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THE BEHAVIOR OF THE SPREAD BETWEEN TREASURY BILL RATES AND PRIVATE MONEY MARKET RATES SINCE 1978

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Preface

The purpose of this working paper is to present regression results mentioned but not reported in our November/December 1983 Economic Review article, "The Behavior of the Spread Between Treasury Bill Rates and Private Money Market Rates Since 1978." To do this we simply added Section VI to the end of the paper. Sections I through V are identical to the Economic Review article.

THE BEHAVIOR OF THE SPREAD BETWEEN TREASURY BILL RATES AND PRIVATE MONEY MARKET RATES SINCE 1978

The Treasury bill rate is generally viewed as the representative money market rate. For this reason bill rates are almost always used in studies of the determinants of short-term interest rate levels and spreads,[1] and bill rates are typically used as the index rate for variable-rate financial contracts.[2] Despite this central role accorded Treasury bill rates, they frequently diverge greatly from other high-grade money market yields of comparable maturity. Furthermore, this differential is subject to abrupt change. These aspects of the spread are illustrated in Chart 1, which uses the three-month prime negotiable CD rate (RCD) as the private money market rate.[3]

An earlier paper by Cook [7] provided an explanation for the spread in the period prior to 1978. According to this explanation, prior to 1978 most individual investors were unable to invest in private money market securities because of the high minimum denomination of those securities.

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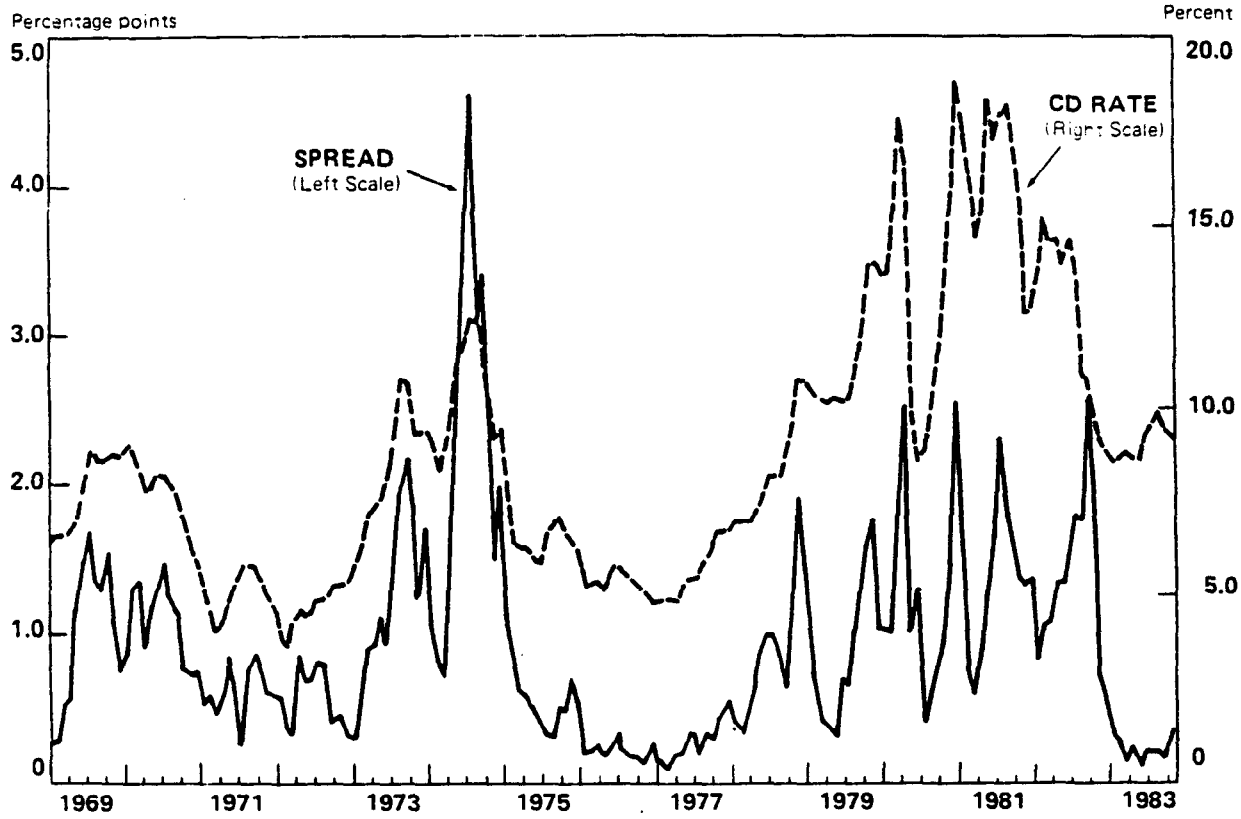
[1] In particular, the spread between private money rates and bill rates is used as a measure of the default risk premium on private securities [20]; the bill rate is generally used to test various hypotheses about the effect of such economic variables as the rate of inflation or the money supply on the general level of short-term interest rates [9, 18]; and bill rates are always used to test hypotheses about the determinants of money market yield curves [11, 13].

[2] For example, the Treasury bill rate is often used as the determinant of the yield on adjustable-rate mortgages. Also, many banks and nonfinancial corporations have recently issued floating-rate notes with rates tied to Treasury bill rates.

[3] The CD rate is used in this article as a representative private money market rate. Commercial paper rates behave similarly to CD rates and statements in this paper regarding the spread between the CD and bill rate apply equally well to the spread between the commercial paper and bill rates.

Chart 1

THE SPREAD BETWEEN THE CD AND T-BILL RATES AND THE LEVEL OF THE CD RATE



Hence, their demand for T-bills was related to the spread between Treasury bill rates and regulated ceiling rates on small time deposits rather than to the spread between bill rates and private money rates. When interest rates rose above deposit rate ceilings at the depository institutions, the resulting "disintermediation" and massive purchases of bills by individuals caused bill rates to fall relative to private money rates.[4]

An empirical implication of this explanation was that the spread between private money rates and bill rates increased in periods of disintermediation when bill rates rose relative to the ceiling rates on small time deposits. The evidence from the earlier study provided strong support for this implication. Because ceiling rates on time deposits were fairly inflexible prior to 1978, this explanation also implied a positive relationship between the level of rates and the spread. As shown in Chart 1, this was clearly true in the pre-1978 period.

Institutional and regulatory developments in 1978 eliminated the underpinnings of this explanation by providing individuals with ways to earn money market rates without investing in Treasury bills. Most importantly, that year saw the beginning of the rise in popularity of money market mutual funds. (Money market fund shares grew from $3.3 billion at the end of 1977 to $9.5 billion at the end of 1978 to $42.9 billion at the end of 1979.)

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[4]This explanation of the spread in periods of disintermediation raises an obvious question: Why didn't other investors sell their bills and buy private money market securities, thereby offsetting the impact of individual purchases on the spread? In fact, other investors in Treasury bills did react to the rise in the spread in periods of disintermediation by decreasing their holdings of bills, but this reaction was insufficient to eliminate the large movements in the spread caused by sharp increases in purchases of bills by individuals. This question is discussed in detail in [7].

Also, in June of 1978 depository institutions were first allowed to offer money market certificates in denominations as low as $10,000 with an interest rate tied to the 6-month T-bill rate.

Chart 1 shows that since 1978 the spread has not approached the levels reached in 1974. Nevertheless, the spread has been very large at times and it has been even more volatile than in the earlier period. A number of times it has exceeded 200 basis points and then fallen sharply, sometimes within a couple of months, to well below 100 basis points. Also, the spread in the post-1978 period has continued to show a tendency to move with the level of interest rates, although a given level of interest rates has generally been associated with a smaller spread than in the earlier period.

This article examines the behavior of the spread in the post-1978 period using models that assume, contrary to the situation in the earlier period, that all investors can freely choose between Treasury bills and private money market securities. The major conclusion is that movement in the spread can be fairly well explained in this period under this assumption by default risk, taxes, and the relative supply of Treasury bills. Section I presents three models of the spread and discusses institutional information relevant to each. Section II looks briefly at the behavior of two types of investors in the bill market. Section III reports regression results for the three models. Section IV discusses the effect on the spread of the introduction of money market deposit accounts in late 1982.

I. MODELS OF THE SPREAD IN THE POST-1978 PERIOD

This section discusses three models of the spread between the rate on private money market securities (RMM) and the rate on Treasury bills (RTB). All three models assume that investors can choose freely between investing in private money market securities or bills. The first model focuses on default risk, while the second looks at a combination of default risk and taxes. Both models assume that all investors react the same to any given RMM-RTB spread. The third model drops this assumption.

The focus throughout is on the demand for Treasury bills as a function of the RMM-RTB spread. It is assumed that the relative supply of Treasury bills is not sensitive to the spread, i.e. that the ratio of bills to private money market securities supplied is completely inelastic with respect to the spread. Gaps between U.S. government expenditures and receipts are the primary determinant of the amount of T-bills issued; while the Treasury at times alters the average maturity of U.S. Treasury debt, there is no evidence that such decisions are influenced by the RMM-RTB spread. Furthermore, it is reasonable to assume that the aggregate supply of private money market securities is not varied in reaction to movements in the RMM-RTB spread. (This latter assumption is discussed below).

Default Risk Model The simplest view of the RMM-RTB spread in the post-1978 period is that it results solely from default risk on private money market securities. Treasury bills are backed by the full faith and credit of the U.S. government and are generally considered default free. In contrast, private money market securities such as CDs or commercial paper are backed by the promise of private corporations and, consequently, there is a general perception that default is possible on these securities.

Since investors care about expected, not promised, yields, they demand a higher promised yield on private money securities than on bills in order to offset the perceived risk of default and to equalize expected returns. Investors may also demand an additional premium for holding a riskier asset. The extra yield required by investors because of these factors is called the default-risk premium. According to the default-risk model, the RMM-RTB spread is a direct measure of this default-risk premium (DRP) on private money market securities:

$$(1)\quad RMM - RTB = DRP$$

Hence, according to this model, movements in the spread simply reflect movements in DRP. Figure 1 illustrates the simple default-risk model of the spread. For any value of the default-risk premium the demand curve for T-bills is infinitely elastic with respect to the RMM-RTB spread. This implies that shifts in the relative supply of bills have no effect on the spread.

The default risk premium on private money securities is dependent on the attitudes of investors, which are not directly measurable. However, the simple default-risk model of the RMM-RTB spread can be evaluated by comparing it to yield spreads that are solely a function of default risk: if the default-risk model is correct, the RMM-RTB spread should behave similarly to these spreads.[5] One money market default-risk spread that has been available since the beginning of 1974 is the spread between the one-month medium-grade and prime-grade commercial paper rates (CPS). Chart 2

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[5]These spreads typically rise in periods of recession and fall in periods of economic expansion. See Van Horne [21].

