Advance Refundings of Municipal Bonds*

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Abstract

Municipal bonds are often "advance refunded." Bonds that are not yet callable are defeased by creating a trust that pays the interest up to the call date, and pays the call price. New debt, generally at lower interest rates, is issued to fund the trust. Issuing new securities to fund payments on existing liabilities generally has zero net present value. In this case, however, value is lost for the issuer through the pre-commitment to call. We estimate that on average in an advance refunding the option value lost to the municipality is approximately 0.82-0.85% of the par value not including fees. This translates to an aggregate value lost of $7.2-9.2 billion, depending on the option pricing model used, from 1995 to 2013 for the bonds in our sample, which are roughly two-thirds of the advance refunded bonds that traded during the period. The worst 5% of the transactions represent a loss of $5.1-7.2 billion for taxpayers. We discuss various motives for the transaction, and argue that a major one is the need for short-term budget relief. Advance refunding enables the issuer to borrow for current operating activities in exchange for higher interest payments after the call date. We find that municipalities in states with poor governance do worse advance refunding deals in terms of lost option value.

1 Introduction

In an advance refunding, or pre-refunding, a municipality issues new debt to pay off an existing bond that is not yet callable. The new bond is typically issued at a lower yield than the outstanding bond. The proceeds from the new debt fund a trust that covers the remaining coupon payments up to the call date along with the call price of the existing bonds. The trust generally holds risk-free U.S. Treasury bonds, which are specially issued by the Treasury for this purpose (and are called State and Local Government Securities, SLGS, or "slugs").[1]

The practice of advance refunding is widespread in municipal finance. New issues of municipal bonds in recent years have varied between $300 and $400 billion a year. On average, over the last decade, slightly over half of this volume was "new money," used to fund new investment projects. Some 30% of the new issues went to refund existing debt, because the bonds were advanced refunded, were called, or they matured, while 17% combined new money and refunding.[2]

Figure 1 shows par value amounts of municipal bond redemptions, by year and by different categories. Bonds can be retired at maturity, either because they were never callable or because the call was never exercised. Bonds can be called during the time period when the call provision is in effect, in a so-called "current refunding." The third category of bond redemptions in the figure are bonds that are called after having previously been defeased through an advance refunding. In 2012, for example, $450 billion of municipal debt was extinguished through redemption (including $53 billion in maturing short-term notes, not shown in the figure). Of this total, $76.5 billion were bonds that were called after having previously been pre-refunded. In the early years of the last decade, more pre-refunded bonds

[1]This prevents the issuer from earning the (taxable) rate on assets funded by tax-exempt municipal debt, while also providing inexpensive financing for the U.S. Treasury.

[2]Source: Spreadsheet titled "A Decade of Municipal Bond Finance" available on the BondBuyer's web site.

were called than non pre-refunded bonds. In recent years the volume of called, pre-refunded bonds has been about half of the volume of current refundings.

In an advance refunding, one security is issued to fund payments on another. One of the most basic lessons of an introductory finance course is that such a transaction cannot create value. It can only transfer value between the various claimants involved. In this case, there are four parties involved: the municipal issuer, the holders of the bonds being refunded, the financial intermediaries collecting fees for arranging the transaction, and the U.S. Treasury, which issues and prices the SLGS.

Advance refunding can provide short-term budget relief for the issuing municipality. As the interest rate on the new debt is lower than the yield on existing debt, advance refunding decreases the municipality's interest cost between the pre-refunding date and the date at which the original bonds could have been called. It also hedges the issuer's future borrowing costs, and industry professionals argue that alternative means of hedging can be costly.

Unfortunately, however, advance refunding clearly destroys value for the issuer. By pre-committing to call, the issuer surrenders the option not to call should interest rates rise before the call date. The value lost to the issuer, and transferred to bondholders, is the value of a put option on the bonds. In addition, since the assets in the trust are Treasury securities, the transaction provides free credit enhancement for the bondholders, also at the expense of the issuer. Finally, the intermediaries who create the trust and issue the new bonds collect fees to do so. Payment of these fees would be delayed if the issuer waited to refund at the call date, and, since pre-refundings do not extend the maturity of the debt, would be avoided altogether if after the call date the call option were ultimately not exercised. Indeed, underwriters and traders are known to jokingly refer to advance refundings as "de-fees-ance."

In this paper, we describe and quantify the effects of pre-refunding on the cash flows and the present value of the issuer's obligations. We examine a sample of over 200,000 bonds that were pre-refunded from 1995 to 2013, with a total par value of $577 billion. We estimate that advance refunding of these bonds has cost roughly \$7-9 billion in option value for taxpayers, depending on the option pricing model used. The distribution of the option value lost to the issuers is highly skewed. The majority of advance refundings represent only small losses, because the put option is deep out of the money, or the bonds are close to the call date. The worst 5% of advanced refundings, however, represent \$5.1 to \$7.2 billion of lost value, depending on the valuation model employed. The fees municipalities paid in these "de-fees-ance" deals are substantial compared to the option value lost. If we include a 2% transaction cost as a fraction of the refunded bond value, the aggregate value of losses to advance refunding approaches \$20 billion. Assuming our sample is representative, these numbers can be raised roughly fifty percent to assess the aggregate impact of advance refunding. In cross-sectional analysis, we find that states with the highest number of convictions of public officials per capita are also states where municipal officials have destroyed more option value by advance refunding.

