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CONDITIONAL TESTS OF A SIGNALLING HYPOTHESIS:
THE CASE OF FIXED VERSUS ADJUSTABLE RATE DEBT

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by

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Conditional Tests of a Signalling Hypothesis: The Case of Fixed versus Adjustable Rate Debt

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ABSTRACT

This paper develops and tests a signalling model where managers choose between borrowing at a fixed and an adjustable interest rate. Like other signalling models, investors are assumed to know the cross-sectional distribution of firm quality while managers know the quality of their own firms. The decision to issue adjustable rate debt is shown to provide a negative signal and fixed rate debt a positive signal about stock value depending upon circumstances surrounding the level of volatility in Treasury Bill prices and the sensitivity of firm value to changes in these prices. Regardless of firm value sensitivity however, high quality firms are not able to separate themselves from low quality firms until TBill volatility reaches a minimum threshold.

Our empirical investigation into the stock price response to adjustable and fixed rate debt announcements is designed to exploit the existence of a threshold in the data. We attempt to identify the TBill volatility threshold below which signalling does not occur. Simultaneously, we estimate the average difference in stock price reaction to the announcement of adjustable and fixed rate debt conditional upon being above and below the threshold. Our methods would seem to apply to the investigation of signalling models whenever observable parameters enter the characterization of the signalling region.

We examine a matched sample of 47 firms issuing adjustable and fixed rate debt over the period 1978 to 1986, a period containing the greatest activity in the United States adjustable rate market. We find that the whole sample reveals a marginally significant negative difference in stock price reaction at announcement. On the other hand, the data indicate rather strongly the existence of a threshold in TBill volatility above which a negative difference in stock price reaction occurs and below which there is no reaction. We conclude that part of the data seems to come from a region where the type of debt issued reveal something material about firm quality and part comes from a region where no separation of firm quality occurs. Within the former region, the difference in stock price reaction is about -2.4% of stock value.
I. INTRODUCTION

The literature surrounding financing decisionmaking in modern corporations recognizes two important situations where financing matters. The first is where the financing decision affects the future after-tax cash flows generated by the firm's real investment decisions. The second is where the financing decision, although not causing a change in cash flows, serves to reveal or signal the existence and nature of management information about the firm's real cash flow prospects. This latter situation occurs when the manager has different information about the firm's future cash flows than the investing public and the utility of the manager is influenced by both the financing decision and the firm's future cash flows.

In a rational market, wherever inter-relationships between financing and future cash flows are present, one would predict an association between firm value and financing choice. However, a contemporaneous stock price reaction to the announcement of a financing decision is only predicted in situations where the announcement resolves some uncertainty about the stock's future cash flows. Decisions based on public information should be anticipated by investors and not engender a material stock price reaction. This fact has led many researchers to emphasize the signalling aspect of financing decisions in the development of predictions about stock price reactions.¹

One interesting aspect of signalling environments is that courses of action serve as signals only within specific regions of parameter values. For example, particular financing decisions can signal high future cash flows only if firms with low future cash flow find it too costly to mimic high cash flow firms. Otherwise a given decision is an ineffective signal because both high and low quality firms can make the same decision. This feature can be exploited empirically when some of the parameters characterizing the signalling region are observable to the econometrician. Under these circumstances, the power of the test against the null of no stock price reaction can be enhanced by considering the possibility that pooling is the equilibrium within certain regions of the

¹Ross (1977) and Leland and Pyle (1977) are early examples. More recent contributions include Myers and Majluf (1984), Miller and Rock (1985), Grinblatt and Hwang (1989), and Dravid and McNichols (1990).
These points can be illustrated by considering a generic signalling model. Suppose the necessary and sufficient conditions for the existence of a signalling outcome in a particular model are described by the following k inequalities:

\[ f_1(\alpha_1, \ldots, \alpha_n, \beta_1, \ldots, \beta_n) \geq 0 \]
\[ f_2(\alpha_1, \ldots, \alpha_n, \beta_1, \ldots, \beta_n) \geq 0 \]
\[ \vdots \]
\[ f_k(\alpha_1, \ldots, \alpha_n, \beta_1, \ldots, \beta_n) \geq 0 \]

where \( \alpha_1, \ldots, \alpha_n, \beta_1, \ldots, \beta_n \) are continuous parameters specific to the model. Suppose \( \alpha_1, \ldots, \alpha_n \) are observable by the econometrician. For every observable parameter there is a range of values over which a solution for system (1) exists. The \( n \) ranges define the tightest multidimensional rectangle in the \( \alpha_1, \ldots, \alpha_n \) space, that encapsulates the signalling region. Signalling models predict qualitatively different stock responses to events occurring inside and outside the rectangle. The stock response should be, on average, positively related to the intensity of the signal inside the rectangle but unrelated to the signal outside the rectangle. Moreover, an empirical investigation should reveal two separate functions for the stock price response to signal intensity.

This paper uses the above logic to test a signalling model where managers choose between borrowing at a fixed and an adjustable interest rate. Like other signalling models, investors are assumed to know the cross-sectional distribution of firm quality while managers know the quality of their own firms. The decision to issue adjustable rate debt is shown to provide a negative signal and fixed rate debt a positive signal about stock value depending upon circumstances surrounding the level of volatility in Treasury Bill prices and the sensitivity of firm value to changes in TBill prices. Regardless of firm value sensitivity however, high quality firms are not able to separate themselves from low quality firms until TBill volatility reaches a minimum threshold.

Examples include Proposition 1 in Giammarino and Lewis (1988), Proposition 1 in Allen and Faulhaber (1989), and Proposition 1 in Grinblatt and Huang (1989).
Our empirical investigation into the stock price response to adjustable and fixed rate debt announcements is designed to exploit the existence of a threshold in the data. We attempt to identify the TBill volatility threshold below which signalling does not occur. Simultaneously, we estimate the average difference in stock price reaction to the announcement of adjustable and fixed rate debt conditional upon being above and below the threshold. Our methods would seem to apply to the investigation of signalling models whenever observable parameters enter the characterization of the signalling region.

We examine a matched sample of firms issuing adjustable and fixed rate debt and find that the whole sample reveals a marginally significant difference in stock price reaction at announcement. On the other hand, the data indicate rather strongly the existence of a region of TBill volatility within which a negative difference in stock price reaction occurs. We conclude that part of the data seems to come from a region where the type of debt issued does not reveal anything material about firm quality and part comes from a region where separation of firm quality occurs. Within this latter region, the difference in stock price reaction is about \(-2.4\%\) of stock value.

