothesis that the nondefault component is due to taxes.

These results have many implications both for asset pricing as well as corporate finance. For example, these results add to the rapidly growing literature on the effects of liquidity on security prices. Furthermore, the evidence that liquidity effects add to the equilibrium cost of corporate debt is important since it may help explain why firms tend to use less debt in their capital structure than models based on the tradeoff between the costs of financial distress and the tax benefits of debt would suggest (see Leland (1994), Leland and Toft (1996), and Goldstein, Ju, and Leland (2001)). Also, the evidence of systematic time variation in the liquidity component of corporate spreads may shed light on the tendency of corporate debt and equity offerings to cluster.

Appendix A

From the independence assumption,

$$E\left[\exp\left(-\int_0^T r_t + \lambda_t + \gamma_t \, dt\right)\right] = D(T)E\left[\exp\left(-\int_0^T \lambda_t \, dt\right)\right] E\left[\exp\left(-\int_0^T \gamma_t \, dt\right)\right].$$

(A1)

Let $F(\lambda, T)$ denote the first expectation on the right-hand side of (A1). As in Cox, Ingersoll, and Ross (1985), $F(\lambda, T)$ satisfies the partial differential equation,

$$\frac{\sigma^2}{2}\lambda F_{\lambda\lambda} + (\alpha - \beta\lambda)F_\lambda - \lambda F - F_T = 0,$$

(A2)

subject to the boundary condition $F(\lambda, 0) = 1$. Represent $F(\lambda, T)$ as $A(T)\exp(B(T)\lambda)$. Differentiating this expression and substituting into the partial differential equation shows that this will be a solution provided that $A(T)$ and $B(T)$ satisfy the Riccati equations

$$B' = \frac{\sigma^2}{2}B^2 - \beta B - 1, \tag{A3}$$

$$A' = \alpha A B, \tag{A4}$$

subject to $A(0) = 1$ and $B(0) = 0$. These two ordinary differential equations are easily solved by direct integration. The solutions to these are as given in equation (8). Now let $V(\gamma, T)$ denote the second expectation on the right-hand side of equation (A1). Then $V(\gamma, T)$ satisfies the partial differential equation

$$\frac{\eta^2}{2}V_{\gamma\gamma} - \gamma V - V_T = 0, \tag{A5}$$

subject to the boundary condition $V(\gamma, 0) = 1$. Represent $V(\gamma, T)$ as $C(T)\exp(L(T)\gamma)$. Differentiating this expression and substituting it into the partial differential equation shows that this will be a solution provided that $C(T)$ and $L(T)$ satisfy the Riccati equations

$$L' = -1, \tag{A6}$$

$$C' = \frac{\eta^2}{2}L^2 C, \tag{A7}$$

subject to the boundary conditions $C(0) = 1$ and $L(0) = 0$. These two ordinary differential equations are easily solved by direct integration. Substituting the solutions back into the definition for $V(\gamma, T)$ implies that $V(\gamma, T) = C(T)\exp(-\gamma T)$, where $C(T)$ is as defined in equation (8) (here $L(T) = -T$).

Again, from the independence assumption,

$$E\left[\lambda_T \exp\left(-\int_0^T r_t + \lambda_t + \gamma_t \, dt\right)\right] = D(T)V(\gamma, T)E\left[\lambda_T \exp\left(-\int_0^T \lambda_t \, dt\right)\right]. \tag{A8}$$

Let $W(\lambda, T)$ denote the expectation on the right-hand side of (A8). Duffie et al. (2000) imply that $W(\lambda, T)$ satisfies the partial differential equation

$$\frac{\sigma^2}{2}\lambda W_{\lambda\lambda} + (\alpha - \beta\lambda)W_\lambda - \lambda W - W_T = 0, \tag{A9}$$

subject to the boundary condition $W(\lambda, 0) = \lambda$. Now represent $W(\lambda, T)$ as $\exp(B(T)\lambda)(G(T) + H(T)\lambda)$. Again, differentiating and substituting into the partial differential equation show that this is a solution provided that $B(T)$, $G(T)$, and $H(T)$ satisfy the Riccati equations

$$B' = \frac{\sigma^2}{2}B^2 - \beta B - 1, \tag{A10}$$

$$H' = H(\alpha + \sigma^2)B - H\beta, \tag{A11}$$

$$G' = \alpha BG + \alpha H, \tag{A12}$$

subject to $B(0) = G(0) = 0$, and $H(0) = 1$. The equation for B' in (A10) is the same as in (A3) and has the same solution. Equation (A11) can now be solved for $H(T)$ by integration. Finally, with these expressions for $B(T)$ and $H(T)$, the function $G(T)$ can also be solved by a direct integration. The resulting solutions are as given in equation (8) of the text.