Why, given the costs, do municipal issuers pre-refund their bonds? Almost all municipalities are required by statutes, charters, or state constitutions to balance their operating budgets. They can only borrow for capital projects. They are rarely restricted from refunding or pre-refunding existing debt, however, as long as the maturity is not increased. We show that advance refunding allows the municipality to, in effect, borrow against future potential interest savings. Current interest expense, which is paid out of the operating budget, is reduced, while future payments after the call date are increased. The transaction is effectively a swap, with a negative net present value for the municipality.

Similarly, even when borrowing for capital projects, state and municipal leaders may feel less constrained if they can claim not to be increasing, or even to be reducing, the issuer's nominal future liabilities. Pre-refundings allow this if one views the existing liabilities as the interest on the existing debt to maturity, ignoring the option to call in the future.

We estimate that the amount of implicit borrowing being done by advance refunding totals over \$12 billion. Like the distribution of option value lost, the distribution of implicit borrowings is highly skewed. Over half of the amount of implicit borrowing is done in 5% of the deals.

Thus, an advance refunding may help the issuer avoid the need to increase taxes or lay off public workers, which may be laudable, even urgent, priorities. Nevertheless, the restrictions on borrowing to fund these priorities are presumably in place for equally commendable reasons, which are evidently being circumvented. By accelerating interest savings at the expense of future savings, advance refundings can help elected officials defer cost cutting or tax increases in an election year, even though the borrowings done through advance refunding come at the expense of surrendered option value. Thus, advance refundings can be viewed as a non-transparent means of borrowing to fund current activities at the expense of future tax obligations.

Advance refunding is also justified by practitioners and issuers as a means of locking in or hedging future borrowing costs. If the municipality waits to the call date, and does a current refunding, it will pay whatever the prevailing interest rate is at that point. Indeed, preserving the option value means that it may choose not to refund if rates have risen sufficiently in the meantime. As a practical matter, hedging the interest rate risk directly may be difficult to arrange at low transaction costs. Moreover, advocates argue that the forward rates implicit in the transaction are often lower than those available directly, because the yields on the SLGS in the trust exceed short-term municipal rates. Thus, some surplus in the transaction may be created for other participants at the expense of the Treasury. We discuss these considerations in detail in Section 2.3, and estimate the implicit subsidy for every bond in our sample in Section 5.4. We show empirically that the magnitude of this advantage does encourage municipalities to engage in deals that destroy more option value, but also note that in recent years the advantage has disappeared, and yet pre-refunding activity has not. As a matter of policy, we argue that subsidizing a form of hedging through the SLGS rates, which are set at the discretion of the Treasury, is counter productive if it encourages transactions that destroy value for issuers on other dimensions.

Advance refundings of municipal bonds have received very limited attention in the academic literature.[3] In an unpublished note, Dammon and Spatt (1993) describe the transaction and explain how it destroys option value for the issuer. Analyses in specialized journals aimed at practitioners often acknowledge that option value is lost, but generally prescribe comparing this loss, along with fees paid, to the interest savings over the remaining time to maturity. For example, Kalotay and May (1998) or Kalotay and Abreo (2010) advocate calculating "refunding efficiency," the ratio of the present value of interest savings over the life of the newly issued debt to the lost option value. While they acknowledge the option value lost in pre-refunding, these studies do not compute the typical value lost in an advance refunding deal, or compute the implicit borrowing involved.

Two empirical studies examining the determinants of municipal refundings are Vijayakumar (1995) and Moldogaziev and Luby (2012). They do not take into account the losses from advance refunding. Several papers have used pre-refunded, or defeased bonds, in analysis but do not examine the pre-refunding decision. Fischer (1983), for example, uses the public announcement of an advance refunding to examine efficiency of the municipal bond market, and Chalmers (1998) shows that the steeper slope of the municipal yield curve compared to Treasuries cannot be explained by default risk by showing the phenomenon is exhibited in pre-refunded municipal bonds with no default risk.

Debt defeasance has been studied by academic researchers is settings other than the municipal sector. For example, Hand, Hughes, and Sefcik (1990) examine defeasance of corporate bonds, and show that stock and bond price reactions are consistent with a wealth transfer from equity to debt holders. They examine possible motives for the transactions,

[3] There is an older literature looking at the (early) refunding decisions of corporations, like Weingartner (1967) and Kraus (1973).

including avoidance of bond covenants and window dressing for earnings, and find evidence for each of them. This practice was severely curtailed by FASB in 1984 (Technical Bulletin No. 84-4). There was no such corresponding restriction issued by GASB for municipalities. The analogue of boosting earnings has greater bite in the municipal setting because, unlike corporations, municipalities typically cannot borrow to fund operating activities. Dierker, Quan, and Torous (2004) examine defeasance of mortgages in commercial real estate, where it is used by developers to access the equity. [4]

The paper is organized as follows. The next section illustrates the cash flow and valuation effects of advance refundings. Section 3 describes the data and provides descriptive evidence on pre-refundings and the pervasiveness of the practice. Section 4 describes the methods we use to value the put options lost through the transaction for the issuers. Section 5 empirically evaluates the quantitative consequences of pre-refunding. We also discuss which municipalities do the worst deals. We review common misconceptions about advance refunding and conclude in Section 6.