II. THE CHOICE BETWEEN FIXED AND ADJUSTABLE-RATE DEBT

II.1. Assumptions and Notation

Consider a two-period economy with stochastic interest rates, where \(P_t\) represents the price, at \(t\), of a short-term default-free bond that pays $1 at \(t+1\). At date \(t=0\), a firm has access to a positive net present value (NPV) project that requires external financing. The project combined with assets in place generates a single stochastic cash-flow at date \(t=2\). The present value net of the value of any pre-existing debt at \(t<2\), \(V_t\), is a function

\[
V_t = V[P_t, q, Y_t]; \quad V'_q > 0, \quad V''_q < 0, \quad V'_r > 0, \quad V''_r > 0
\]  

(2)

where \(q\) is a parameter capturing firm quality, and \(Y_t\) is a state variable independent of \(P_t\). Firm quality, \(q \in \{G, B\}\), can be either Good (G) or Bad (B), with \(G > B\). Knowledge of \(q\), however, is private to the firm. The market only knows the probability distribution over firm types, plus the fact that the firm knows
its own type. The prior probability of the firm being of the Good-type is \( \theta \). Firm type becomes public information after the new debt issue, at date \( t=1 \).

To fund the project the firm floats discount bonds, subordinate to any existing debt. All bonds mature when the project pays-off at \( t=2 \). The new bonds carry either a fixed or an adjustable interest rate: under a fixed interest rate the firm promises to pay $1 at \( t=2 \); under an adjustable rate, the promised payment is a negative function of the interim short-term, default-free, bond price, \( \pi(P_t) \), with \( \pi(E_P) = $1 \).

The function \( \pi(\cdot) \) is specified to immunize the adjustable-rate bonds against shifts in default-free interest rates at \( t=1 \). Let the market value of fixed and adjustable-rate debt at date \( t \), conditional on message \( m \) at issue, be denoted \( D_t^m \) \( [m=F,A; t=0,1,2] \).

In this market the firm moves first by choosing its borrowing strategy: It sends a message \( m \in M = \{\text{Fixed}, \text{Adjustable}\} \), drawn from a probability distribution \( p(m|q) \). The observation of the borrowing strategy may lead investors to revise their beliefs about firm quality; \( \theta_m \) denotes the posterior probability of the firm being of the Good-type conditional on message \( m \). Whenever possible, posterior probabilities are formed according to Bayesian updating. Finally, lenders make their move: they respond to a fixed-rate issue with \( D_0^F(\theta) \) and to an adjustable-rate issue with \( D_0^A(\theta_A) \); we assume that credit markets are competitive so that lenders price bonds to yield a fair return, given their conjecture of firm quality.

II.2. The Firm's Objective Function

The insider with firm-type \( q \) chooses message \( m = \{F,A\} \) to maximize

\[
S_0^m(P_0, Y_0, \theta_m) - \Omega \text{Var}[S_t^m(P_t, Y_t, q)], \quad \Omega > 0
\]

where \( S_0^m \) is the market value of the stock at issue conditional on message \( m \),

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This condition states that the promised payments on fixed and adjustable-rate bonds are identical if short-term default-free bond prices follow their expected time path between \( t=0 \) and \( t=2 \).

See Cox, Ingersoll, and Ross (1980), and Ramaswamy and Sundaresen (1986) for a discussion of adjustable-rate notes.
\( \text{Var}[S_t^m] \) is the variance of the stock at \( t=1 \), conditional on message \( m \) at \( t=0 \), and \( \Omega \) is a risk aversion parameter. The insider's objective function is a variant of Ross (1977). Basically, it captures the problem faced by a risk averse manager who is paid to maximize stock price but whose job is his major source of wealth.

The variance of the equity for firm-type \( q \), at \( t=1 \), conditional on message \( m (m=\text{F,A}) \) is

\[
\text{Var}[S_t^m(q)] = \text{Var}[V_t(q)] + \text{Var}[D_t^m(q)] - 2\text{Cov}[V_t(q), D_t^m(q)], \quad m=\text{F,A}; \quad q=\text{G,B} \tag{4}
\]

For tractability assume that the risk of \( P_t \) and \( Y_t \) is small so that a series approximation to the variance of the equity is appropriate. Taking a first-order Taylor approximation of functions \( V_t \) and \( D_t^m \) around the point \([E_P, E_Y, q] \) and computing the variance of the equity, yields

\[
\text{Var}[S_t^m(q)] = (\partial D_t^m/\partial P_t) [ (\partial V_t/\partial P_t)^2 - 2(\partial V_t/\partial P_t) ] \text{Var}(P_t) +
+ (\partial D_t^m/\partial Y_t) [ (\partial V_t/\partial Y_t)^2 - 2(\partial V_t/\partial Y_t) ] \text{Var}(Y_t) \tag{5}
\]

where all derivatives are evaluated at the point \([E_P, E_Y, q] \). With adjustable-rate bonds the value of the debt is immunized against shifts in default-free bond prices, and therefore \((\partial D_t^A/\partial P_t)=0\); also, because at the approximation point the promised payment on fixed and adjustable-rate debt are the same, \( \partial D_t^F/\partial Y_t=\partial D_t^A/\partial Y_t \). As a result, the difference between the equity variance of the two strategies is simply

\[
\text{Var}[S_t^F(q)] - \text{Var}[S_t^A(q)] = (\partial D_t^F/\partial P_t) [ (\partial V_t/\partial P_t)^2 - 2(\partial V_t/\partial P_t) ] \text{Var}(P_t) \tag{6}
\]

From (6) we can see that it is the sensitivity of firm value with respect to short-term default-free bond prices, \( \partial V_t/\partial P_t \), that determines which borrowing strategy minimizes the variance of the equity. Specifically, low (high) values of \( \partial V_t/\partial P_t \) make adjustable-rate (fixed-rate) borrowing a better hedge. The effect of bond price volatility, on the other hand, is to magnify the difference between the equity variance of the two strategies.
II.3. Equilibrium Borrowing Strategies

In this section we investigate the existence of separating outcomes that satisfy the Nash Sequential Equilibrium (NSE) criterion of Kreps and Wilson (1982). To do that we first need to prove the following lemma.