Figure 1

DEFAULT-RISK MODEL

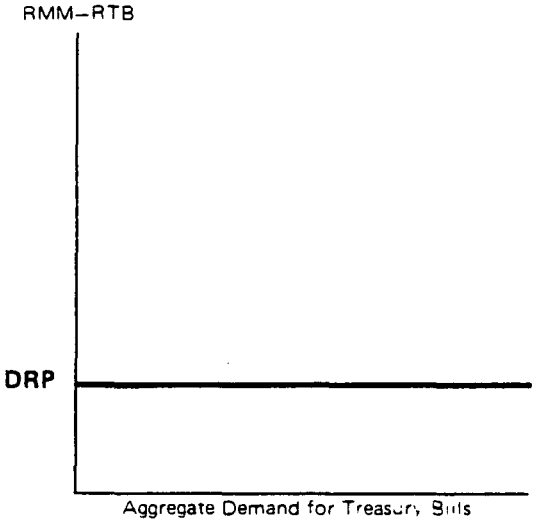


Figure 2

RISK AND TAX MODEL

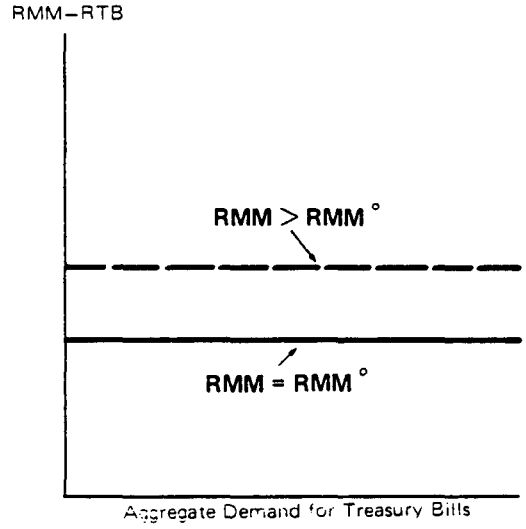


Figure 3

HETEROGENEOUS INVESTOR MODEL

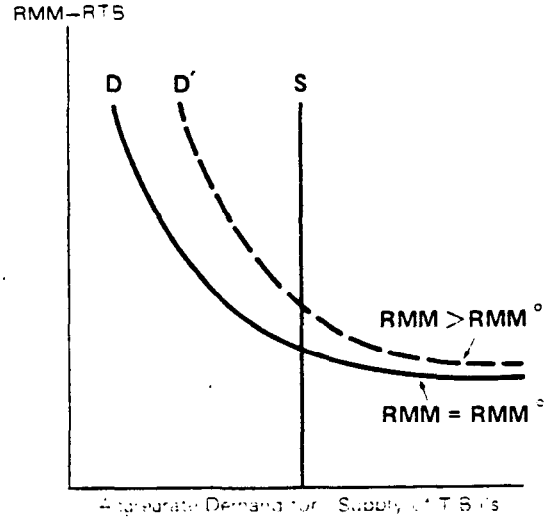
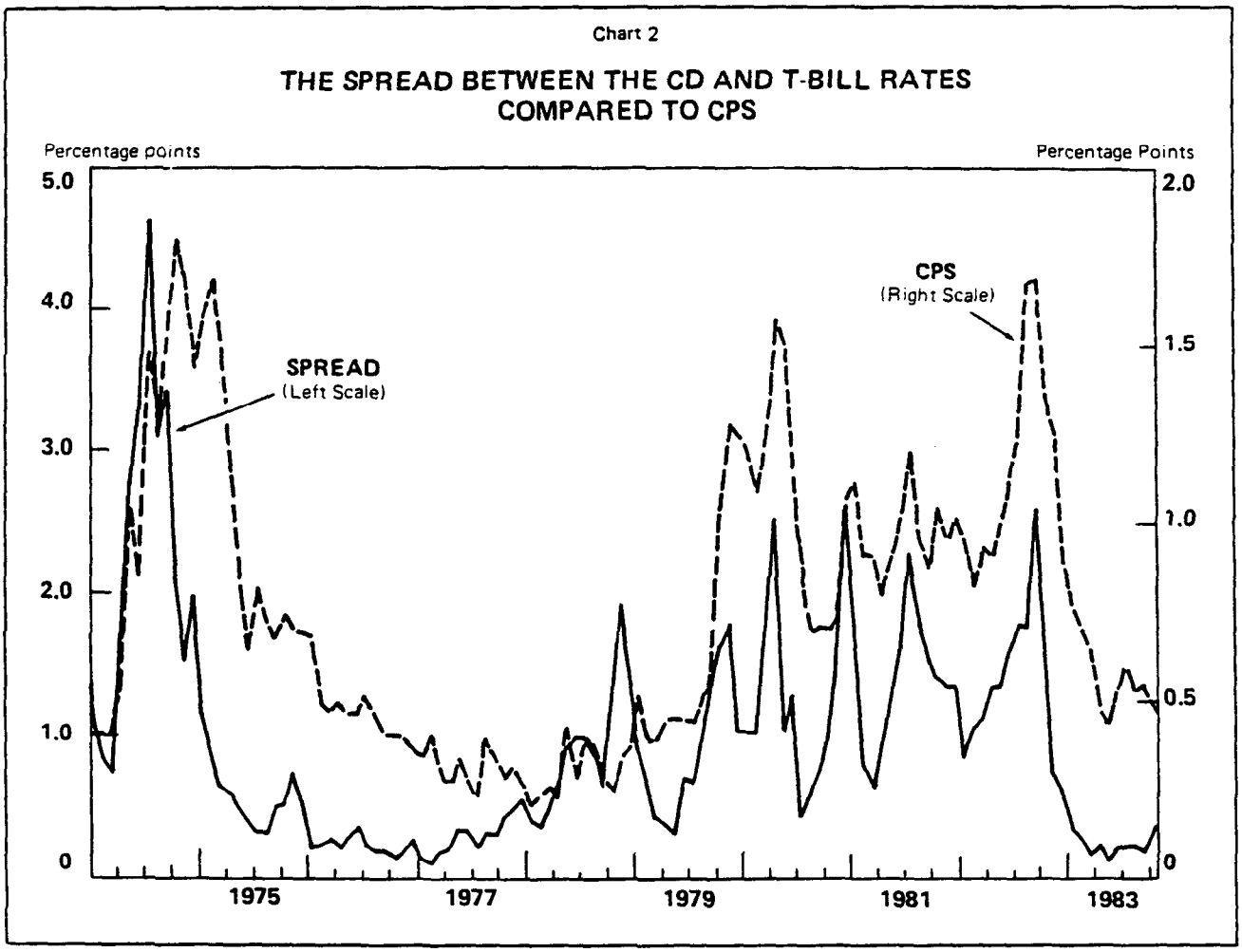


Chart 2

THE SPREAD BETWEEN THE CD AND T-BILL RATES COMPARED TO CPS



compares this spread to the RMM-RTB spread.[6] The chart shows that the RMM-RTB spread does frequently move with the commercial paper rate spread. There are periods, however, such as mid-1980 through the end of 1981, when the RMM-RTB spread behaves very differently than the commercial paper rate spread.

Tax and Risk Model The preceding discussion assumes that interest income earned on Treasury bills and private money market securities is taxed equally, which is true at the Federal level. At the state and local level, however, interest income on T-bills is exempt from income taxes while interest income on private money market securities is not. Individual income tax rates applied to interest income range across states from as low as zero to as high as 17 percent. These rates are shown in Table I.[7] In some cases there are also local income tax rates; for example, in New York City the highest marginal local income tax rate exceeds 4 percent.

Despite the exemption of T-bill interest income from state and local taxation, there are three categories of investors who do not pay a higher tax rate on interest income of private money market securities than bills. The first includes investors who are not subject to state and local taxes, namely state and local governments and foreign investors. The second

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[6]The commercial paper rate spread is only available beginning in 1974 and there are no other yield series available to construct short-term default-risk spreads. Hence the chart starts in 1974.

[7]The tax rates shown are for the highest marginal tax rates. However, in almost all states the maximum tax rate--or one very close to it--is reached at a relatively low income. (The only exceptions are Alaska, Delaware, Louisiana, New Mexico, and West Virginia.) Hence, one can make the assumption that, in general, interest income on private money market investments in a given state is taxed at the highest marginal tax rate in that state.

TABLE I

State Individual Tax Rates on Interest Income
(As of October 1, 1979)

Alabama	5	Montana	11
Alaska	14.5	Nebraska	*
Arizona	8	Nevada	0
Arkansas	7	New Hampshire	5
California	11	New Jersey	2.5
Colorado	8	New Mexico	9
Connecticut	0	New York	14
Delaware	16.65	North Carolina	7
Florida	0	North Dakota	7.5
Georgia	6	Ohio	3.5
Hawaii	11	Oklahoma	6
Idaho	7.5	Oregon	10
Illinois	2.5	Pennsylvania	2.2
Indiana	2	Rhode Island	*
Iowa	13	South Carolina	7
Kansas	9	South Dakota	0
Kentucky	6	Tennessee	6
Louisiana	6	Texas	0
Maine	10	Utah	7.75
Maryland	5	Vermont	*
Massachusetts	17.5	Virginia	5.75
Michigan	4.6	Washington	0
Minnesota	17	West Virginia	9.6
Mississippi	4	Wisconsin	10
Missouri	6	Wyoming	0

Notes: 1. The tax rates shown are maximum rates (see footnote 7).

2. States marked with asterik (*) have tax rates specified as a percent of Federal income tax liability. The percent is 18 percent for Nebraska, 19 percent for Rhode Island, and 23 percent for Vermont.

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includes investors that pay a "franchise" or "excise" tax that in fact requires them to pay state taxes on interest earned on T-bills.[8] Commercial banks in 28 states, including most of the heavily populated states, pay such a tax. And in 17 states there is a franchise tax on nonfinancial corporate income.[9]

The third type of investor taxed equally on interest income of T-bills and private money securities is money market fund (MMF) shareholders. All interest earned through investment in money market funds, including T-bill interest income, is subject to state and local income taxes. Consequently, an investor owning shares in a money market fund that holds T-bills must pay all applicable state and local taxes on the interest income, even though the investor would not have to pay state and local taxes on that income if he purchased the T-bills directly.

The implications of the wide range of relative tax rates on T-bill versus private interest income for the determination of RMM-RTB spread will be considered below. For the present consider the case in which all investors are subject to the same marginal state and local tax rate of t on private interest income; then the relationship between RMM and RTB would be

$$(2) \qquad RMM(1-t) = RTB \qquad \text{or}$$

$$(2a) \qquad RMM - RTB = t \cdot RMM \qquad \text{or}$$

$$(2b) \qquad RMM/RTB = 1/(1-t) \ .$$

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[8] These taxes function exactly like an income tax and were instituted expressly to get around the prohibition of state and local taxes on interest income of Federal securities. See [4] and [15].

[9] These states are listed in [6, p. 652].