2 The Pre-Refunding Decision

This section illustrates the effects advance refunding has on the value of the issuer's liability, and on the pattern of cash flows associated with that liability through time. We begin with the simplest case, a flat term structure with certainty about future rates, as it is sufficient to illustrate the implicit borrowing the transaction involves.

[4]For example, suppose the purchase of a building is financed with 80% debt that is not callable, and the price has risen by 50%. The developer at that point might want to demolish the original building and construct a new one on the site, or refinance the building and withdraw cash. Discharging the original debt through a defeasance makes these things possible.

2.1 Example

Suppose the term structure is flat at all points, and ignore default risk. We assume coupon payments are made annually. A municipal entity has previously issued bonds with \$100 face value and a 6% coupon. Interest rates have since fallen to 4%. There are six years to maturity, and the bonds are callable at \$100 the end of three years. Let us first abstract from the optionality in the call provision for the bonds, and assume it is known with certainty that rates remain at 4% forever.

In the first row of Table 1, we list the cashflows of the existing bond. The value of the original bond at 4% is:

$$\frac{6}{(1.04)} + \frac{6}{(1.04)^2} + ... + \frac{106}{(1.04)^6} = \$110.48.$$

If the bond was callable at the current date, the refunding decision would be straightforward. The municipality would issue new bonds with six years to maturity and refund the old bonds. The annual interest payments per \$100 par value would drop from \$6 to \$4, and the present value of these savings would be:

$$\frac{2}{1.04} + \frac{2}{(1.04)^2} + ... + \frac{2}{(1.04)^6} = \$10.48$$

per \$100 of face value.

Since the bonds are not immediately callable, however, the issuer must choose between waiting three years to call or pre-refunding now. If the issuer pre-refunds it must issue a six-year bond at a coupon rate of 4% sufficient to fund the payments over the next three years and the call price. The face value of the new bond that must be issued is:

$$\frac{6}{(1.04)} + \frac{6}{(1.04)^2} + \frac{106}{(1.04)^3} = \$105.55.$$

The coupon payments on the new bonds are:

$$105.55 \times 0.04 = \$4.22.$$

The cashflows of the refunding issue are given in the second row of Table 1. After the new bond is issued, the original bond is defeased and no longer appears as a liability on the balance sheet of the municipality.

Standard industry practice, endorsed in 1995 and 2010 by the Government Finance Officers Association (GFOA), which is the professional association of municipal finance officers in the U.S. and Canada, is to compare the cash flows of the original bond (row 1) with the cash flows of the new bond (row 2). The best practice guidelines of the GFOA recommends that a refunding be considered when the "minimum net present value (NPV) savings" is at least 3-5%.[5] Row 3 of Table 1 computes this value by taking the difference between the original bond's coupons of \$6 and the cashflows of the pre-refunded bond of \$4.22. The "NPV" of the savings are

$$\frac{1.78}{(1.04)} + \frac{1.78}{(1.04)^2} + ... + \frac{-3.77}{(1.04)^6} = \$4.94.$$

It appears that using the "NPV method," the municipality obtains a savings of 4.5% = 4.94/105.55. This analysis, however, ignores what the issuer is giving up—the ability to call the bond at the end of three years. The relevant comparison is not advance refunding or leaving the existing bond in place to maturity. The relevant comparison is advance refunding or waiting until the call protection expires and proceeding with a current refunding.

If the issuer waits the three years to call the bonds, it pays \$6 for three years, and the strike price at the end of three years, financed by issuing a new three-year bond at 4%. We

[5] Analyzing and Issuing Refunding Bonds (1995 and 2010) (DEBT), GFOA Best Practice approved by the GFOA's Executive Board in February 2011. This practice follows early academic studies like Dyl and Joehnk (1976) and Joehnk and Dyl (1979) that ignore the option value of pre-refunding.

examine the cashflows associated with the call decision in the rows labeled "Wait to Call" in Table 1. The savings of waiting to call, and calling at the end of three years, compared to paying the coupons of the original bond to maturity are

$$\frac{2}{(1.04)^4} + \frac{2}{(1.04)^5} + \frac{2}{(1.04)^6} = \$4.94.$$

That is, the savings from waiting to call are exactly equal to the apparent savings from the issue of the pre-refunding bond. In this case, interest rates are certain, so the present values of the interest savings under the two alternatives are equal. Only the timing of the interest savings differs. The final line in the table shows the savings associated with pre-refunding less the savings associated with waiting to call. The pre-refunding accelerates the interest savings at the expense of higher interest payments over the later years, and an higher payment at maturity.