Lemma 1

If \[\frac{\partial^2V_i}{\partial P_i \partial q} \geq \frac{\partial^2D_i^F}{\partial P_i \partial q} > 0\] then
\[\frac{\partial \{S_0^F(\theta_F) - \Omega \text{Var}[S_0^F(q)] - S_0^A(\theta_A) + \Omega \text{Var}[S_0^A(q)]\}}{\partial q} > 0.\]

Proof in the appendix.

Lemma 1 spells out a sufficient condition that gives the insider of a Good-type firm a comparative advantage in fixed-rate borrowing.\(^5\) Thus, it opens the possibility for firms to signal high quality with fixed-rate debt when the volatility of the equity under fixed-rate borrowing exceeds the volatility under adjustable-rate borrowing. Without such a comparative advantage, separating outcomes cannot exist since it always pays for the Bad-type to mimic and issue fixed-rate bonds. Lemma 1 also excludes the possibility for the firm to signal high quality with adjustable-rate bonds when fixed-rate borrowing hedges the value of the equity. Since the Bad-type has a comparative advantage in adjustable-rate, its incentive compatibility is violated whenever the constraint on the Good-type is satisfied.

Is the sufficient condition of Lemma 1 reasonable? Generally, one would expect interest rate shifts to produce larger effects on the present value of a high cash-flow than on the present value of a low cash-flow. Since high quality implies larger overall project cash-flows, this would imply \[\frac{\partial^2V_i}{\partial P_i \partial q} > 0\] and \[\frac{\partial^2D_i^F}{\partial P_i \partial q} > 0.\] Furthermore, because cash-flows to creditors are less dependent on firm quality, one would expect the interest rate sensitivity of firm value to be more responsive to firm quality than the interest rate sensitivity of a fixed-rate bond.

\(^5\)For those readers familiar with the signalling literature, Lemma 1 is related to Riley's (1979) assumption 5.
**Proposition I**

In the above market, there exists a NSE separating outcome in which Good-type firms issue fixed-rate debt and Bad-type firms issue adjustable-rate debt; there isn’t, however, a symmetric NSE separating outcome in which the Good-type issues adjustable and the Bad-type sells fixed-rate debt. Proof in the Appendix.

Proposition I states that firms can signal high quality with fixed-rate debt when adjustable-rate borrowing makes a better hedge. Since the Good-type has a comparative advantage in hedging with fixed rate, it finds economical to take on more equity variance and capture a high stock price at issue. The Bad-type, on the other hand, finds the loss in hedging from borrowing at a fixed-rate too costly.

An important feature of the separating outcome of proposition I is that it requires a minimum level of volatility in default-free bond prices to deter the Bad-type from mimicking. Intuitively this can be seen from equation (6). When bond price volatility is low, fixed and adjustable-rate debt are not materially different, and the two strategies hedge the equity in a similar fashion. The Bad-type is better off by mimicking under these conditions. This intuition is substantiated in Proposition II.

**Proposition II**

A necessary condition for the existence of the separating NSE outcome described in Proposition I is that the variance of short-term, default-free, bond prices, \( \text{Var}(P_t) \), is not below a threshold \( \text{Var}(P_t)^*>0 \). Proof in the appendix.

The empirical analysis below exploits the existence of a volatility threshold. Below the threshold the market cannot infer firm quality from the choice between fixed and adjustable-rate debt. Thus at low levels of volatility the model predicts no differential stock price response to the announcement of fixed and adjustable-rate bond issues. Above the threshold, on the other hand, there are firms which signal high quality by borrowing at a fixed-rate. Hence, at high levels of volatility, announcements of fixed-rate bond issues should elicit a more favorable stock price response than announcements of adjustable-
rate bond issues. Our empirical approach is to estimate a volatility threshold in Treasury Bill prices, and measure the average differential stock price response to announcements of fixed and adjustable-rate bond issues, above and below the threshold.

III. DATA AND EMPIRICAL METHODS

III.1. Data

A sample of 47 pairs of debt issue announcements was collected over the time period spanning 1979 to 1985. The sampling design was motivated by the relative scarcity of adjustable-rate debt issues. First we attempted to collect as many observations as possible on adjustable-rate debt issue announcements. We then looked for suitable fixed-rate matches.

Information on the fixed and adjustable rate debt issues examined in this study was taken from the Registered Offering Statistics (ROS) tape of the Securities and Exchange Commission. The ROS tape contains information on public corporate debt issues made in the U.S. market between 1977 and 1987. Table 1 shows the aggregate face value of all debt listed on the tape as non-convertible and unsecured. This aggregate is broken down by year of issue and also on the basis of whether the debt offers a fixed or adjustable rate. The proportion offering an adjustable rate is only 1% in 1978 but climbs to a maximum of 13% in 1983. The time distribution of our final sample is also reported in the table and conforms closely to the total population of adjustable rate debt. Finally, the table shows the average annualized TBill yield in each of the years along with the average TBill price volatility. We discuss our measure of volatility in III.2.c.

The ROS tape reports a total of 162 public issues of non-convertible, unsecured adjustable rate debt sold by companies listed on either the New York or American Stock Exchange. For these 162 debt issues, the Wall Street Journal Index (WSJI) and the Dow Jones News Retrieval Service (DJNRS) were searched for announcement dates. When news announcing an adjustable rate debt issue appeared in both sources, the earliest report was selected. Observations were screened for confounding announcements of multiple securities and for missing stock returns. An observation was dropped out of the sample if there were more than 30
missing daily stock returns over the 140 days preceding the announcement day. The resulting sample consists of 59 announcements.

In the second step we attempted to match each adjustable-rate debt announcement with a suitable fixed-rate debt announcement. A total of 47 pairs were obtained by employing the following matching criteria:

(i) Timing: a clean fixed-rate debt issue announcement had to be found within a 6 month period centered around the adjustable-rate debt issue announcement date.

(ii) Industry classification: the fixed-rate debt issue announcement had to be made by a firm in the same industry as the firm announcing the adjustable rate debt issue.

(iii) Maturity: whenever more than one match for an adjustable rate issue announcement satisfying (i) and (ii) above could be found, the one with the maturity closest to that of the adjustable-rate issue was selected.