Equation (2a) states that the RMM-RTB spread is positively related to the level of interest rates; the after-tax yields will remain equal only if the before-tax yield spread rises or falls in proportion to changes in the level of interest rates. Equation (2b) indicates that the ratio of RMM to RTB is constant over time when taxes are the only factor affecting the spread and marginal income tax rates are the same for all investors.[10]

Chart 1 demonstrates that the RMM-RTB spread does tend to move with the level of interest rates. Chart 3, which plots the ratio of the three-month CD rate to the three-month T-bill rate, illustrates that this ratio is not constant. Although variability of the RMM/RTB ratio is inconsistent with the simple tax model, the RMM/RTB ratio in the post-1978 period has been much less variable than the RMM-RTB spread. Moreover, the ratio, unlike the spread, is not strongly correlated to the level of rates over this period.[11]

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[10]Suppose an investor is subject to a marginal Federal income tax rate of t_f and a marginal state income tax rate of t_s. State taxes paid can be deducted from Federal income taxes. Hence, if the investor pays state income tax on private money market securities but not on Treasury bills, then the before-tax yields on Treasury bills and private money market securities that result in equal after-tax yields will be:

$$RMM\ (1 - t_f - t_s + t_f t_s) = RTB(1-t_f)$$

which can be reduced to:

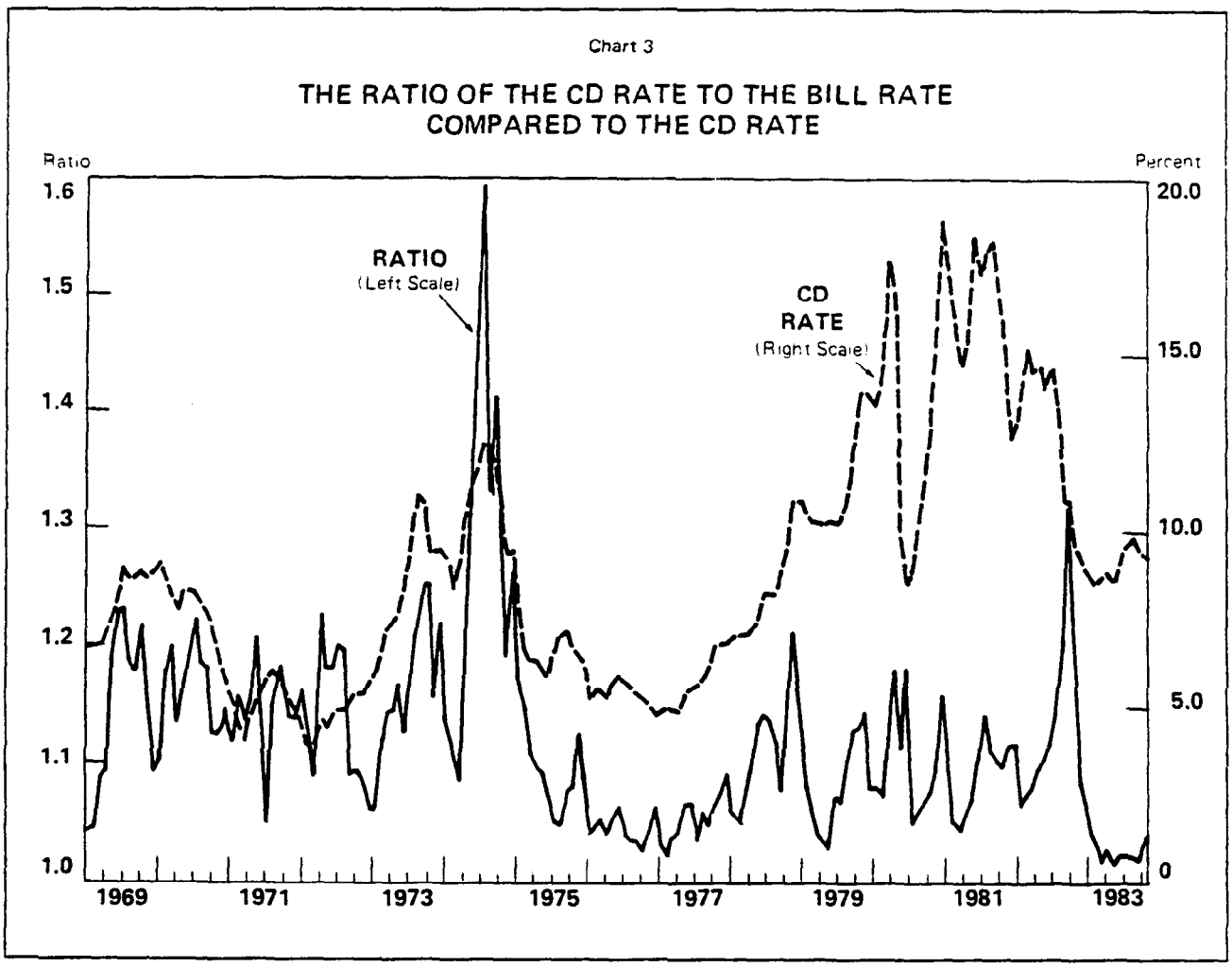
$$RMM(1-t_s) = RTB,$$

which is the formula in the text.

[11]For the period from January 1979 through June 1983 the correlation coefficient between the RMM-RTB spread and the level of the Treasury bill rate is .520. However, the correlation coefficient between the ratio and the level of the bill rate is only .068. (Note in Chart 3 that in the pre-1978 period the RMM/RTB ratio is as volatile as the spread and that it is also highly correlated with the level of rates. Over the 1974-77 period the correlation coefficient between the spread and the level

Chart 3

THE RATIO OF THE CD RATE TO THE BILL RATE COMPARED TO THE CD RATE



Of course, this simple tax model is deficient in that it ignores the effect of the default-risk premium on the spread. The tax and default-risk models can be joined by combining equations (1) and (2):

$$(3) \qquad RMM(1-t) = RTB + DRP \qquad \text{or}$$

$$(3a) \qquad RMM-RTB = tRMM + DRP \qquad \text{or}$$

$$(3b) \qquad RMM/RTB = (1/(1-t)) + DRP/RTB(1-t)$$

In this tax and risk model, the RMM-RTB spread is positively associated with the level of interest rates as in the simple tax model. However, in equation (3b) the RMM/RTB ratio is not constant but changes with the DRP/RTB ratio.

Figure 2 illustrates the aggregate demand curve for T-bills implied by the combination of the simple default-risk model and the simple tax model. As the figure shows, at any given level of interest rates and default-risk premium, the demand for T-bills is infinitely elastic with respect to the after-tax RMM-RTB spread. If RMM rises and the default-risk premium remains unchanged, then the whole demand curve simply shifts upward by an amount equal to the product of the tax rate times RMM. Moreover, it can be seen from Figure 2 that changes in the relative supply of T-bills, if unaccompanied by changes in the level of interest rates or default-risk premium, have no effect on the RMM-RTB spread.

Chart 4 compares the RMM/RTB ratio to the ratio of the commercial paper spread and RTB in the 1979-83 period. The two series move fairly closely together over the whole 1979-83 period, suggesting that the risk and

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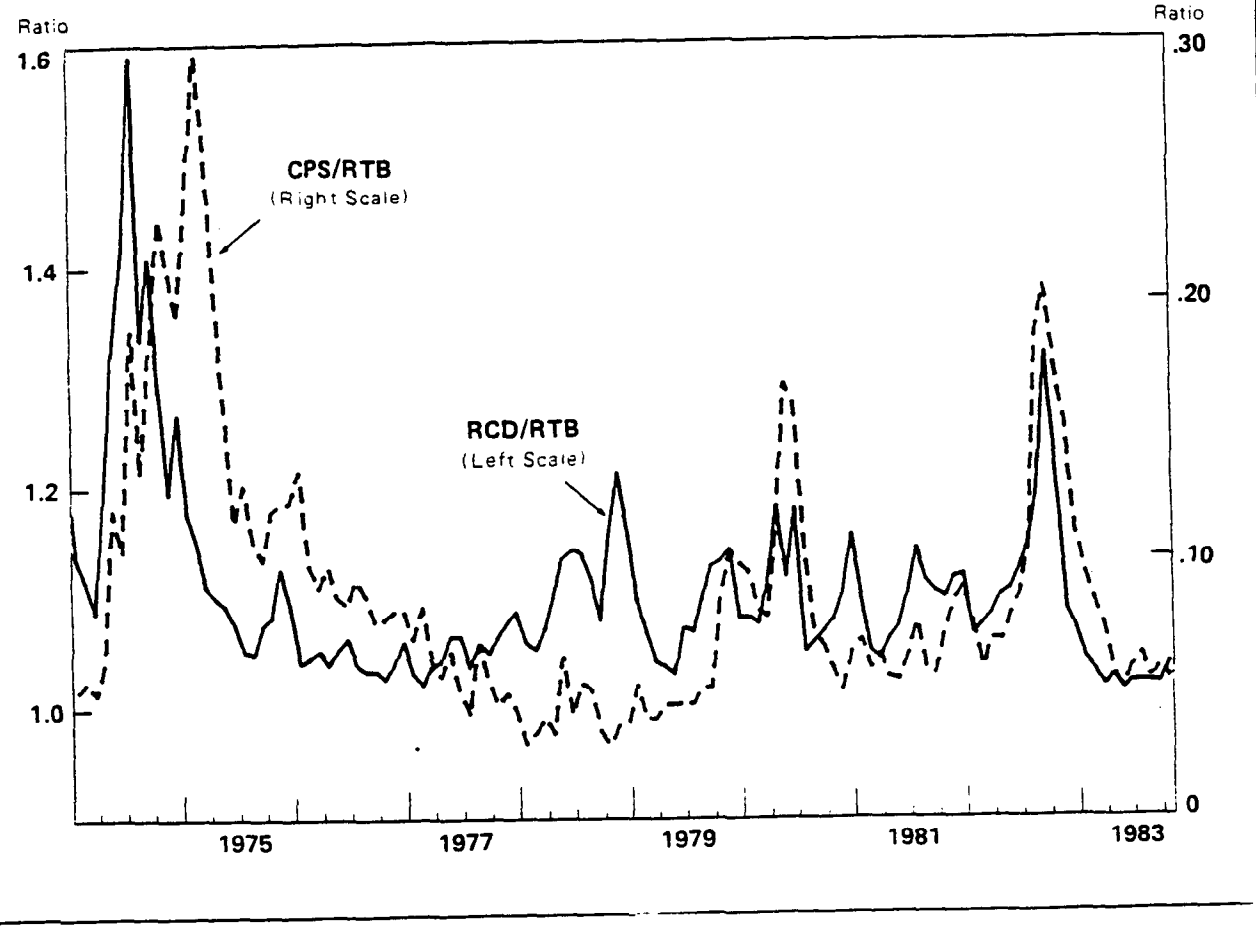
of the bill rate is .799 while the correlation coefficient between the ratio and the level of the bill rate is .758.)