The last row of Table 1 shows this explicitly. It takes the difference between the cash flows of the pre-refunding case and waiting to call. The present values of the positive and negative flows are equal. The issuer is effectively borrowing against future interest savings associated with the opportunity to call, as well as a higher principal repayment, to reduce interest expense now. The present value of the accelerated interest savings, \$4.95 per \$100 face value, is achieved by surrendering the same present value of savings later. Alternatively, the issuer could achieve the payment stream associated with pre-refunding by entering a swap contract that paid the municipality \$1.78 each year for three years, in exchange for the promise to pay \$0.22 annually starting in year four, augmented by \$5.55 in year six. It has zero present value at the current date, but effectively borrows over the first three years in exchange for payments over the last three years.

Evidently then, under certainty about the evolution of future interest rates, waiting to refund, versus pre-refunding has no effect of the present value of the issuer's liability. Why then would an issuer want to do this? When pre-refunding, the issuer has interest expense each period between the $6 associated with the existing debt and the $4 it will pay after the call date if it waits to call. Though this has no effect on the present value of the issuer's liabilities, it may very well affect its freedom to spend money or reduce taxes. Municipalities can only borrow to fund capital projects, and even then there are often elaborate restrictions (or safeguards), such as requiring approval of voters or of a state-wide board for a new bond issue. There are generally no such restrictions associated with refunding activities, however, so long as they do not extend the maturity of the original debt.

2.2 Uncertainty

To this point, the pre-refunding is neutral in terms of present value because interest rates are fixed. Suppose, however, there is some possibility interest rates will rise over the next three years above the 6% rate on the existing debt. Then the pre-commitment to call must be destructive of option value for the issuer, because it forces the firm to call even when it is suboptimal to do so.

When there is uncertainty about future rates, the interest savings that will eventually be realized by waiting to call are uncertain, and so are the differences through time associated with an advance versus a (delayed) current refunding.[6] Indeed, part of the appeal of pre-refunding is that it "locks in" interest savings that might be lost should rates rise before the call date. If the goal is to hedge this uncertainty, then a variety of hedging strategies can achieve this without pre-committing to call. Even if the goal is to accelerate or borrow against the uncertain future interest savings associated with the call provision, a swap contract could achieve this more efficiently. If we denote the uncertain three-year spot rate that will prevail three years from now as $\tilde{r}_3$ percent, then the interest payments from years 4-6 associated

[6]Under the tax code, a bond is current refunded when there are 90 days, or fewer, between the closing of the refunding issue and the final payment of the refunded issue.

with waiting to call are $\min\{6, \tilde{r_3}\}$. The issuer could arrange to swap some portion of this liability for cash payments of equal present value over the first three years. Such a step, however, would be more transparent as "borrowing" to the public, to the Internal Revenue Service, or to any supervisorial authority, and thus might be politically or legally infeasible. This raises the question, however, of why the issuer should be permitted to borrow in an opaque manner that destroys value when doing so directly and transparently would not be allowed.

To illustrate this in more generality, suppose the price of a bond at date t is V_t. The bond is callable at an exercise price of \$$K$ at date τ and matures at date $T > \tau > t$. It pays a continuous coupon of rate c. We consider the simplest case of a one-time opportunity to pre-refund the bond at the current date of t, and a single opportunity to call at date τ. That is, we treat the call provision as a European option. As we explain below, this is conservative for our purposes. The consequences of credit risk on present values are obvious, though difficult to quantify theoretically and empirically, so as in the previous example, we ignore them here. Keep in mind that the credit risk for most of the municipal sector has been quite low in modern times compared to the corporate sector—recent fiscal problems at the state and local level notwithstanding.[7]

Let V_τ be the present value of the coupon stream between the call date and maturity. Let $r(s)$ denote the instantaneous riskless rate prevailing at date s. We can represent the value of any security as the discounted expectation of its payoffs under the risk-neutral measure:

$$V_\tau = E^*_\tau \left\{ \int_\tau^T c e^{-\int_\tau^s r(v)dv} ds + 1 e^{-\int_\tau^T r(v)dv} \right\}, \tag{1}$$

where $E^*_\tau(\cdot)$ denotes the risk-neutral expectation conditional on information available at date τ.

[7] See, for example, Cornaggia, Cornaggia and Hund (2014) and Cornaggia, Cornaggia and Isrealsen (2014), which explore the misalignment of ratings across municipal and corporate bonds.

Consider two alternatives:

1. Wait until the call date and then decide whether to call and refund the bonds.

2. Advance refund the bonds at the current date, t.

The payoffs up to the call date are the same in either case. If it waits to call, the issuer pays the coupon until the call date. If the issuer pre-refunds the bonds, the old debt is defeased, but new debt must be issued to fund the trust making the payments up to the call date. The issuer's liability at the call under the first alternative is $\min\{K, V_\tau\}$. Under the second alternative, the advance refunding, the issuer must pay K unconditionally. The difference between the two alternatives is then

$$K - \min\{K, V_\tau\} = \max\{K - V_\tau, 0\}. \tag{2}$$

This is the payoff on a put option on the bond. The present value of this put is the option value transferred from the issuer to the bondholders by the advance refunding. Thus, the value of the issuer's liability today if the bond is not pre-refunded, L_t, is

$$L_t = E_t^* \left\{ \int_t^\tau c e^{-\int_t^s r(v)dv} ds + \min\{K, V_\tau\} e^{-\int_t^\tau r(v)dv} \right\}. \tag{3}$$