Table 2 reports selected summary statistics on the matched sample. The average maturity is 10.9 years with average principle of $128.3 Million. The average asset size of the issuing firms is $24.8 Billion. Within the SIC classifications represented, the most noteworthy feature is the relatively large number of depository institutions with SIC code 602. There are 18 in total. This reflects the acknowledged importance of banks in the adjustable-rate note market. We break out the banking subsample during our discussion of the empirical results.

III.2. Empirical Model

III.2.A. Preliminaries

Our model postulates a relationship between the level of volatility in Treasury Bill prices and the difference in stock price reaction to the announcement of adjustable and fixed rate debt. Above a particular threshold of volatility, some firms with good cash flow prospects should be able to distinguish themselves from other firms by offering fixed rate debt. Firms finding it too costly to mimic issue adjustable rate debt. Below the threshold there is little material difference between a fixed and adjustable rate debt
issue and firms will be pooled in either fixed or adjustable rate.

Above the threshold, it is not generally possible to formulate an explicit
relationship between TBill volatility and the size of the stock market reaction
other than the prediction that the sign of the reaction is positive on average.
There is no reason to expect, for example, a monotonic relation between TBill
volatility and stock price reaction. There are two reasons for this. First, the
characteristics of the population from which the sample data are drawn can easily
change over time and as a function of the volatility of TBill prices. Moreover,
when the threshold is reached, the percentage of firms that are in a signalling
equilibrium is likely to change as volatility changes. Second, in models where
there can be more than two types of firms, the average quality difference between
firms issuing fixed rate debt and those issuing adjustable rate debt may either
increase or decrease as the volatility of TBill prices increases.6

The empirical model has the following form. Consider the difference in the
stock price reaction to the announcement of adjustable rate debt for firm j and
the stock price reaction to the announcement of fixed rate debt for a suitable
control firm. Call this difference the abnormal return to firm j’s announcement.
The model predicts

\[ E(R_j) = 0 \quad h_j < h^* \]
\[ E(R_j) < 0 \quad h_j > h^* \]  \hspace{1cm} (7)

where \( R_j \) is the abnormal return at announcement for firm j, \( h_j \) is the volatility
in TBill prices existing at the time of announcement for firm j, and \( h^* \) is the
threshold level of TBill volatility below which signalling does not take place.
Our primary goal is to detect a negative average abnormal return for firms that
announce adjustable rate debt when TBill volatility is above an unknown
threshold. We proceed by positing a switch in means for the abnormal return
process and by attempting to simultaneously estimate the switch point, \( h^* \), and
the two means. The empirical model is represented as

6 In general, we would expect the average quality of firms issuing fixed
rate debt to increase with interest rate volatility because the cost of
signalling increases. Firms that switch to adjustable rate debt serve to raise
the average quality of adjustable rate issuers. The average difference in firm
quality depends on the unconditional distribution of firm quality.
where $R_j$, $h_j$, and $h^*$ are as defined in equation (7), $\alpha_1$ and $\alpha_2$ are the mean abnormal returns in the two regions of $h$, and $e_j$ is a mean zero error term. The model predicts $\alpha_1 = 0$ and $\alpha_2 < 0$. The null hypothesis that there is no region within which good firms can signal with fixed rate debt implies that $\alpha_1$ equals $\alpha_2$ and that both are equal to zero. If there are good firms able to signal throughout the range of TBill volatility in the sample, no threshold should be detected and both sample means should be negative.

Before describing how the parameters of the abnormal return process are estimated, we describe the abnormal return and TBill volatility measures.

III.2.B. Abnormal Return Calculation

The stock price reaction to a debt announcement is estimated for every firm in the sample using standard event study methodology. The stock price reaction for firm $j$ on day $t$, $AR_{jt}$, is defined as

$$AR_{jt} = R_{jt} - a_j - b_j R_m$$

where $R_j$ is the return on the common stock of firm $j$ on day $t$, $R_m$ is the return for the CRSP equally-weighted market index on day $t$, and $a_j$ and $b_j$ are the ordinary least squares coefficients of the market model estimated over the period [-140,-21] preceding the announcement day. The stock price reaction to the announcement is defined as the sum of the reactions on the announcement day (day 0) and the day immediately preceding the announcement day (day -1).

The abnormal stock return for each firm $j$ announcing an adjustable rate debt issue is the difference between the stock price reaction for the firm and the stock price reaction for its fixed-rate control firm.

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7 Our focus on the difference between the stock-price reaction to firms announcing adjustable rate debt and those announcing fixed rate debt controls for the general effects of debt announcements.
III.2.C. Estimation of volatility of Treasury Bill prices

Data on short-term Treasury Bills were gathered from the Fama files in the CRSP tape, which report monthly observations of nominal one and three-month risk-free rates from 1925 to 1987.

The traditional approach to estimating the volatility of a financial variable is to compute, say, sample variance over an interval of observations. To capture changing volatility, a moving window of observations might be adopted. More recently, the fitting of an ARCH or GARCH model to financial data has been suggested as a means of estimating time varying volatility. We adopt the latter approach.

Most adjustable rate debt contracts are written on the three month Treasury Bill yield or three month LIBOR rate. We posit the volatility of the three month Treasury Bill price as the risk measure underlying the adjustable rate debt decision. The TBill price is assumed to follow a random walk with time varying volatility that conforms to a simple GARCH(1,1) process. Let

\[ Y_t = Y_{t-1} + u_t \]
\[ h_t = \gamma_0 + \gamma_1 u_{t-1}^2 + \gamma_2 h_{t-1} \]
\[ u_t \sim N(0, h_t) \]