Chart 4

THE RATIO OF RCD TO RTB
COMPARED TO THE RATIO OF CPS TO RTB



tax model is superior to either the default-risk model or the tax model alone.[12]

Heterogeneous Investor Model The tax and risk model assumes that all investors bear the same relative tax rates on private money securities and T-bills. As discussed above, however, there are substantial differences across investors with respect to the relative taxation of private versus T-bill interest income; that is, investors differ with respect to the tax rates they face.

A second source of investor heterogeneity involves various implicit returns that some investors receive from holding T-bills--i.e., returns not measured by the stated T-bill yield. These implicit returns arise from various laws and regulations, many of which have changed over time. Banks, in particular, receive various implicit returns from holding Treasury bills. For example, banks (and other depository institutions) can use Treasury bills at full face value to satisfy pledging requirements against state and local and Federal deposits. Also, Treasury bills improve the ratio of equity to risk assets, a measure bank regulators use to judge a bank's capital adequacy. Moreover, prior to the Monetary Control Act of 1980, nonmember banks in over half the states had reserve requirements that could be satisfied at least partially--and in some cases totally--by holding unpledged Treasury bills. Finally, funds acquired by a bank that enters into a repurchase agreement are free of reserve requirements if the securities involved are obligations of the U.S. or Federal agencies.[13]

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[12] In contrast, it is evident from Chart 4 that in the 1974-77 period the tax and risk model does a poor job of explaining the spread.

[13] These implicit returns are discussed in more detail in [7].

Treasury bills also provide implicit returns by virtue of their preferred position in certain financial markets. They are accepted without question as collateral for margin purchases or short sales of securities. And they can be used to satisfy the initial margin requirements for many types of financial futures contracts, whereas private money market securities cannot be used for this purpose.

With different tax rates and implicit returns, investors will react differently to a particular RMM-RTB spread. For example, even at a large RMM-RTB spread and a very small default-risk premium, the demand for T-bills will be positive because investors with a high marginal state and local tax rate on private interest income and a zero-tax rate on T-bill interest income will find it advantageous to buy T-bills instead of CDs or commercial paper. As the spread falls, more and more investors with smaller differentials between the tax rates on interest income of private securities and T-bills will find it advantageous to buy T-bills.[14] A similar

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Pledging requirements are described in [1, 10, 14], state reserve requirements prior to the Monetary Control Act in [12], regulations on repurchase agreements in [17], and bank capital adequacy measures in [19].

[14]An assumption in this discussion is that the possible investment in Treasury bills by a particular investor is limited. The argument might be made that there are risk-free arbitrage opportunites that would provide incentives for investors to borrow funds in the bill (CD) market and lend them in the CD (bill) market. These opportunities generally are not present because only the Treasury can issue T-bills and only the direct holder of T-bills receives the state and local tax exemption. For example, it might be argued that at large values of the spread, there is an opportunity for investors with equal tax rates on bill and private interest income to borrow bills at a rate slightly above the bill rate, sell them and invest the proceeds in private securities. However, investors that loan bills under this arrangement lose the tax exemption on T-bill interest income; hence, they need to be paid at least RTB/(1-t) to be induced to loan their bills. This eliminates the arbitrage opportunity for the equal tax rate investor.

Conversely, suppose the spread is zero; then there appears to exist arbitrage opportunities for investors with unequal tax rates on

conclusion holds for differential implicit returns. If these vary across investors, then a decline in the spread will induce investors receiving lower implicit returns to buy bills.

Consequently, with differing tax rates and implicit returns, the aggregate demand for T-bills--given some constant default-risk premium--decreases only gradually as the RMM-RTB spread rises. When the RMM-RTB spread is high relative to the default-risk premium, the aggregate demand for T-bills will be relatively low; as the RMM-RTB spread declines, the aggregate demand for T-bills will increase. When the spread falls to the level of the default-risk premium, the demand will be completely elastic as in the simple default-risk model.

Figure 3 illustrates the heterogeneous investor model. The figure shows that an increase in the level of interest rates can affect the RMM-RTB spread because of the tax effect. However, the effect of a rise in the level of rates on the spread depends on the relative supply of T-bills; the greater the relative supply of bills, the smaller the effect on the spread of a given increase in the level of rates.

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private and T-bill interest income. These investors could issue private securities (deducting the interest paid from their taxable income) and invest the funds in bills. However, as discussed in the text, investors with the highest tax rate on private versus bill interest income are individuals. They clearly are not able to and do not engage in this kind of activity. If individual investors pool their funds to buy bills, then they are in effect forming a financial intermediary to buy bills indirectly and they lose the tax exemption on T-bill interest. This is precisely the situation of money market funds (see Section II of this article). However, in periods of very low values of the spread, there does appear to be arbitrage opportunities for large investors (i.e. banks) in states with high income tax rates who are not subject to excise or franchise taxes on T-bill interest income. In periods of small spreads, one might expect to see banks in these states issuing CDs to buy bills.

Moreover, changes in the supply of T-bills can have a direct effect on the RMM-RTB spread. For instance, if the relative supply of T-bills falls, the RMM-RTB spread might rise, as a greater proportion of T-bills are purchased by investors with a high marginal tax rate on private versus T-bill interest income.

II. INVESTMENT IN T-BILLS BY INDIVIDUALS AND MMFS

Additional evidence on the effect of differential taxation (of interest income on bills versus private securities) on the spread in the 1979-83 period is contained in monthly data on T-bill investment by individuals and MMFs. As discussed earlier, individuals as a group have the largest differential between the tax rates paid on private versus T-bill interest income. At the other extreme are the shareholders of MMFs who are taxed equally on the interest of T-bills and private instruments.

No data is available on individual investment in T-bills. However, the percentage of bills awarded to noncompetitive bidders[15] at weekly Treasury bill auctions is a widely used barometer of individual investment activity in the bill market.[16] Chart 5 shows that the percent of noncompetitive bids at the weekly auction moves closely with the level of interest rates.[17]

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[15]Investors who purchase $1,000,000 or less of bills at the weekly auction can make a "noncompetitive bid," whereby the investor agrees to pay the average price of accepted competitive bids. This amount was raised in 1983 from $500,000.

[16]See [5].

[17]Based on Treasury Department data for 1980, 60 percent or more of the dollar volume of noncompetitive bids at the weekly Treasury bill auctions during that year (excluding noncompetitive bids made by Government

Chart 5

NONCOMPETITIVE BIDS AT WEEKLY AUCTION COMPARED TO LEVEL OF RATES

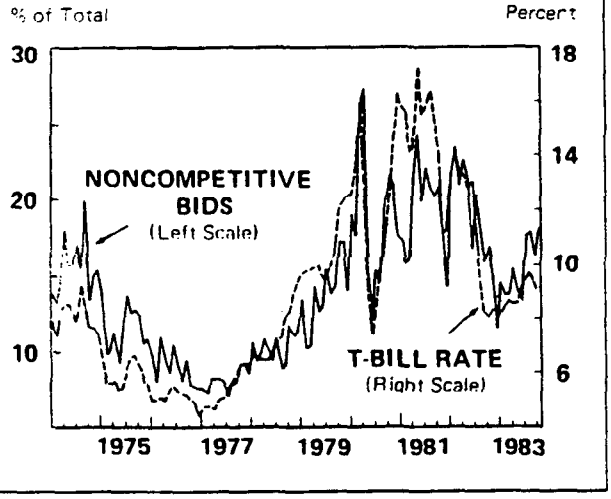

Chart 6

TREASURY BILLS AS A PERCENT OF TOTAL MMF ASSETS COMPARED TO RCD–RTB SPREAD

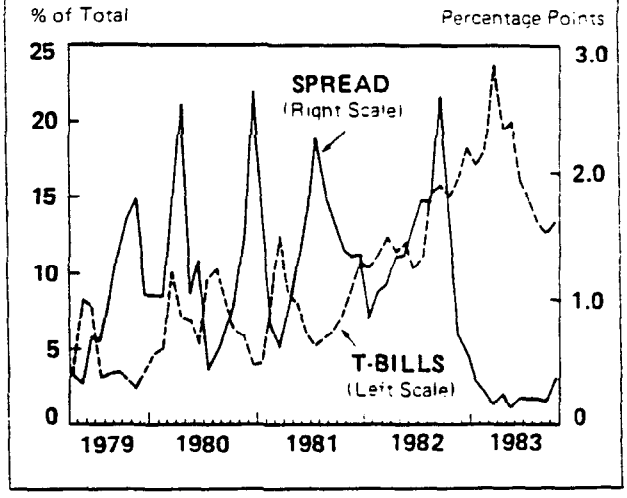

Chart 7

NONCOMPETITIVE BIDS AT WEEKLY TREASURY BILL AUCTION COMPARED TO THE CD RATE

(November 1982 – February 1983)

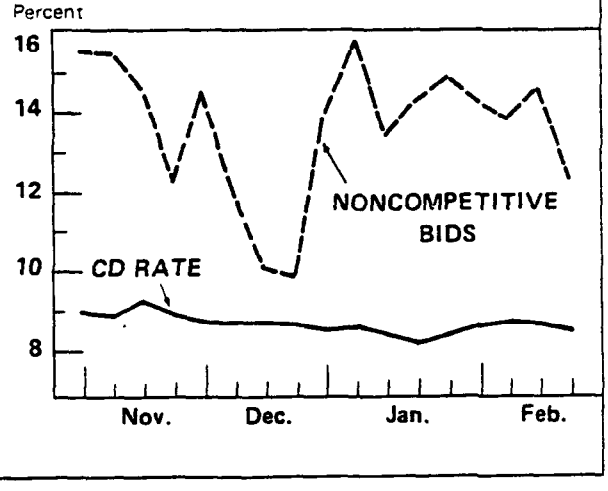

Chart 6 compares the bill holdings of MMFs to the RMM-RTB spread. MMF investment in bills is negatively and strongly correlated to the spread.[18] Hence, even though MMFs primarily buy bills indirectly for individual investors, their response to changes in the spread differs markedly from that of individual investors.

The pattern of investment in T-bills by individuals and MMFs can be explained by the different tax rates applicable to the two groups and, in addition, strongly suggests that taxes played a role in the behavior of the spread in the post-1978 period. The reasoning is as follows. As interest rates rise, at a given level of the before-tax RMM-RTB yield spread, the after-tax yield spread falls for investors (individuals) taxed on private interest but not on T-bill interest, inducing them to increase their bill purchases.[19] This puts downward pressure on the bill rate and increases the before-tax RMM-RTB yield spread. At the same time, the increase in the before-tax yield spread causes a comparable increase in the after-tax yield spread for investors (MMFs)who pay equal tax rates on T-bill and private interest income. This rise in the after-tax yield spread induces them to

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accounts or the Federal Reserve) were made at the New York Federal Reserve District, whch has by far the highest district-wide average state income tax rate.