Substituting these expressions for $F(\lambda, T), V(\gamma, T)$, and $W(\lambda, T)$ into equations (4) and (7) gives the solutions for the value of the corporate bond shown in equation (8) and the credit default swap premium shown in equation (9).

Equation (8) gives the price of a coupon bond when there are both default and liquidity components. The price of the corporate bond when there is no liquidity component is given by setting $C(t) = 1$ and $\gamma = 0$ in equation (8). Similarly, the price of a riskless bond (no liquidity or default component) is given by setting $A(t) = C(t) = 1, G(t) = 0$, and $\lambda = \gamma = 0$ in equation (8).

Appendix B

A. *Credit Default Swap Data*

The credit default swap data for the study are taken from an extensive data set of premia for 5-year contracts provided by Citigroup that includes observations for the time period from March 15, 2001 to October 9, 2002. (Enron is the sole exception in that its credit default swap data begins on December 5, 2000.) Before September 26, 2001, the data consist of Thursday quotations. After September 26, 2001, the data are recorded on Wednesday. There is one period during the sample period in which only a few firms have credit default swap premia quotations recorded. This is the period from December 5, 2001 to January 2, 2002.

B. *Bond Yield Data*

In collecting bond yield data, the following criteria are applied.

- Only SEC-registered dollar-denominated issues are included.
- Medium-term notes are avoided where possible.
- Only fixed coupon issues are used.
- Where possible, larger issues are chosen. Issues with total notional amount less than \$10 million are excluded. The issue sizes range from a low of \$18 million to a high of \$6.5 billion, with a mean of \$735 million and a median of \$500 million.
- Bonds with callable or puttable features are excluded. The only exceptions are bonds with a make-whole provision. A make-whole provision stipulates that if the issuer calls the bond, the amount paid for the call is based on a yield computed as a specific spread over Treasuries. Thus, the call price moves inversely with interest rates, making refunding less likely (see Fabozzi (2001) p. 11).

- At least two bonds need to be included in the bracketing set for a firm to be included in the sample.

The algorithm for identifying candidate bonds for inclusion in the bracketing set is as follows. We first attempt to find a bond with a maturity shorter than 5 years as of the first observation date for each firm. In most cases, this involves finding a bond with a maturity date before March 15, 2006, which can then be used as the lower limit of the bracketing interval. Maturity dates of bonds used for the lower limit range from 2003 to 2006. Similarly, we then attempt to find a bond with a maturity longer than 5 years as of the last observation date for each firm. This last observation date is typically October 9, 2002. The maturity of this bond is then used as the upper limit of the bracketing interval. Maturity dates for bonds used for the upper limit range from 2007 to 2011. Once the bonds defining the lower and upper limits of the bracketing interval are identified, bonds with intermediate maturity dates are identified to provide roughly equally spaced coverage of the entire bracketing interval. To be included in the bracketing set, the candidate bonds identified in this manner also need to satisfy the criteria described above.

The yield data obtained from Citigroup have missing observations for some bonds on some dates. The yield data are checked against yield data from Bloomberg and the agreement is generally reasonable. For dates for which the yields diverge significantly, the observation is deleted from the sample.

Some filtering of the bond yield data is necessary. Most of the filtering concerns yields, which change by large amounts on a given date compared to the yields of the other bonds for the firm. In these cases, the yields for those bonds are removed from the sample for that date. In other cases, part or all of the time series of yields for a particular bond is removed from the sample. Typically, this is because part or all of the time series of yields for the bond exhibits large movements that are clearly inconsistent with the movements of other bonds for that firm. Three firms deserve special mention in this regard. Qwest Capital, Sprint, and Worldcom were in severe financial distress during the latter part of our sample period. During this period, the yield data for these companies exhibited what was clearly asynchronous updating. Week-to-week changes in various yields often differed by hundreds of basis points. Because of this, their yield data during these time periods are not included in the sample. For Qwest Capital, 16 weekly data points remain after the data selection process, covering the period from September 26, 2001 to January 30, 2002. For Sprint, 33 weekly data points remain after the data selection process, covering the period from March 29, 2001 to February 6, 2002. For Worldcom, 33 weekly data points remain after the data selection process, covering the period from March 15, 2001 to January 23, 2002. Worldcom filed for bankruptcy on July 21, 2002.

There are two mergers during the sample period. TRW was acquired by Northrup-Grumman. The completion date of the merger was December 12, 2002, which is after the end of the sample. Thus, only bonds with TRW as the issuer are used. Conoco was acquired by Conoco-Phillips. The completion date

for the merger was September 3, 2002, which is a few weeks before the end of the data set. Bonds with Conoco as the issuer are used throughout the sample.

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