(10)

\[^{8}\text{See Bollerslev, Chou, Jayaraman and Kroner (1990) for a review. Specific examples include French, Schwert and Stambaugh (1987) for stock returns and Engle, Lilien and Robins (1987) for forward interest rate premia.}\]

\[^{9}\text{Where managers are interested in the volatility of longer term bond prices, our measures of short term bond price volatility are still of interest. Suppose the term structure is determined by two state variables, the short rate and the long rate as in Brennan and Schwartz (1982). Then the volatility of intermediate bonds can be written in terms of the volatility of these two state variables. Over time, the level of volatility in the short term bond price will do a good job of ordering the level of uncertainty in bond prices generally if either (1) most of the changes in volatility come through changes in the volatility of the short rate, or (2) changes in the volatility of long and short rates are highly correlated over time. We would hypothesize that both of these suppositions are true.}\]

\[^{10}\text{The assumption of a random walk in the price series is not an unreasonable approximation. There is little autocorrelation in the price differences and the autocorrelations are sensitive to the time period over which they are estimated.}\]
where $y_t$ is the three month TBill price in month $t$, $h_t$ is the conditional variance of the change in price from $t-1$ to $t$, and $u_t$ is the change in price from $t-1$ to $t$. The parameters of the variance process, $\gamma_0$, $\gamma_1$, and $\gamma_2$, are estimated with iterative scoring as suggested in Engle (1982). Results do not appear sensitive to the choice of starting values. The time period chosen for the estimation is the ten year period 1977-1986. This period includes all of the adjustable rate debt issues in our sample. The point estimates of $\gamma_0$, $\gamma_1$ and $\gamma_2$ are .063, .22 and .81. From these estimates and the realizations of $u_t$, a volatility measure in each month is calculated from equation (10). These volatilities are used to indicate the uncertainty about future TBill prices existing at each point in time. The volatility measures are plotted against time in Figure 1. As can be seen volatility is high in the middle of the time period from the third quarter in 1979 to the second quarter of 1983. A reference line has been drawn in the figure to identify the threshold level of volatility estimated in the next section.

III.2.D. Estimating the volatility threshold and the abnormal return means

The estimation of models having discrete parameter variation has been studied by Goldfeld and Quandt (1972), Quandt (1958, 1960), and Hinkley (1970). Our approach follows most closely that of Hinkley (1970). He considers a discrete time process with independent observations in which a change in means occurs at an unknown point in the process. The researcher is interested in the switch point and in the two means. For the case where the error terms are normally distributed, Hinkley (1970) shows that the method of maximum likelihood involves finding the point in time where dividing the sample and estimating both means, generates the smallest sum of squared errors. Although inference about

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1 The corresponding t-ratios for these estimates are .57, 1.47 and 5.11, suggesting significant explanatory power for the model. The bond prices are scaled to the price per $1,000 of face value before estimating volatility.

2 Where the fixed rate announcement for the control firm occurs in a different month than the adjustable rate announcement, the volatility estimates are averaged to arrive at the volatility measure used for that pair of firms.

3 Kon and Jen (1978) and Sanders and Unai (1988) use the framework of the Goldfeld and Quandt switching regression to estimate switches in regime for, respectively, market model beta and short term interest rate volatility.
the switch point is problematic, inferences about the means are not. Simulations reveal that the sample means conform well to their asymptotic distributions based on the standard deviation of the residuals from the fitted model and the number of observations in each regime.

In our application, the switch in regimes is determined by TBill price volatility and not a time subscript. Our first step is to rank the observations on volatility and find the switch that produces the minimum residual variance from the fitted model with two means. If the model is correct, the two sample means are consistent estimates of the true means in the two regimes, with standard errors approximated by $\sigma/\sqrt{t_1}$ and $\sigma/\sqrt{(T-t_1)}$, where $T$ and $t_1$ are the total number of observations and the number in regime one, and $\sigma$ is the standard deviation of the residuals approximated by $\sqrt{(SSE/(T-3))}$.

Several results are shown in Table 3. The first panel shows the average abnormal return for the entire sample and for the banking subsample. For the whole sample, the average attains a value of -.0097 with a t-statistic of -1.92. The banking subsample has an average abnormal return of -.019 with a t-statistic of -2.24. This panel provides marginally significant evidence of a negative overall difference in stock price reaction to adjustable rate debt announcements. The negative impact is over twice as large for the banking subsample but the difference in means between the banking subsample and the rest of the sample is not significant at conventional levels. The difference is -.0157 with a t-ratio of -1.56 based on the assumption that the true but unknown standard deviation is the same for both subsamples. Cross-sectional measures of variability are used throughout the analysis.

Panel 2 shows the two means and associated t-ratios when a threshold for

---

14 See Hinkley (1970). Simulation evidence in related contexts such as those investigated by Goldfeld and Quandt (1972) and Quandt (1960) indicates that where there are sufficient observations in each regime, the sampling distributions of the processes in each regime conform well to their distribution under the assumption that the switch point is known.

15 We assume that the estimation errors in the volatility series are sufficiently small that they do not affect the ranking of the volatilities, at least in the neighborhood of the switch in regimes.

16 Consistency of the sample means can be shown for a limit as the number of observations in each regime increases. Consistency of estimation of the switch point is not a primary consideration for our study since we are not interested in drawing inferences about when the switch takes place.
volatility is estimated. The mean of the first regime is .002 and insignificant, while the mean of the second regime is -.024 with a t-ratio of -3.44. The likelihood ratio for the model suggests a significant overall fit. The volatility threshold is at 2.1, which splits the sample into 26 announcements below the threshold and 21 announcements above the threshold. The estimated threshold is shown graphically in Figure 1 as two horizontal line segments. Although there is no necessity within the estimation procedure, the threshold cuts both the volatility and the sample points roughly in half.

Results for the banking subsample are broken out separately in Panel 2 as well. The means and t-ratios are based on the same threshold estimate from the whole sample. The mean from the low volatility period is -.009 and insignificant while the mean from the high volatility period is -.030 with a t-ratio of -2.43. There are 9 banks in each volatility regime.

The estimate of the threshold volatility relies heavily on the observations directly surrounding the switch point. Observations far from the switch point have very little influence. As a result, the likelihood function does not necessarily fall away smoothly from the maximum. Figure 2 shows a plot of the sum of squared errors as a function of the switch point. Note that the figure reveals several switch points with relatively low sums of squared errors. To check for sensitivity of our results to changes in the switch point, we examined the means implied by each of the five best switch points. For none of the five is the mean of the first regime significantly different from zero at the 5% level. For each of five, the mean of the second regime generates a t-ratio more negative than -2.