[18]The correlation coefficient between the percent of MMF assets invested in bills and the spread over the period in Chart 6 is -.438. In contrast, the correlation coefficient between noncompetitive bids and the spread is +.506.

[19]It is relevant to this argument that following the growth of MMFs in 1978 and the introduction of MMCs in that year, the effect of taxes on the after-tax yields of these investments relative to the yields earned by direct investment in bills was well publicized. For instance, in March 1979 the Wall Street Journal published an article entitled "Where State and Local Taxes Hurt, Investors Can Earn More in Direct Purchases of Bills" [22]. See also [3, 5].

decrease their purchase of bills. Hence, a rise in the level of interest rates is followed (1) by an increase in the holdings of bills by investors with unequal tax rates on T-bill and private interest income, (2) by a rise in the RMM-RTB spread, and (3) by a decrease in the holdings of bills by investors with equal tax rates on the two types of interest income.

III. ESTIMATES OF THE SPREAD MODELS

Risk and Tax Models Regression estimates of the alternative models of the spread are presented in Table II.[20] The spread between the medium-grade and prime-grade commercial paper rates ("CPS") is used as a proxy for the default risk premium on CDs, the assumption being that the true default risk premium is linearly related to this spread.

The coefficient of CPS in the risk equation regression, equation 1 in Table II, has the correct sign and is highly significant. In the regression equation of the tax and risk model, equation 3, the coefficients of both the risk and tax variables have the correct signs and are highly significant. The overall fit of the estimated tax and risk model is

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[20]The reported regressions follow the conventional procedure of using the risk-free rate (the T-bill rate) as the right-hand side (independent) variable. Actually, the tax and risk model is an equilibrium relationship. Because of this, there is no a priori reason to use the Treasury bill as opposed to the CD rate as the right-hand side variable in the regression equations. The regressions were also estimated with the CD rate as the right-hand side variable. The estimated coefficient of the interest rate variable in these regressions (reported in Section VI) is somewhat higher; however, none of the conclusions reached in this section are different.

TABLE II

RCD-RTB Spread Regressions
1979-1 to 1983-6

	Constant	CPS	RTB	TB/L	$e^{-14(TB/L)}RTB$	ρ	D.W.	SER	$\bar{R}^2$	Implied tax rate
1. Risk Model	-.11	1.35				.52	1.94	.376	.642	0.0
	(.45)	(5.46)						(.441)	(.506)	
2. Tax Model	-.27		.118			.63	1.76	.423	.546	10.6%
	(.58)		(3.07)					(.542)	(.257)	
3. Risk and Tax Model	-1.02	1.21	.090			.40	1.92	.343	.701	8.3%
	(3.16)	(5.89)	(3.57)					(.376)	(.643)	
4a. Heterogenous Investor Model	.12	1.22	.082	-14.96		.36	1.94	.333	.719	7.6%
	(.20)	(6.38)	(3.46)	(2.09)				(.357)	(.677)	
4b. Heterogeneous Investor Model	-1.04	1.21			.247	.37	1.94	.329	.725	6.3 to 10.1%
	(3.70)	(6.39)			(4.38)			(.354)	(.683)	

NOTES:

1. The Durbin-Watson statistics in the ordinary least-squares regressions were in the neighborhood of 1.0 to 1.2, indicating the presence of autocorrelated residuals. Consequently, the equations were re-estimated using the Hildreth-Lu procedure to correct for first-order serial correlation. The values of ρ in the transformed equation are shown in the table.

2. Numbers in parentheses under coefficients are t-statistics. Numbers in parentheses under the SER and $\bar{R}^2$ are the values of the statistics for the comparable ordinary least-squares regressions. (The ordinary least-squares regression coefficients, reported in section VI, were extremely close to those reported here.)

3. CPS is the spread between the one-month medium-grade and prime-grade commercial paper rates
   RTB is three-month bond equivalent secondary market Treasury bill rate
   RCD is the three-month bond equivalent prime negotiable CD rate
   TB is the outstanding stock of Treasury bills less amount held by Federal Reserve
   L is total liquid assets as defined by the Federal Reserve

4. Treasury bills outstanding are from the Treasury Bulletin and the Monthly Statement of the Public Debt of the United States. All other data are from the Board of Governors of the Federal Reserve System.

considerably better than the simple risk model[21] and the value of the autocorrelation coefficient, ρ, is considerably lower.

These results support the conclusion that differential taxation of interest income on T-bills and private money securities was an important determinant of the RMM-RTB spread in the 1979-83 period. The tax rate implied by the coefficient of RTB in equation 3 is 8.3 percent,[22] which is well within the range of state individual tax rates on interest income given in Table 1. Hence, the magnitude of the interest rate coefficient is consistent with the tax explanation of the relationship between the level of rates and the spread in the post-1978 period.

Heterogeneous Investor Model The implications of the heterogeneous investor model discussed in Section I were that (1) the RMM-RTB spread may be negatively related to the relative supply of T-bills and (2) the effects of the level of rates and the relative supply of T-bills on the spread may be interdependent; that is, the effect of an increase in the level of interest rates on the spread may depend on the supply of bills outstanding.[23]

The supply variable used in the heterogeneous investor model regressions is the ratio of T-bills outstanding net of Federal Reserve holdings (TB) to total liquid assets (L), a proxy for the overall size of

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[21]This statement is especially true for the ordinary least-squares summary statistics, which provide a more meaningful comparison across regressions since they do not depend on the value of the autocorrelation coefficient.

[22]The implied tax rate is calculated from equation 2 in the text as $c/(1+c)$ where c is the coefficient of the Treasury bill rate.

[23]For previous evidence of supply effects on the spread see [16].

the money market.[24] Two regressions are reported in Table II. The first regression simply adds the relative supply variable to the tax and risk model. The variable's coefficient has the correct sign and is statistically significant.[25] The magnitude of the coefficient implies that if the relative share of T-bills in total liquid assets rises by one percentage point, the RMM-RTB spread falls by 15 basis points. Treasury bills range from approximately 5.6 to 9.3 percent of total liquid assets over the period covered by the regressions; hence, the regression results imply that supply factors explain a relatively small part of the movement in the spread in that period.

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[24]The specific form of the supply variable used in these regressions is by necessity somewhat arbitrary. Regressions with alternative forms of the supply variable, reported in Section VI, did not alter the conclusion that the relative supply of Treasury bills affected the spread in the post-1978 period. First, L, the denominator of the relative supply variable, was replaced with two narrower measures: (1) T-bills plus large CDs plus commercial paper plus bankers acceptances and (2) T-bills plus large CDs. In both cases the t-statistic of the coefficient of the supply variable rose. Second, marketable U.S. government securities of foreign accounts held in custody at the Federal Reserve were netted out of the numerator of the relative supply variable. When this was done, the t-statistic of the coefficient of the supply variable rose.

[25]A reasonable question regarding this result is whether the coefficient of TB/L is affected by simultaneous equations bias, i.e. whether a change in the RMM-RTB spread induces a response that alters the relative supply of T-bills outstanding. We do not think this is a serious problem because the movement in the TB/L ratio is determined mainly by the movement in Treasury bills outstanding and the Treasury's supply of bills is clearly not responsive to the RMM-RTB spread. Admittedly, on a priori grounds it is possible that the supply of private securities by some agents may be marginally responsive to the spread. (Although see footnote 14 on this point). For example, it might be argued that at large values of the spread, depository institutions that pay equal tax rates on bill and private interest income would sell bills and simultaneously run down their CDs outstanding. However, we are not aware of any evidence that the RMM-RTB spread is an important determinant of the aggregate supply of private short-term securities.

The second regression reported in Table II uses a specification in which the effects of the interest rate and supply variables are interdependent:

$$\text{Spread} = a + b \cdot \text{CPS} + c \cdot e^{d \cdot \text{TB/L}} \cdot \text{RTB},$$

where e is the base of the natural logarithm. This specification also implies that the larger the relative share of bills to liquid assets (TB/L), the smaller the effect on the spread of further increases in the share, which should be the case if the aggregate demand for T-bills flattens out at low levels of RMM-RTB, as argued earlier. This equation was estimated by experimenting with different values of d and choosing that value of d for which the sum of squared residuals in the ordinary least squares regression was lowest. The coefficient of the interest rate/supply variable is highly significant while the summary statistics of the regression are only slightly better than for the regression with the linear supply variable. The estimate of the tax rate implied by the coefficient of RTB ranges from 6.3 percent to 10.1 percent over the estimation period.[26] While this specification yields results that are very close to the first one, it makes more sense a priori and for that reason should fit the data better than the first specification in the future. Since the bill share variable TB/L should rise in coming years because of large budget deficits, this means that a rise in the level of rates should be associated with a smaller rise in the spread than in the 1979-83 period.

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[26]This is calculated as c*/1+c* where c* is the coefficient of RTB in regression (4b) in Table II and is dependent on TB/L.

IV. THE EFFECT OF MMDAS ON THE SPREAD

In mid-December 1982, all interest rate ceilings on short-term deposits with minimum denominations of $2500 at depository institutions were removed. The "money market deposit accounts" (MMDAs) that resulted from this deregulation were very popular, reaching a level of $278 billion by the end of February. A final question addressed here is whether the introduction of MMDAs decreased the demand for T-bills and thereby lowered the RMM-RTB spread.

Following the introduction of MMDAs, the RMM-RTB spread fell to extremely low levels; by March 1983 it had fallen to an average level of 16 basis points. However, the role played by MMDAs is difficult to isolate from other influences occurring at the time. Specifically, MMDAs were introduced at a time when there were major changes in the default-risk premium and tax rate variables that would also cause the spread to fall. Table III shows that the spread had already fallen sharply before the introduction of MMDAs in reaction to the decline in the default-risk premium and the lower level of interest rates. Also, as was shown in Chart 6, the demand for bills by individuals--as measured by noncompetitive bids at the weekly auction--had also fallen sharply prior to the introduction of MMDAs in reaction to the decline in market interest rates.

Chart 7 shows the weekly data for noncompetitive bids around the time of the introduction of MMDAs. Noncompetitive bids dropped substantially the two weeks following the introduction of MMDAs. This occurred in a period of stable short-term interest rates, which indicates that initially MMDAs decreased the demand for bills by individuals. By the first weekly auction in January, however, noncompetitive bids had returned to their pre-MMDA level. Hence, there is little evidence from the noncompetitive

TABLE III

Behavior of the RCD-RTB Spread, RCD and CPS

	RCD-RTB	CPS	RCD
1982			
August	1.76	1.68	10.75
September	2.61	1.68	10.81
October	1.67	1.38	9.64
November	0.72	1.26	9.07
December	0.57	0.90	8.78
1983			
January	0.35	0.76	8.48
February	0.26	0.69	8.66
March	0.16	0.63	8.81

RCD is the three-month prime bond equivalent prime CD rate.

RTB is the three-month bond equivalent Treasury bill rate.