The issuer's liability under a pre-refunding, $\hat{L}_t$, is:

$$\hat{L}_t = E_t^* \left\{ \int_t^\tau c e^{-\int_t^s r(v)dv} ds + K e^{-\int_t^\tau r(v)dv} \right\}. \tag{4}$$

The difference between these, $\hat{L}_t - L_t$, is the value that is destroyed for the issuer by the advance refunding. Evidently,

$$\hat{L}_t - L_t = E_t^* \left\{ \max\{K - V_\tau, 0\} e^{-\int_t^\tau r(v)dv} \right\}, \tag{5}$$

which is the the value of a put option on the coupon bond exercisable on the call date.

Note that we treat the call option as a European option here. This gives a conservative estimate of the cost of early exercise. If the call is American, as most are, this increases the set of circumstances under which calling as soon as the call protection expires would be suboptimal, and thus increases the value destroyed for the issuer by precommitting to do so. Industry participants sometimes argue that pre-refunding is like any other exercise of an American option, in that time value is lost.[8] This is misleading, however. A pre-refunding is minifestly different than exercising an American call in a current refunding because the interest payments on the original debt still have to be paid.

2.3 A Subsidized Hedge?

Industry professionals frequently argue that, as a practical matter, it is expensive or impossible to hedge against increases in an issuer's future borrowing costs using existing instruments. While we would concede that this may be the case if one's goal were to exactly replicate the hedge implicit in the pre-refunding, it is not difficult or expensive to hedge a general rise in interest rates, the source of most of the risk for a typical municipality. To illustrate, we ran a linear regression of the 20-year Bond Buyer municipal yield series against three variables using monthly data from January 1996 to December 2012: the 20-year Treasury yield, the 20-year maturity spread over the one-year rate, and a corporate credit spread (BAA less 20-year Treasury). The resulting adjusted r-squared is 87.9%.[9] Thus, for municipal rates in general, most of the variation is due to variables that are trivial to hedge using widely traded instruments.

Some practitioners go on to argue, however, that the hedge implicit in the advance refunding is "subsidized." If we consider the issuers, financial intermediaries, and bondholders

[8] See, for example, Kalotay (2013), a critique of an earlier version of this paper.

[9] All data are from Boomberg or the St. Louis Fed. The same regression using the Bond Buyer 11-year yield series, with 10-year Treasury rates and maturity spread yields an r-squared of 89.2%.

as a group, there is one remaining possible source of surplus for them—the Treasury, which issues the SLGS. The SLGS are zero-coupon bonds that are created by the Treasury to exactly match the remaining payments on the bonds being defeased. The yield on the assets in the escrow is capped by the yield on the new, long-term bonds that are issued to fund the trust, unless current short-term Treasury rates are below that level. Estimates of the Treasury's cost of borrowing at different maturities are published on its web site on a daily basis. The intent of the capping the return on the assets in the trust with issuer's cost of new borrowing is to rule out the obvious tax arbitrage of issuing tax-exempt debt to purchase (higher yielding) taxable securities. When the issuer's borrowing cost determines the cap, the SLGS give the Treasury the opportunity to issue debt at rates below current (taxable) Treasury rates, implicitly allowing it to share in the benfits of tax-exempt financing for municipal entities. The intent of capping the yield with the Treasury's borrowing cost is to ensure this benefit is positive.

Note, however, that the assets in the trust are short maturity, while the debt being issued to fund it is long maturity. Industry professionals point to this as a rational motive for advance refundings. The transaction hedges the issuer's borrowing rate from the call date to maturity. The issuer is borrowing long term, and lending short term (the latter by purchasing SLGS in the escrow). The SLGS may pay higher rates than short-term municipal rates. Accordingly, the forward interest rate implicitly obtained through the pre-refunding is more attractive than the rate that could be achieved if the issuer had to hedge directly by borrowing long term and lending short term at the rates embedded in the municipal term structure.

In effect, the issuer faces different short-term borrowing and lending rates, and as in other such cases this creates some ambiguity regarding what the opportunity cost of the transaction actually is. The municipality is only "lending" to fund the repayment of its own securities, and if it did not borrow long term to do this, there would not be any point to the transaction. Is the "cost" of funding the trust the rate on the long-term bond? Or, is it the short-term municipal rate? Crediting the advance refunding with the subsidy due to the difference between the yield on the trust and the short-term municipal rates effectively treats the short-term municipal rates as the cost of funds for the trust. The advance refunding would indeed be a good deal if issuers could borrow at the (low) short-term muni rates and lend at the SLGS rates. But they cannot do that.[10] If they attempted to, the cap would be the short-term rate. On the other hand, it is certainly the case that if the issuer attempted to exactly replicate the hedge associated with the advance refunding by borrowing at long municipal rates and lending at short municipal rates, the terms would be less favorable than those implicit in the advance refunding.