III.2.E. An additional test

As discussed in the motivation for our empirical tests, the model of adjustable rate debt choice does not necessarily imply a negative slope in a

17 Since the switch model is nonlinear, statistical inference can often be sharpened by simulating an empirical distribution of traditional test statistics under the null hypothesis. We applied our search algorithm to 500 samples of randomly generated normal errors. These errors were paired with the same volatility measures used in the study and the algorithm searched for a switch point and two means. There were seven cases of a t-ratio exceeding 3.4 in absolute value. There were 51 cases of Chi-squared statistics exceed 7.6.
regression of abnormal return on TBill price volatility. Nevertheless, a simple linear regression of abnormal return on volatility is presented in the last panel of Table 3. For the whole sample, the slope is negative and significant with a t-ratio of -2.40. It is natural to expect a negative slope even though it is not, strictly speaking, an implication of the theory. The significance of the regression is insensitive to transformations of the volatility from variance to standard deviation, but a regression based on the rank of the volatilities has a somewhat less significant slope. In this case the t-ratio increases to -1.95 (not reported in the table). The banking subsample does not have a significant slope coefficient although the magnitude of the slope is the same as for the overall sample. The t-ratio is -1.47. Viewed in total, it does not appear that the banking subsample is materially different from the overall sample even though they have participated more heavily in the adjustable rate debt market.

### III.3. Summary and Conclusions

This paper proposes to test a signalling hypothesis about the decision to borrow at an adjustable interest rate by exploiting the possibility that all of the data do not fall within the signalling region. We argue that the fixed versus adjustable rate decision cannot convey information about the firm until the volatility in Treasury Bill prices exceeds a threshold. The data indicate that the announcement of an adjustable rate debt issue is viewed as a negative signal when the economy is above a threshold that is simultaneously estimated from the data. The matched sample methodology controls for the impact on firm value of more traditional fixed rate debt announcements. The recognition that a threshold of volatility might exist in the data has improved the power to detect a difference in the announcement effects of fixed and adjustable rate debt, although the results appear marginally significant even if a threshold is not estimated.

Finally, a word on future applications. An additional opportunity to test the specific model of adjustable rate debt choice is available in the Eurobond market where data on adjustable rate securities are in greater abundance. It is possible that the higher interest rate volatilities of many foreign markets will provide a larger sample of firms operating within the signalling region. One
interesting question is whether these regions differ across countries as a function of how well firms are able to index their operating cash flow to changes in interest rates.

In addition, exploiting the concept of a threshold would seem to apply to signalling models generally whenever the signalling region imposes restrictions on observable parameters. For example, in Miller and Rock (1985), signalling high cash-flows with cash payouts limits the amount of funds available for profitable investment. If the firm has few and poor investment opportunities, payouts cannot convey information. The challenge in this case is to find a good proxy for the firm's investment opportunity set. In other models, a maximum level of financial slack is required for the signalling outcome to exist. For example, in John and Williams (1985) firms can signal only when the investment outlay plus the amount of "liquidity" demanded by shareholders exceeds the internal supply of cash. In other models, low quality firms choose not to mimic to avoid incurring higher transaction costs from issuing securities in the capital market (Bhattacharya (1979), Flannery(1986)). In these models, pooling occurs whenever transaction costs are below a threshold. Given the fixed nature of these costs, firm size could maybe be used to estimate a threshold.
Proof of Lemma 1:

Since $S_0^f(\theta_f)$ and $S_0^A(\theta_A)$ are independent of $q$, we only need to show that

$$\frac{\partial \{\text{Var}(S_1^f(q)) - \text{Var}(S_1^A(q))\}}{\partial q} = \frac{\partial \{\text{Var}(D_1^f(q)) - 2\text{Cov}(V_1(q), D_1^f(q)) - \text{Var}(D_1^A(q)) + 2\text{Cov}(V_1(q), D_1^A(q))\}}{\partial q} > 0 \quad (A1)$$

Since the equity risk at $t=1$ is local, we can evaluate $\text{Var}(D_1^m(q))$ and $\text{Cov}(V_1(q), D_1^m(q))$ based on a series expansion of $D_1^m(P_1, Y_1, q)$ and $V_1(P_1, Y_1, q)$ around point $[EP_1, EY_1, q]$. Based on such expansion, we obtain

$$\text{Var}(D_1^m(P_1, Y_1, q)) = [\partial D_1^m/\partial P_1]^2 \text{Var}(P_1) + [\partial D_1^m/\partial Y_1]^2 \text{Var}(Y_1) + [\partial^2 D_1^m/\partial P_1^2] \text{Var}(P_1 - EP_1)^2 + [\partial^2 D_1^m/\partial Y_1^2] \text{Var}(Y_1 - EY_1)^2 + \cdots \quad (A2)$$

$$\text{Cov}(V_1(P_1, Y_1, q), D_1^m(P_1, Y_1, q)) = [\partial D_1^m/\partial P_1][\partial V_1/\partial P_1] \text{Var}(P_1) + [\partial^2 D_1^m/\partial Y_1^2][\partial^2 V_1/\partial Y_1^2] \text{Var}(Y_1 - EY_1)^2 + \cdots \quad (A3)$$

where all derivatives are evaluated at the point $[EP_1, EY_1, q]$, and the covariance $(A3)$ reflects the fact that $P_1$ and $Y_1$ are independent random variables. Under an adjustable interest rate, the value of the bonds is insensitive to $P_1$ and thus all first and higher-order partial derivatives of $D_1^A$ involving $P_1$ are zero. Furthermore, since at the approximation point the promised payments on fixed and adjustable-rate bonds are the same, all partial derivatives involving exclusively $Y_1$ are identical for the two bond types. Hence, we can write

$$\text{Var}(D_1^f(q)) - 2\text{Cov}(V_1(q), D_1^f(q)) - \text{Var}(D_1^A(q)) + 2\text{Cov}(V_1(q), D_1^A(q)) =$$

$$= [\partial D_1^f/\partial P_1]^2 \text{Var}(P_1) - 2[\partial D_1^f/\partial P_1][\partial V_1/\partial P_1] \text{Var}(P_1) +$$

$$+ [\partial^2 D_1^f/\partial P_1^2] \text{Var}(P_1 - EP_1)^2 - 2[\partial^2 D_1^f/\partial P_1^2][\partial^2 V_1/\partial P_1^2] \text{Var}(P_1 - EP_1)^2 +$$

Take the derivative of (A4) with respect to firm type, \(q\). Since \(\text{Var}(P_1 - EP_1)\) and \(\text{Var}(P_1 - EP_1)[Y_1 - EY_1]\) are one order of magnitude smaller than \(\text{Var}(P_1)\), the sign of the derivative is the same as the sign of

\[
\partial \left( \frac{\partial^2 D_r}{\partial P_1} \right)^2 - 2 \left( \frac{\partial D_r}{\partial P_1} \right) \left( \frac{\partial V_i}{\partial P_1} \right) / \partial q
\]

But with \(\frac{\partial^2 V_i}{\partial P, \partial q} \geq \left( \frac{\partial^2 D_r}{\partial P, \partial q} \right) > 0\), (A5) is positive. Q.E.D.