CPS is the spread between the bond equivalent medium-grade and prime-grade commercial paper rates.

bids data of a lasting effect of MMDAs on the demand for bills. To test for an effect on the RMM-RTB spread, a dummy variable was incorporated into the spread regression (equation 4a in Table II). This variable was set equal to 1 for the months beginning in December 1982.[27] The variable's coefficient was close to zero and not significant, which reinforces the evidence from the noncompetitive bids data.

V. CONCLUSIONS

The volatile behavior of the RMM-RTB spread over the post-1978 period can be fairly well explained by models that assume investors can chose freely between Treasury bills and private money market securities.[28] Variable default-risk premiums and differential taxation of interest income on bills and private securities were found to be the two major determinants of the spread in this period. A model of the spread that allowed for

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[27]The dummy variable was given a value of 0.5 in December since MMDAs were introduced December 15.

[28]This raises the question of whether these models can explain the behavior of the spread in the pre-1978 period. Unfortunately, a key variable used in this article--the commercial paper rate spread--is available only since 1974 and the only swing in the RMM-RTB spread in the 74-77 period occurred in 1974. (In contrast there were 5 major swings in the spread in the 1979-83 period.) However, the models discussed in this paper clearly do a poor job of explaining what happened to the spread in 1974. This conclusion is based on Charts 2, 3, 4 and footnotes 11 and 12. Chart 2 shows that the RMM-RTB spread fell sharply in the latter part of 1974 even though CPS stayed very high until the end of the 1974-75 recession. Chart 4 shows that the tax and risk model has the same problem.

The main implication of the simple tax model is similar to that of the disintermediation argument: both imply that the spread is positively related to the level of interest rates. However, the tax model clearly can not explain the extremely high levels of the RMM/RTB ratio, shown in Chart 3, in 1974. (Nor can the tax model explain values of the ratio persistently above 1.2 in earlier periods of disintermediation, such as 1969-70 and 1973). Regressions for the 1974-77 period, reported in Section VI, reinforce the comments made here.

investors experiencing different tax rates and implicit returns was discussed. This model holds that the relative supply of bills can affect the spread. Regression results supported this contention, although the effect of the bill supply variable was small compared to the other two determinants of the spread.

VI. ADDITIONAL REGRESSION RESULTS

This section reports supplementary regression results that were mentioned in our Economic Review article (i.e. the first five sections of this working paper) but not reported there. The section is divided into five parts. The first part gives, with little or no comment, regression results that were asserted in the Economic Review article to be very close to those reported there. The second part reports regression results using different versions of the supply variable. The third part discusses potential problems in interpreting the coefficient of the supply variable. The fourth part reports regression results designed to test for the effect of MMDAs on the spread. Lastly, regression results for the 1974-77 period are presented.

1. Assorted Regression Results Mentioned But not Reported in the Economic Review Article

Table IV reports the OLS regression results for the various models. These results are very close to the Hildreth-Lu estimates in Table II.

Table V reports the estimates of the spread models with the CD rate (RCD) rather than the T-bill rate used as the right-hand side interest rate variable. As noted in footnote 20, the results are very similar to those reported in Table II using RTB. One exception is the coefficient of RCD in the simple-tax model, which is very high. However, in the more

TABLE IV

RCD-RTB Spread Regressions: OLS Estimates
1979-1 to 1983-6

	Constant	CPS	RTB	TB/L	$e^{-14(TB/L)}_{RTB}$	D.W.	SER	$\bar{R}^2$	Implied tax rate
1. risk model	-.10 (.55)	1.34 (7.44)				0.94	.441	.506	0.0
2. tax model	-.24 (.75)		.117 (4.39)			0.74	.542	.257	10.5%
3. risk and tax model	-.96 (3.99)	1.18 (7.56)	.086 (4.56)			1.17	.376	.643	7.9%
4a. heterogeneous investor model	.05 (.11)	1.21 (8.13)	.078 (4.28)	-13.12 (2.55)		1.27	.357	.677	7.2%
4b. heterogeneous investor model	-.96 (4.55)	1.20 (8.21)			.229 (5.47)	1.26	.354	.683	

TABLE V

RCD-RTB Regressions: RCD Used as Tax Variable
1979-1 to 1983-6

	Constant	CPS	RCD	TB/L	$e^{-14(TB/L)}RCD$	ρ	D.W.	SER	$\bar{R}^2$	Implied tax rate
1. risk model	-.11 (.45)	1.35 (5.46)				.52	1.97	.376 (.441)	.642 (.506)	0.0
2. tax model	-.92 (2.32)		.159 (5.40)			.66	1.75	.367 (.478)	.659 (.421)	15.9%
3. risk and tax model	-1.22 (4.27)	1.04 (5.23)	.110 (5.11)			.44	1.94	.310 (.343)	.756 (.702)	11.0%
4a. heterogeneous investor model	-.20 (.35)	1.06 (5.65)	.101 (4.88)	-12.83 (1.84)		.40	1.95	.304 (.329)	.766 (.726)	10.1%
4b. heterogeneous investor	-1.15 (4.52)	1.07 (5.75)			.277 (5.67)	.43	1.97	.299 (.326)	.773 (.730)	6.7% to 11.5%

NOTES:

1. The Durbin-Watson statistics in the ordinary least-squares regressions were in the neighborhood of 1.0 to 1.2, indicating the presence of autocorrelated residuals. Consequently, the equations were re-estimated using the Hildreth-Lu procedure to correct for first-order serial correlation. The values of ρ in the transformed equation are shown in the table.

2. Numbers in parentheses under coefficients are t-statistics. Numbers in parentheses under the SER and $\bar{R}^2$ are the values of the statistics for the comparable ordinary least-squares regressions.

3. CPS is the spread between the one-month medium-grade and prime-grade commercial paper rates
   RTB is three-month bond equivalent secondary market Treasury bill rate
   RCD is the three-month bond equivalent prime negotiable CD rate
   TB is the otustanding stock of Treasury bills less amount held by Federal Reserve
   L is total liquid assets as defined by the Federal Reserve

4. Treasury bills outstanding are from the Treasury Bulletin and the Monthly Statement of the Public Debt of the United States. All other data are from the Board of Governors of the Federal Reserve System.

complete models the interest rate coefficient--and, hence, the estimate of the tax rate--is much closer to that reported in Table II.

Table VI reports regression estimates with the commercial paper rate (RCP), rather than the CD rate (RCD) used as the private money market interest rate. As implied in footnote 3, the results are almost identical to those reported in Table II.

2. Alternative Specifications of the Supply Variable

As noted in footnote 24, the specific form of the supply variable used in the regressions in Table II is by necessity somewhat arbitrary, although it was the one we felt made the most sense. We also did regressions with other specifications of the supply variable. These regressions are reported in Table VII.

First, marketable U.S. government securities of foreign accounts held in custody at the Federal Reserve were netted out of the numerator of the relative supply variable. When this was done, the t-statistic of the coefficient of the supply variable rose (Equation 2 in Table VII). Second, L, the denominator of the relative supply variable, was replaced with two narrower measures: (1) T-bills plus large CDs plus commercial paper plus bankers acceptances and (2) T-bills plus large CDs. In both cases the t-statistic of the coefficient of the supply variable rose. (Equations 3 and 4)

In summary, regressions with alternative forms of the supply variable did not alter the conclusion that the relative supply of Treasury bills affected the spread in the post-1978 period. The question remains why we chose to report regression results with TB/L as the supply variable in the Economic Review article. With regard to the numerator of this variable, we could not convince ourselves that foreign purchases of bills are not

TABLE VI

RCP-RTB Regression Results
1979-1 to 1983-6

	constant	CPS	RTB	TB/L	$e^{-14(TB/L)}RTB$	ρ	D.W.	SER	$\bar{R}^2$	implied tax rate
1. risk model	-.09 (.37)	1.37 (5.10)				.48	1.97	.425 (.485)	.583 (.457)	0.0
2. tax model	-.44 (.93)		.136 (3.49)			.55	1.82	.462 (.551)	.508 (.299)	12.2%
3. risk and tax model	-1.14 (3.49)	1.18 (5.67)	.105 (4.10)			.31	1.94	.380 (.400)	.668 (.632)	9.5%
4a. heterogeneous investor model	.01 (.02)	1.20 (6.26)	.096 (4.06)	-14.76 (2.14)		.25	1.94	.368 (.380)	.688 (.667)	8.6%
4b. heterogeneous investor model	-1.12 (4.07)	1.19 (6.34)			.277 (5.03)	.25	1.94	.363 (.375)	.696 (.675)	6.5 to 11.1%

NOTES:

1. The Durbin-Watson statistics in the ordinary least-squares regressions were in the neighborhood of 1.0 to 1.2, indicating the presence of autocorrelated residuals. Consequently, the equations were re-estimated using the Hildreth-Lu procedure to correct for first-order serial correlation. The values of ρ in the transformed equation are shown in the table.

2. Numbers in parentheses under coefficients are t-statistics. Numbers in parentheses under the SER and $\bar{R}^2$ are the values of the statistics for the comparable ordinary least-squares regressions.

3. CPS is the spread between the one-month medium-grade and prime-grade commercial paper rates
   RTB is three-month bond equivalent secondary market Treasury bill rate
   RCD is the three-month bond equivalent prime negotiable CD rate
   TB is the otustanding stock of Treasury bills less amount held by Federal Reserve
   L is total liquid assets as defined by the Federal Reserve

4. Treasury bills outstanding are from the Treasury Bulletin and the Monthly Statement of the Public Debt of the United States. All other data are from the Board of Governors of the Federal Reserve System.

TABLE VII

RCP-RTB Regressions: Different Supply Variables
1979-1 to 1983-6

		constant	CPS	RTB	supply variable	ρ	D.W.	SER	$\bar{R}^2$	implied tax rate
1.	TB/L	.12 (.20)	1.22 (6.38)	.082 (3.46)	-14.96 (2.09)	.36	1.94	.333 (.357)	.719 (.677)	7.6%
2.	TBNET/L	-.53 (1.42)	1.30 (6.58)	.082 (3.44)	-14.08 (2.20)	.37	1.96	.332 (.356)	.722 (.679)	7.6%
3.	$\frac{TB}{TB+CD+CP+BA}$	1.41 (1.36)	1.05 (5.47)	.070 (2.95)	-5.66 (2.43)	.32	1.89	.330 (.348)	.725 (.693)	6.5%
4.	$\frac{TB}{TBNET+CD}$	2.09 (1.85)	1.08 (5.88)	.067 (2.88)	-4.46 (2.83)	.31	1.92	.324 (.341)	.734 (.706)	6.3%
5.	$\frac{TB}{LTREND}$	.11 (.18)	1.22 (6.36)	.082 (3.44)	-14.72 (2.09)	.36	1.94	.333 (.357)	.718 (.676)	7.6%

NOTES:

1. See Table II.

2. TBNET is the outstanding stock of Treasury bills less the amount held by the Federal Reserve minus marketable U.S. government securities of foreign accounts held in custody at the Federal Reserve.

dependent on the RCD-RTB spread. Furthermore, the only available measure for foreign holdings of bills--the one used above--includes all marketable U.S. securities held in custody at the Federal Reserve, not just short-term securities. For these reasons we did not net out foreign holdings in the Economic Review article. With regard to the denominator of the supply variable, we felt that in view of the difficulty in choosing which assets are close substitutes to T-bills, the most logical choice was the broadest available measure of liquid assets, L.