A normative question for an issuer anxious to hedge future borrowing costs is a quantitative one. Is the subsidy for the implicit hedge sufficient to offset the value lost on other dimensions? We address this question quantitatively in Section 5.4, and estimate the subsidy to the hedge for each bond in our sample. We show that the size of the implicit subsidy is, indeed, correlated with the option value lost. For the moment, however, we note that since the financial crisis in 2008 Treasury rates have generally been so low that this subsidy to the hedge cannot provide a motive for advance refundings. As can be seen in Figure 2, Treasury rates have been below both short-term and long-term municipal rates, a situation referred to by practitioners as "negative arbitrage." Nevertheless, as the figure also shows in the upper panel, the volume of advance refundings has continued to be significant.

The broader policy question is why the Treasury would wish to subsidize advance refundings, and why financial markets are so incomplete in this sector that something as straightforward as hedging future borrowing costs should be inextricably bound up with the need to surrender option value and with borrowing for current cash needs. If the Treasury does not wish to subsidize these transactions, they can simply set the yields on the SLGS

[10]Section 148(f) of the Internal Revenue Code places limits on "arbitrage" issues.

to reflect short-term rather than long-term municipal rates. If the Treasury does wish to subsidize municipalities in this non-transparent way, it is counter-productive to force them to precommit to call. Nevertheless, attempts to decouple the option from the advance refunding are explicitly disallowed by the IRS. For the defeasance to be effective, the issuer is not permitted to have any contingent control over the trust or the payments on the bonds. Finally, if hedging by municipalities is a good thing, and their citizens benefit from reducing the risk associated with future borrowing, why not encourage the introduction and marketing of simple, transparent, sensibly regulated derivative or insurance instruments that would protect them from a general rise in rates? It seems ironic that the usefulness of advance refundings to hedge interest rate risk is directly related to the value destruction through precommitment to call. In situations where the option is deep in the money and there is a short time to call, little option value is destroyed, but there is also not much interest rate risk to hedge!

2.4 A Case Study

Consideration of a specific example may provide some sense of the political context in which advance refundings are carried out. In the spring of 2005 the city of Pittsburgh, Pennsylvania, faced some very difficult choices. The city's debt had accumulated to $821 million in gross bonded debt, representing $2,456 owed for every person living in the city. Debt service amounted to a quarter of spending by the city.[11] A state board had been appointed under Pennsylvania state law to oversee the city's finances. The administration of Mayor Tom Murphy, in a desperate effort to balance the 2004 budget, had accelerated revenues and deferred expenses. Revenue shortfalls relative to that budget were $7 million, and expenses exceeded the budget by $13 million, depleting the city's cash reserves. By early 2005, the city

[11] *Pittsburgh Post-Gazette* "City's Debt Looms: Large Principal and Interest Now 25% of Spending," April 30, 2005.

council found itself with no funds available for continuing maintenance on the city streets, and the mayor had previously pledged not to increase the city's debt any further.

At this point, the city council debated two proposals aimed at generating funds for road maintenance.[12] Murphy's proposal involved advance refunding approximately $200 million of city bonds that had been issued in 1995 and 1997. The 1995 bonds would otherwise have been callable in September of 2005, or in roughly four months. The 1997 series would otherwise have been callable in August of 2007. The transaction would, after $2.4 million in fees, contribute $6 million in funds over the next year for street resurfacing and "fixing pot holes." The alternative, offered by the chairman of the Council's Finance Committee, Doug Shields, was to borrow $5 million from a regional development authority for one year, with interest and fees of $164,000. The fees for the advance refunding included approximately $1.86 million for bond insurance, $1 million to the underwriters, Lehman Brothers and National City, and $370,000 for the bond counsel and underwriter's attorneys.

After two hours of debate, the city council voted 6 to 2 for the advance refunding. Proponents of the mayor's plan argued it did not require the city to increase its debt. Councilman Sala Udin declared, "The $6 million is free money. I think it would be a mistake to leave $6 million on the table." Afterwards, the mayor's spokesman explained, "The mayor made a commitment that he would not increase the city's debt this year, and the Shields plan obviously would have done that."

3 Data Sources and Descriptive Statistics

We draw data from several sources.

[12]Details and quotations from *Pittsburgh Post-Gazette* "Council OKs Bond Refinancing Plan Will Fund Paving, Other Work," April 7, 2005.

3.1 Municipal Bond Transactions

We obtain transaction data for municipal bonds from the Municipal Securities Rule Making Board (MSRB). This database includes every trade made through registered broker-dealers, and identifies each trade as a purchase from a customer, a sale to a customer, or an interdealer trade. We augment this with data from Bloomberg that includes information about the refunding status of the bonds.

Over our sample period from January 1995 to December 2013, the MSRB database contains 138,571,970 individual transactions involving 3,071,610 unique municipal securities, which are identified through a CUSIP number. The MSRB database contains only the coupon, dated date of issue, and maturity date of each security. We obtain other issue characteristics for all the municipal bonds traded in the sample from Bloomberg. Specifically, we collect information on the bond type (callable, putable, sinkable, etc.); the coupon type (floating, fixed, or OID); the issue price and yield; the tax status (federal and/or state tax-exempt, or subject to the Alternative Minimum Tax (AMT); the size of the original issue; the S&P rating; whether the bond is insured; and information related to advance refunded municipal bonds. The information on advance refunded municipal bonds includes an indicator for whether the bond is a pre-refunded bond, the pre-refunded date, the pre-refunded price, and the escrow security type.