**Proof of Proposition I:**

To prove existence a NSE separating outcome in which Good-type firms issue fixed-rate debt and Bad-type firms issue adjustable-rate debt, we show that there is a region of the parameter space that satisfies the two incentive compatibility constraints:

\[
S_0^r(\theta_r=1) - \Omega \text{Var}[S_i^r(q=G)] - S_0^A(\theta_A=0) + \Omega \text{Var}[S_i^A(q=G)] \geq 0 \quad (A6)
\]

\[
S_0^r(\theta_r=1) - \Omega \text{Var}[S_i^r(q=B)] - S_0^A(\theta_A=0) + \Omega \text{Var}[S_i^A(q=B)] \leq 0 \quad (A7)
\]

Consider parameter values that make \(\text{Var}[S_i^r(q)] > \text{Var}[S_i^A(q)]\). Then there exists a risk-aversion parameter, \(\Omega > 0\), and a firm type, \(B \leq q^* \leq G\), such that

\[
S_0^r(\theta_r=1) - \Omega \text{Var}[S_i^r(q=q^*)] - S_0^A(\theta_A=0) + \Omega \text{Var}[S_i^A(q=q^*)] = 0 \quad (A8)
\]

But from Lemma 1 (A8) is increasing in \(q\). Thus the two incentive compatibility constraints are satisfied.

To show that there isn’t a NSE separating outcome in which the Good-type issues adjustable and the Bad-type sells fixed-rate debt, suppose the incentive compatibility constraint for the Bad-type is satisfied, i.e., assume

\[
S_0^r(\theta_r=0) - \Omega \text{Var}[S_i^r(q=B)] - S_0^A(\theta_A=1) + \Omega \text{Var}[S_i^A(q=B)] \geq 0 \quad (A9)
\]
But if (A9) holds Lemma 1 implies that the incentive compatibility constraint for the Good-type is violated. Thus, the two incentive compatibility constraints on this separating outcome cannot be simultaneously satisfied. Q.E.D.

Proof of Proposition II:

The incentive compatibility constraint on the Bad-type in the separating outcome described in Proposition I is

\[ \text{Var}[S_i^F(q=B)] - \text{Var}[S_i^A(q=B)] \geq [S_0^F(\theta_F=1) - S_0^A(\theta_A=0)]/\Omega \] (A10)

Since the right-hand side of (A10) is positive, the left-hand side also has to be positive if (A10) is to hold. Rewrite (A10) as

\[
\begin{align*}
\text{Var}[D_i^F(q=B)] - 2\text{Cov}[V_i(q=B), D_i^F(q=B)] - \text{Var}[D_i^A(q=B)] + 2\text{Cov}[V_i(q), D_i^A(q=B)] \\
\geq [S_0^F(\theta_F=1) - S_0^A(\theta_A=0)]/\Omega
\end{align*}
\] (A11)

But from (A4)

\[
\text{Var}[D_i^F(q=B)] - 2\text{Cov}[V_i(q=B), D_i^F(q=B)] - \text{Var}[D_i^A(q=B)] + 2\text{Cov}[V_i(q), D_i^A(q=B)] = \\
\left\{[\partial D_i^F/\partial P_i]^2 - 2[\partial D_i^F/\partial P_i][\partial V_i/\partial P_i]\right\}\text{Var}(P_i) + \Delta[\text{Var}(P_i)]
\] (A12)

where the derivatives are evaluated at \([E_P, E_Y, q] \), and \(\Delta\) is a small (in absolute value) remainder term whose absolute size is increasing in \(\text{Var}(P_i)\); (A12) is positive when \(\text{Var}(P_i) > 0\) and zero otherwise. Since the remainder term is small (in absolute value) vis-à-vis the first term, it follows that

\[
\left\{[\partial D_i^F/\partial P_i]^2 - 2[\partial D_i^F/\partial P_i][\partial V_i/\partial P_i]\right\} > 0,
\] (A13)

and there is a positive threshold volatility, \([\text{Var}(P_i)]^*\), that makes the incentive compatibility constraint to hold tightly. Finally, because (A12) is monotonically increasing in \(P_i\), the incentive compatibility constraint is violated whenever \(\text{Var}(P_i) < [\text{Var}(P_i)]^*\). Q.E.D.
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Bhattacharya, 1979, Imperfect information, dividend policy and the "Bird in the Hand" fallacy, Bell Journal of Economics, Spring, 259-270.


Hinkley, D. V., 1970, Inference about the Change-point in a Sequences of Random Variables, Biometrika, 57, 1, p. 1-17, Imperial College.


Table 1
Corporate Debt and Treasury Bill Information
over the Period 1978-1986

<table>
<thead>
<tr>
<th>Year</th>
<th>Fixed Rate</th>
<th>Adjustable Rate</th>
<th>Proportion of adjustable</th>
<th>Av. Yield on 3-month TBill</th>
<th>Av. Volatility 3-month TBill</th>
<th># pairs in sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>19,466</td>
<td>200</td>
<td>1.0%</td>
<td>7.54%</td>
<td>0.9797</td>
<td>1</td>
</tr>
<tr>
<td>1979</td>
<td>23,093</td>
<td>803</td>
<td>3.4%</td>
<td>10.32%</td>
<td>2.0225</td>
<td>4</td>
</tr>
<tr>
<td>1980</td>
<td>63,230</td>
<td>669</td>
<td>1.0%</td>
<td>11.85%</td>
<td>19.5625</td>
<td>1</td>
</tr>
<tr>
<td>1981</td>
<td>39,017</td>
<td>676</td>
<td>1.7%</td>
<td>14.12%</td>
<td>13.0694</td>
<td>3</td>
</tr>
<tr>
<td>1982</td>
<td>90,425</td>
<td>7,899</td>
<td>8.0%</td>
<td>10.68%</td>
<td>12.6158</td>
<td>6</td>
</tr>
<tr>
<td>1983</td>
<td>61,556</td>
<td>9,158</td>
<td>13.0%</td>
<td>8.84%</td>
<td>4.3993</td>
<td>10</td>
</tr>
<tr>
<td>1984</td>
<td>105,344</td>
<td>12,440</td>
<td>10.6%</td>
<td>9.70%</td>
<td>1.6103</td>
<td>10</td>
</tr>
<tr>
<td>1985</td>
<td>142,483</td>
<td>7,635</td>
<td>5.1%</td>
<td>7.62%</td>
<td>1.9544</td>
<td>10</td>
</tr>
<tr>
<td>1986</td>
<td>236,167</td>
<td>9,233</td>
<td>3.8%</td>
<td>6.04%</td>
<td>1.0589</td>
<td>2</td>
</tr>
<tr>
<td>Sum</td>
<td>780,781</td>
<td>48,703</td>
<td>5.9%</td>
<td>9.63%</td>
<td>6.36</td>
<td>47</td>
</tr>
</tbody>
</table>