3. Other Potential Problems with the Supply Variable

Three other potential problems with the regression results for the supply variable are discussed in this section.

a. Reverse causation. As noted in footnote 25, a reasonable question regarding the result reported in Table II is whether the coefficient of TB/L is affected by simultaneous equations bias, i.e., whether a change in the RMM-RTB spread induces a response that alters the relative supply of T-bills outstanding. We argued in footnote 25 that this is not a serious problem because the movement in the TB/L ratio is determined mainly by the movement in Treasury bills outstanding and the Treasury's supply of bills is clearly not responsive to the RMM-RTB spread. However, we raised the possibility that the supply of private securities--and, hence, L--might be marginally responsive to the spread.

In actuality this was not a problem in interpreting the regression results because virtually all the movement in TB/L is due to movement in TB. To show this we reconstructed L so that all its growth over the period--which was at an annual rate of 10.7 percent--occurred at a constant monthly growth rate. TB divided by this variable (LTREND) is compared to TB/L in Chart 8. The two series are virtually identical. Regression

results using TB/LTREND are the same as those for TB/L, as shown in equation 5 of Table VII.

b. Missing variable. A second potential problem, not discussed in the ER article, is whether a trend in the supply variable, TB/L, is simply picking up a trend in some variable missing from the regression. Charts 9 and 10 show the four supply variables used in the regressions in Table VII. The two supply variables with L as the denominator do have an upward trend over the period. The other two supply variables, which have the same cyclical movement, do not have a trend.

We point to two pieces of evidence that the coefficient of the supply variable in Table II is not simply picking up a trend in a missing variable. First, as shown in Table VII, when narrower measures of liquid assets that do not have trends are used in the regressions the supply variable coefficient still comes in significantly. Second, we separated TB/L into its trend and cyclical components and did the regression with these as the supply variables. The results are reported in Table VIII. The coefficient of the cyclical component of TB/L is significant regardless of whether or not the trend component is included in the regression.

c. MMDA effect on supply variable. A final question regarding the supply variable result reported in Table II is whether it is picking up the effect of MMDAs in the spread. As shown in Charts 9 and 10, the supply variable reaches its highest level at the end of the estimation period. This raises the possibility that the coefficient of the supply variable may be picking up the negative influence of the introduction of MMDAs on the spread. This possibility will be discussed below.

CHART 8

TB/L and TB/LTREND

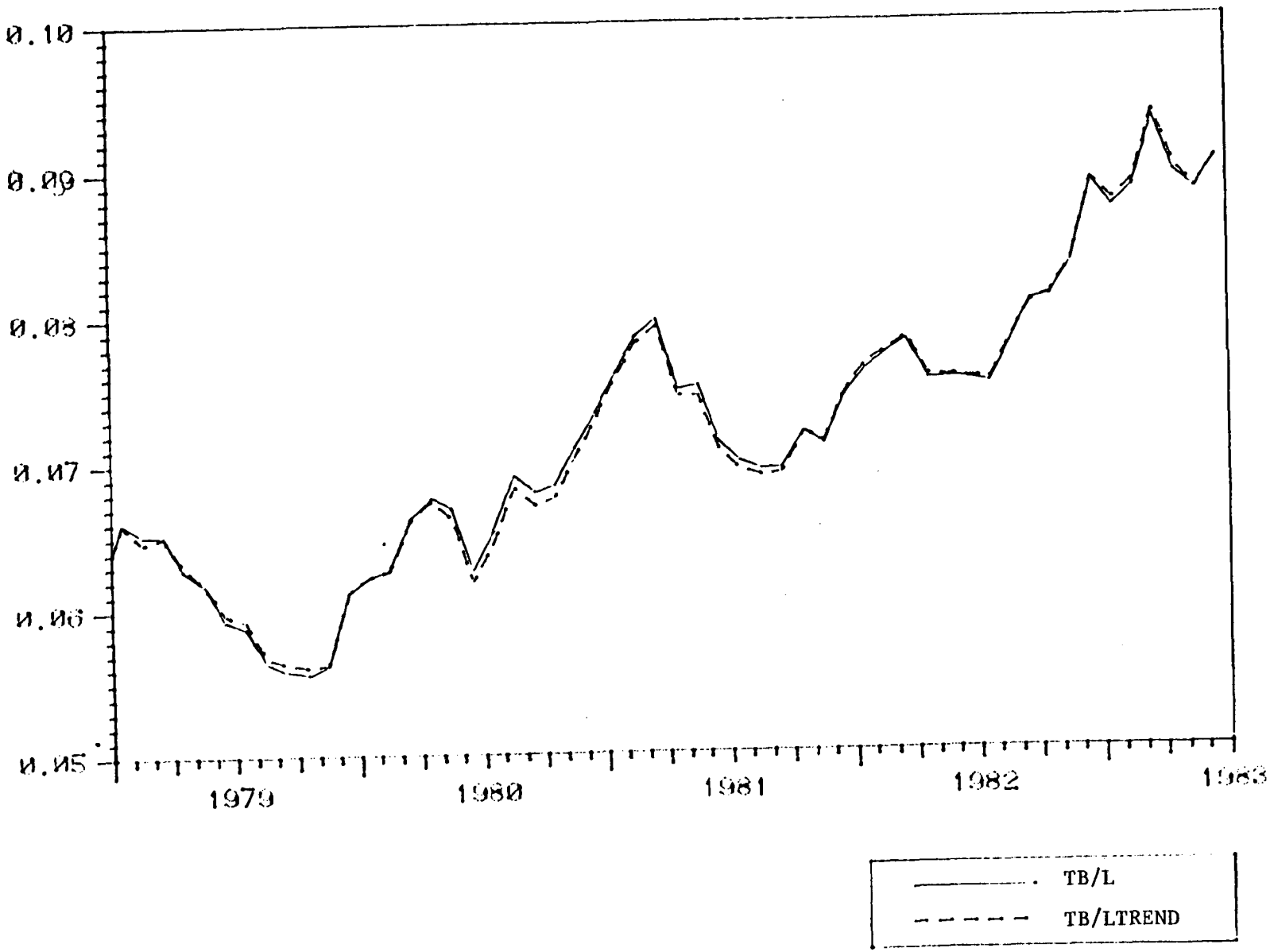

CHART 9

TB/L and TBNET/L

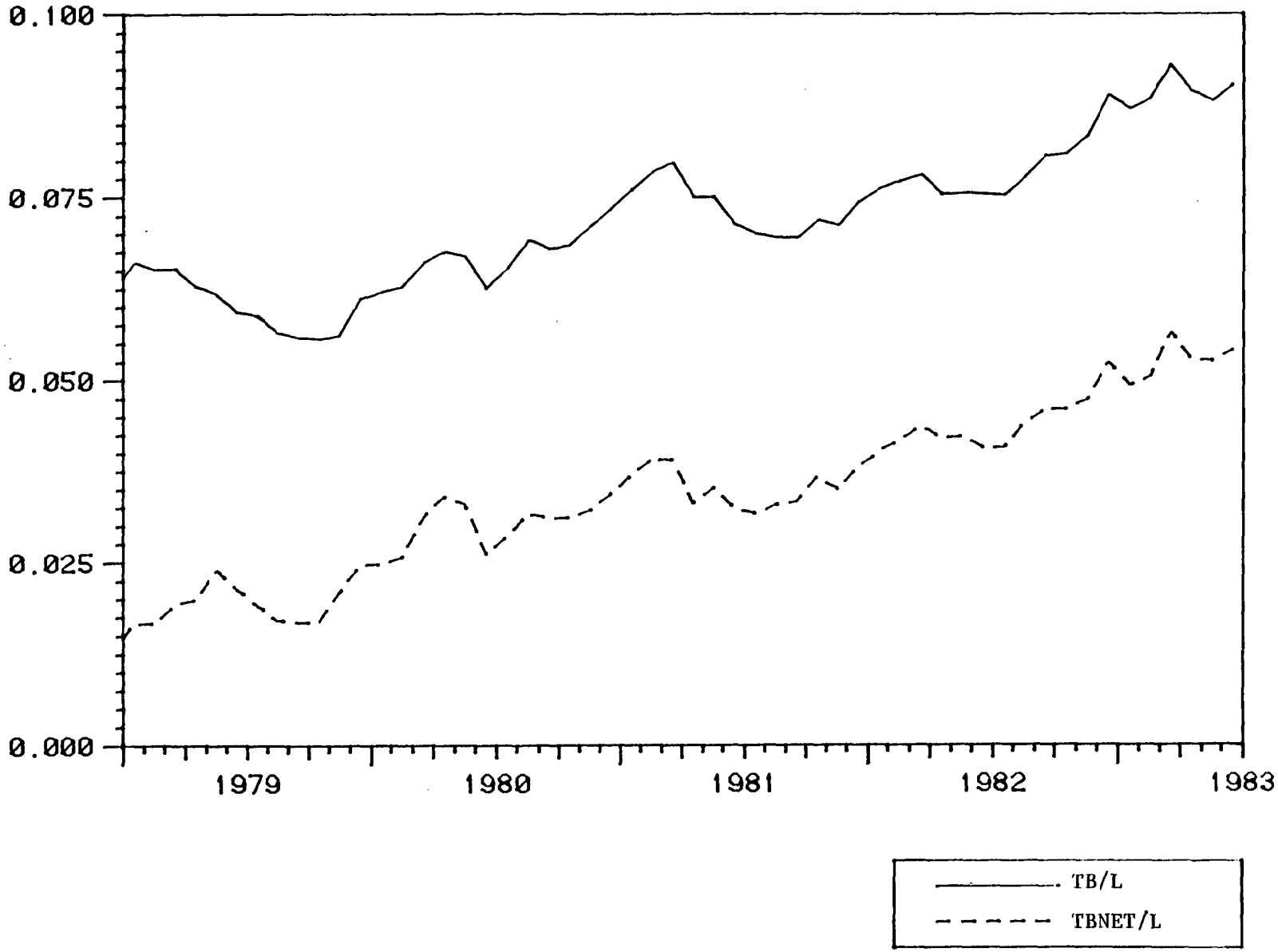

CHART 10

TB/(TB+CD+CB+BA) and TB/(TB+CD)