We wish to price the options on coupon bonds, which are the primary source of the value lost through pre-refunding, and also to evaluate the present values of interest savings to the call date, which represents the amount of borrowing implicit in the refunding. For these purposes we require information on the term structure for tax-exempt bonds. We follow Ang, Bhansali and Xing (2010) and use zero-coupon rates inferred from transactions prices on municipal bonds in the MSRB database. These zero-coupon yield curves are constructed using the Nelson and Siegel (1987) method, fit each day in the sample period to interdealer prices on highly rated bonds. Details are provided in the internet appendix to Ang, Bhansali and Xing (2010).

To estimate the implicit "subsidy" associated with the hedge embedded in pre-refunding, we need to compute the cap on the yield of assets in escrow that fund remaining payments on the bonds. This requires the SLGS rate caps, which are posted on the Treasury's web site on a daily basis for maturities up to thirty years. We obtained the full history of these rates through a request under the Freedom of Information Act.

3.2 Advance Refunding Sample

Pre-refunded municipal bonds are collateralized by some of the safest securities available. The most common types of collateral used are: U.S. Treasury Securities; State and Local Government Securities (SLGS); U.S. Agency Securities: FNMA, FHLMC, TVA, HUD and FHA ; Aaa/AAA rated Guaranteed Investment Contracts (GICS). Among them, SLGS are a form of U.S. Treasuries created explicitly for municipalities to use for debt refinancing purpose.

Among the 3,071,610 unique cusips, 362,196 are identified by Bloomberg as pre-refunded bonds with a total par value of $1.144 trillion. We apply the following data filters. We focus on pre-refunded bonds that are exempt from federal and within-state income taxes and are not subject to the AMT. This reduces our sample to 343,271 bonds. We include only pre-refunded bonds with the following escrow security type: U.S. Treasury Securities; SLGS; and cash. This reduces our sample to 332,159. We also limit our bond universe to bonds issued in one of the 50 states, and so we exclude bonds issued in Puerto Rico, the Virgin Islands, other territories of the U.S. such as American Samoa, the Canal Zone, and Guam. After this filter, we have 332,095 bonds. We require bonds to have non-missing information on when they became pre-refunded and this left us 245,632 bonds. And finally, we require all bonds to have a non-missing fixed, semi-annual coupon, non-missing information on the call date, call price, a valid CUSIP and time when they became prerefunded falling between

Jan 1995 and Dec 2013. We delete some obvious data errors, leaving us with 234,714 bonds with a par value of $669.061 billion.

Bloomberg identifies as advance refunded many cusips (31,507) that were refunded with fewer than 90 days to the call date, despite the fact that the IRS treats such transactions as "current" rather than "advance" refundings.[13] Issuers and their intermediaries may well issue new bonds before, but close to, the call date simply as a matter of convenience or for market timing reasons. While the funds to pay off the old bonds are placed in escrow and there is a pre-commitment to call, the "no-arbitrage" restrictions on the investment of the funds in escrow for advance refundings do not apply to these current refundings. Nevertheless, some (typically very small) amount of option value might be surrendered in these cases. For most purposes, we exclude these bonds from our analysis, while noting in footnotes where appropriate the quantitative effects of including them.

Our final sample of 203,207 bonds represents 56.10% of the CUSIPs and 50.64% of total aggregate par amount of the full set of pre-refunded bonds that traded during the sample period. Thus, our estimates of the aggregate impact of pre-refunding transactions are clearly conservative. The bonds that trade during the sample period, and therefore appear in MSRB database, are a subset of the bond universe. Of these, over half have sufficient information to compute the lost option value and are also categorized by the IRS as advance refunded. If our sample is representative, then our estimates of aggregate impacts of advance refundings could be increased by a half to a whole to approximate the aggregate losses to issuers and their tax payers.

Municipal bonds are typically issued in "series." In a single underwriting bonds of a wide range of maturities are issued, and the longer maturities often have the same call protection, typically ten years. Advance refundings, then, typically involve multiple cusips from the

[13]The 90-day criteria for advance refundings is described in detail in IRS training materials available at `www.irs.gov/Tax-Exempt-Bonds/Tax-Exempt-Bonds-Training-Materials`. See, in particular, p. C-24.

same original series. We refer to bonds from the same issuer that were advance refunded on the same date as a "deal," and we have data on 22,683 such deals.

Table 2 compares the bonds for which we have data that we excluded from our sample due to missing data (Panel A) to to those for which we have complete data (Panel B). The excluded CUSIPs have slightly larger par value outstanding. For both the included and excluded bonds, the mean par value exceeds the upper quartile, reflecting the extreme skewness in the size of the bond issues in the municipal market. The excluded bonds also have slightly shorter maturities and higher coupons. Given the general secular decline in interest rates through this period, this suggests the bonds with incomplete data (primarily, the pre-refunding date) tend to be older bonds that were issued at earlier points in time. That is, the missing data fields are a problem primarily in the early years of the sample period. Panel C then reports the same statistics for the bonds with more than 90 days between the refunding and the call date. That is, it excludes the current refundings. This has little qualitative or quantitative effect other than the obvious one of slightly increasing the average time to call. Finally, Panel D reports descriptive statistics where the units of observations are deals rather than individual cusips.