Notes: Amounts of fixed and adjustable rate debt are in $ Million of principal as reported in the Registered Offering Statistics of the SEC. TBill information taken from CRSP. Volatility based on GARCH(1,1) applied to TBill issue price changes with units equal to dollars per thousand of principal. Number of pairs in sample is the final sample used in empirical tests.
Table 2
SIC breakdown of debt issues and selected summary statistics for the adjustable and matched fixed rate bond sample

<table>
<thead>
<tr>
<th>Floating rate debt</th>
<th>Fixed rate debt</th>
</tr>
</thead>
<tbody>
<tr>
<td># of observations:</td>
<td># of observations:</td>
</tr>
<tr>
<td>Average maturity(years):</td>
<td>Average maturity(years):</td>
</tr>
<tr>
<td>Average principal(millions):</td>
<td>Average principal(millions):</td>
</tr>
<tr>
<td>Average asset size of the issuing firm(millions):</td>
<td>Average asset size of the issuing firm(millions):</td>
</tr>
<tr>
<td>SIC classification:</td>
<td>SIC classification:</td>
</tr>
<tr>
<td>Extractive</td>
<td>Extractive</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>Transportation</td>
<td>Transportation</td>
</tr>
<tr>
<td>Communication</td>
<td>Communication</td>
</tr>
<tr>
<td>Electric, Gas &amp; Water</td>
<td>Electric, Gas &amp; Water</td>
</tr>
<tr>
<td>Banks, Bank Holding Co, and Thrifts(depository institut.)</td>
<td>Banks, Bank Holding Co, and Thrifts</td>
</tr>
<tr>
<td>Financial excluding Banks, Bank Holding Co, and Thrifts</td>
<td>Financial excluding Banks, Bank Holding Co, and Thrifts</td>
</tr>
<tr>
<td>Commercial and Other</td>
<td>Commercial and Other</td>
</tr>
</tbody>
</table>
Table 3
Estimates of the announcement effect of adjustable rate debt
Matched sample results based on 47 pairs of announcements
over the period 1979-1986

Parameter Estimates

<table>
<thead>
<tr>
<th>Panel 1: Mean abnormal return</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>t-ratio</td>
</tr>
<tr>
<td>All Firms</td>
<td>-.0095</td>
<td>-1.92</td>
</tr>
<tr>
<td>Banks</td>
<td>-.0192</td>
<td>-2.24</td>
</tr>
<tr>
<td>Banks - Others</td>
<td>-.0157</td>
<td>-1.56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel 2: Switch in regimes based on equation (3) in the text</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_1$</td>
</tr>
<tr>
<td>All Firms</td>
</tr>
<tr>
<td>Banks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel 3: Linear regression of abnormal return on volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model fit over time period</td>
</tr>
<tr>
<td>int</td>
</tr>
<tr>
<td>All Firms</td>
</tr>
<tr>
<td>Banks</td>
</tr>
</tbody>
</table>

Notes: Banks are the subsample of 18 pairs with SIC code 602. Panel 1 contains simple means for entire time period. Banks - Others is the difference in mean for the two subsamples. T-ratio is based on a common estimate of variance and a difference in means test applied. Panel 2 contains estimated means from two regimes. MLE of switch point is at volatility of 2.1, which puts 26 firms in first regime and 21 in second regime. Banks have 9 firms in each regime. Linear regression is for comparison purposes. Chi-square test is $-2\log\lambda$ where $\lambda$ is the likelihood ratio (the ratio of the sum of squared errors from panel 1 divided by the sum of squared errors from the model in the respective panel, all raised to the power of 47/2). Each statistic can be construed to have one degree of freedom although the conformity with the Chi-squared distribution with one degree of freedom is approximate for the nonlinear model in panel 2. The statistic in panel 3 would conform asymptotically to a $X^2(1)$ under the null hypothesis. The statistic in panel 3 is reported for comparison. For the linear regression, exact tests based on the t-ratio of the slope or, equivalently, an F-test provide more precise inferences. Test reported for complete sample only.
Volatility is estimated with a GARCH(1,1) model in the price changes of three month T Bills. Volatility is in dollars per thousand dollars of face value.

At each switch point, the mean abnormal return for the two regimes is calculated and the total sum of squared errors computed. The MLE estimate of the switch point and of the means corresponds to the point with lowest SSE.
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<th>Title</th>
<th>Authors</th>
</tr>
</thead>
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<td>by David Lei, John W. Slocum, Jr., and Robert W. Slater</td>
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<tr>
<td>90-071</td>
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<td>by David Lei and Joel D. Goldhar</td>
</tr>
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<td>by David Lei and John W. Slocum, Jr.</td>
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<td>by John W. Slocum, Jr. and David Lei</td>
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<tr>
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</tr>
<tr>
<td>91-092</td>
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<tr>
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<td>by G. Sharathchandra</td>
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<tr>
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<td>John R. Grout and David P. Christy</td>
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<td>&quot;An Inventory Model of Incentives for On-Time Delivery in Just-In-Time Purchasing Contracts,&quot;</td>
<td>John R. Grout and David P. Christy</td>
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<td>&quot;The Effect of Early Resolution of Uncertainty on Asset Prices: A Dichotomy into Market and Non-Market Information,&quot;</td>
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