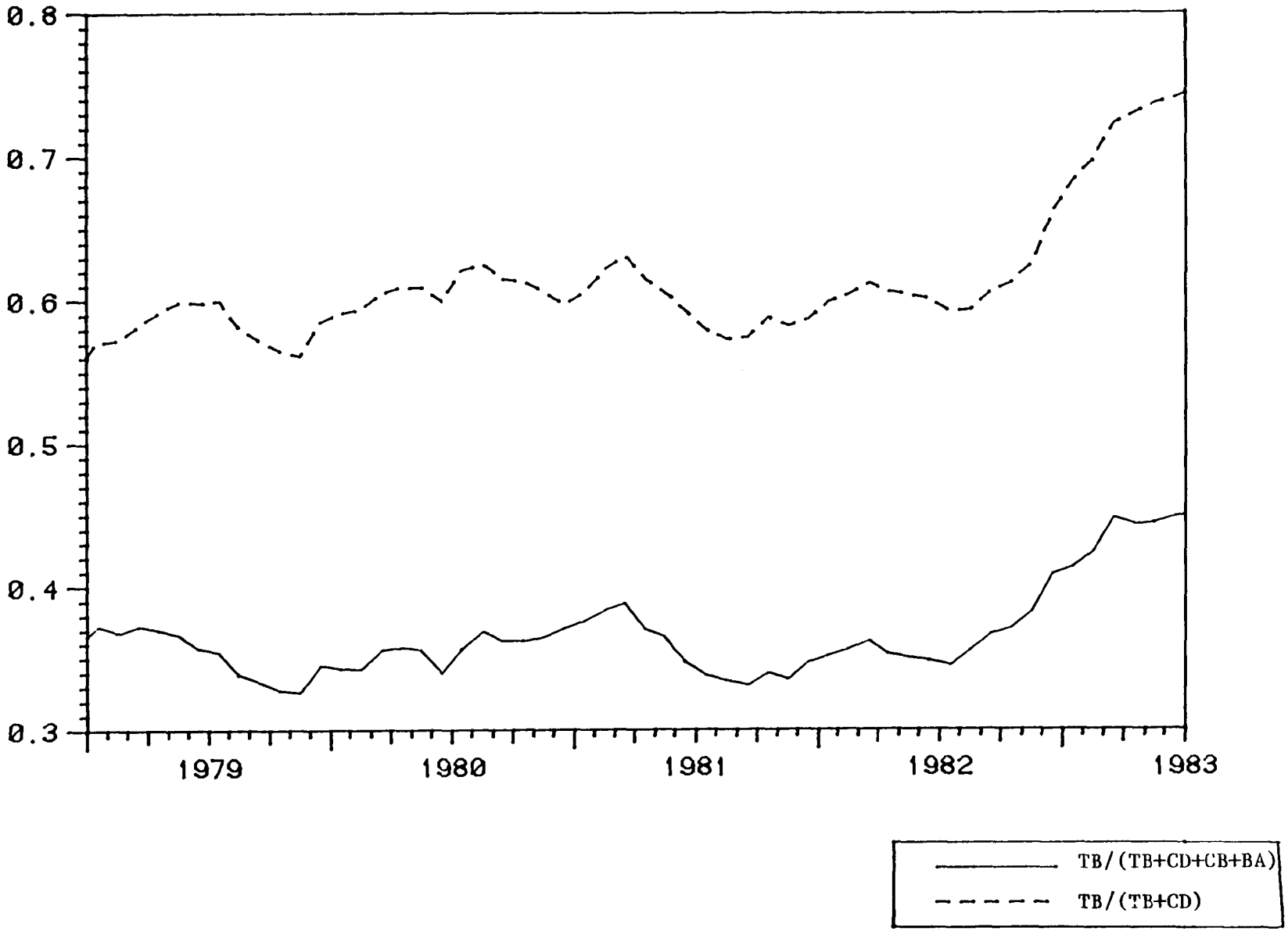

TABLE VIII

RCD-RTB Regressions: TB/L Broken Into Trend and Cyclical Components

		constant	CPS	RTB	TB/L	TB/L TREND	TB/L - TB/L TREND	ρ	D.W.	SER	$\bar{R}^2$	implied tax rate
1.	TB/L	.12 (.20)	1.22 (6.38)	.082 (3.46)	-14.96 (2.09)			.36	1.94	.333 (.357)	.719 (.677)	7.6%
2.	Trend Component	-.18 (.23)	1.26 (6.13)	.086 (3.43)		-11.42 (1.21)		.38	1.94	.342 (.370)	.704 (.653)	7.9%
3.	Cyclical Component	-.92 (3.18)	1.08 (5.66)	.085 (3.79)			-34.95 (2.38)	.32	1.86	.330 (.350)	.724 (.690)	7.8%
4.	Trend and Cyclical Components	-.36 (.52)	1.12 (5.68)	.083 (3.63)		-7.63 (.89)	-32.37 (2.16)	.32	1.89	.331 (.350)	.722 (.689)	7.7%

4. The Impact of MMDAs on the Spread

In Section IV we noted that when we added a dummy variable set equal to one for the months beginning in December 1982, the variable's coefficient was close to zero and not significant. This result is reported in Table IX. As a second experiment we truncated the estimated period in November 1982 to exclude the period when MMDAs were available to investors.[29] As shown in Table X the coefficients of all the variables are little changed from those in Table II. The t-statistic of the supply variable coefficient falls somewhat, but the coefficient is still significant of the 5 percent level using a one-tailed test. These results provide assurance that the coefficient of the supply variable in Table II is not simply picking up the effect of a missing MMDA variable.

Note that if we are right about supply effects on the RMM-RTB spread, the implication of the surge in the supply of bills by the Treasury is that it will lose part, if not all, of the advantage of having its debt exempt from state and local income taxes. The potential revenue consequences of this loss are substantial. Currently there are about $300 billion of T-bills outstanding net of Federal Reserve holdings. Suppose, for example, the tax rate of the marginal investor in bills is initially 8 percent and suppose that the Treasury begins to supply so many bills that equal tax rate investors need to be induced to buy bills. Then, at a RMM level of 15 percent, the annual income lost to the Treasury would be $3.6 billion.[30]

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[29] We initially did other MMDA regressions because we expected MMDAs to affect the spread. We were surprised by the regression results, until we looked at the weekly noncompetitive bids data discussed in Section IV.

[30] The arithmetic is [.15-.15(1-.08)]*300 = $3.6.

TABLE IX

RCD-RTB Spread Regressions: MMDA Dummy Variable Regressions
1979-1 to 1983-6

	constant	CPS	RTB	TB/L	$e^{-14(TB/L)}_{RTB}$	MMDA	ρ	D.W.	SER	$\bar{R}^2$	implied tax rate
3. risk and tax model	-.76 (2.15)	1.12 (5.59)	.077 (3.07)			-.31 (1.33)	.34	1.90	.342 (.363)	.704 (.666)	7.1%
4a. heterogeneous investor model	.23 (.33)	1.26 (5.76)	.086 (3.30)	-17.60 (1.67)		.11 (.33)	.38	1.95	.336 (.360)	.714 (.672)	7.9%
4b. heterogeneous investor model	-.99 (2.66)	1.20 (6.02)			.239 (3.56)	-.05 (.20)	.36	1.94	.333 (.355)	.720 (.681)	

NOTES:

1. See Table II.

2. MMDA is a dummy variable described in the text.

TABLE X

RCD-RTB Spread Regressions
1979-1 to 1982-11

	constant	CPS	RTB	TB/L	TB/(TB+BA+CD+CP)	ρ	D.W.	SER	$\bar{R}^2$	implied tax rate
1. risk model	.10 (.39)	1.20 (4.86)				.40	1.77	.391 (.423)	.532 (.452)	0.0
2. tax model	.05 (.10)		.098 (2.47)			.57	1.72	.442 (.534)	.400 (.127)	8.9%
3. risk and tax model	-.78 (2.06)	1.14 (5.25)	.078 (2.89)			.34	1.82	.363 (.384)	.597 (.547)	7.2%
4a. heterogeneous investor model	.32 (.40)	1.29 (5.39)	.088 (3.13)	-19.81 (1.66)		.40	1.89	.356 (.382)	.611 (.552)	8.1%
4a. heterogeneous investor model	2.80 (1.64)	1.09 (5.13)	.075 (2.83)		-9.82 (2.17)	.36	1.84	.348 (.370)	.628 (.579)	7.0%

NOTE: See Table II.

5. 1974-77 Regressions

In footnote 28 we asserted that the models discussed in Sections I-III do a poor job of explaining what happened to the RMM-RTB spread in the 1974-77 period. As noted in the footnote a key variable used in this article--the commercial paper rate spread--is available only since 1974 and the only swing in the RMM-RTB spread during the 74-77 period occurred in 1974.

Table XI reports regression results for the 1974-77 period. The results differ sharply across equations depending on whether RCP or RTB is used as the right-hand-side variable and depending on whether the equation is estimated using OLS or the Hildreth-Lu procedure. When RCD is used as the right-hand-side interest rate variable, the interest rate coefficient is highly significant and implies a tax rate of 40 to 45 percent in both the OLS and the Hildreth-Lu regressions. Clearly, the high magnitude of this coefficient is inconsistent with taxes as an explanation for the correlation between the level of rates and the spread in the 1974-77 period.

When RTB is used as the right-hand side variable, the OLS regression result for the interest rate coefficient gives roughly the same picture: the coefficient is very significant and too high to be consistent with the tax explanation. When the Hildreth-Lu procedure is used, the coefficient is no longer significant. This result is also inconsistent with the tax explanation, because the tax explanation requires a close link between RMM and RTB. That close link is not evident in the Hildreth-Lu regression results.

TABLE XI

RCD-RTB Regressions: 1974-1 to 1977-12

	constant	CPS	RTB	RCD	TB/L	ρ	D.W.	SER	$\bar{R}^2$	implied tax rate
1. Tax and risk model: RCD										
OLS	-2.18 (12.62)	.29 (2.12)		.405 (13.98)			.90	.354	.883	40.5%
H-L	-2.29 (7.54)	.48 (2.43)		.400 (8.80)		.57	2.00	.295	.919	40.0%
2. Heterogeneous investor model: RCD										
OLS	-3.28 (3.80)	.293 (2.13)		.445 (10.56)	10.99 (1.29)		.95	.351	.885	44.5%
H-L	-2.76 (2.16)	.473 (2.39)		.414 (6.86)	5.05 (.39)	.56	2.00	.298	.917	41.4%
3. Tax and risk model: RTB										
OLS	-2.84 (6.90)	.72 (3.48)	.519 (7.01)				.82	.565	.702	34.2%
H-L	-.53 (.59)	1.05 (3.12)	.11 (.87)			.82	1.84	.423	.833	not significant
4. Heterogeneous investor model: RTB										
OLS	-1.27 (.80)	.69 (3.31)	.44 (4.01)		-14.08 (1.02)		.76	.565	.702	30.6%
H-L	4.29 (2.10)	.95 (3.01)	.02 (.12)		-57.12 (2.65)	.80	1.74	.397	.853	not significant

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