The average CUSIP that is advance refunded involves a bit under $3 million in par value, though the lower median suggests skewness in the size of pre-refundings. The smallest CUSIPs that were pre-refunded were issued by small health care facilities and school districts. The largest pre-refundings involved New Jersey Tobacco Settlement Bonds, the Los Angeles Unified School District, Long Island Power, and the Tri-Borough Bridge and Tunnel Authority. All of these were pre-refunded 2-5 years before they became callable.

The distribution of the time to call is of particular importance in evaluating the financial implications of the advance refundings. If the only bonds being pre-refunded are bonds that are about to be called in any case, not much option value is being lost. Table 2 reports that the average time to call for our final sample is is 2.6 years.[14] There is, however, considerable dispersion in the time to call. About 23 thousand of the 203,207 advance refunded CUSIPs have less than six months to call, and the short maturity suggests that the option value lost in the refunding decision may be small in these cases. On the other hand, there is a substantial number (30 thousand) of the bonds with five or more years to call, and small numbers (164) with ten or more years to call.

Figure 2 shows the number of advance refundings in our sample by month, along with three interest rate series: the one-year Treasury rate, the one-year BondBuyer average yield, and the eleven-year BondBuyer municipal average yield. The volume of pre-refunding activity rises as interest rates fall, though evidently with something of a lag. Activity peaked in 2005, and slowed when municipal credit spreads rose in response to the credit crisis of 2007-2008 and the collapse of the major bond insurance firms, which played a major role in municipal markets. Over the most recent period, municipal credit spreads have fallen and long-term interest rates have achieved historic lows. This has led to a revival of advance refunding activity.

4 Valuing the Advance Refunding Option

The value lost to issuers from the pre-refunding decision is the value of a put option exercisable at the call price of the original bond with a maturity equal to the call date of the original bond. We compute a value for the put for each pre-refunded bond in the sample. The single-factor Vasicek (1977) model provides a particularly simple means of doing this, although it has well-known limitations. In the Vasicek setting, the value of an option on pure-discount bond can be expressed in closed form. A more flexible one-factor model is the

[14]This row is missing for the excluded bonds since the lack of the required dates to determine time to call is typically the reason for exclusion.

Hull and White (1990) model which allows a deterministic time-varying central tendency.[15]

Using both the Vasicek model or the Hull and White model, the method of Jamshidian (1989) can then be used to price options on coupon bonds. Since a coupon bond can be viewed as a portfolio of pure-discount bonds, and since the prices of all zero-coupon bonds are monotonic in the the short-term rate for a single-factor model, the value of an option on a coupon bond can be expressed as a portfolio of options on the zero-coupon components, each with an appropriately chosen exercise price.

We assume that the underlying call option on the bond is a European option, and that the decision to pre-refund is made at a single point in time. In both cases, these assumptions would lead our estimates of the lost option value to be conservative.

4.1 Single-Factor Term Structure Models

The Vasicek (1977) model postulates that the short interest rate, $r(t)$, is Gaussian and mean-reverting under the physical measure:

$$dr(t) = \kappa(\theta - r(t))dt + \sigma dW(t), \tag{6}$$

where $W(t)$ is a Brownian motion. We assume that under the risk-neutral measure, the short rate follows:

$$dr(t) = \kappa(\bar{\theta}(t) - r(t))dt + \sigma dW^*(t), \tag{7}$$

where

$$\bar{\theta}(t) = \theta - \frac{\sigma\lambda(t)}{\kappa}.$$

[15]Since municipal yield curves have, to date, always sloped upwards, we expect that our option values using a two-factor model will be very similar since our one-factor models already incorporate time-varying prices of risk. The great advantage of the single-factor model is that it allows us to compute option values for coupon bonds directly.

We further assume that the market price of risk is linear in the short rate:

$$\lambda(t) = \lambda_0 + \lambda_1 r(t). \tag{8}$$

Substituting the last two expressions into (7), the dynamics under the risk-neutral measure can be written as:

$$\begin{aligned} dr(t) &= (\kappa + \sigma\lambda_1)\left[\left(\frac{\kappa\theta - \sigma\lambda_0}{\kappa + \sigma\lambda_1}\right) - r(t)\right] dt + \sigma dW^*(t) \\ dr(t) &= \kappa^*(\theta^* - r(t))dt + \sigma dW^*(t), \end{aligned} \tag{9}$$

where

$$\kappa^* = \kappa + \sigma\lambda_1$$

and

$$\theta^* = \frac{\kappa\theta - \sigma\lambda_0}{\kappa + \sigma\lambda_1}$$

are both constants.

These parameters can then be used in the standard expressions for bond yields under the Vasicek model, in terms of the parameters under the risk-neutral dynamics. The yield on a bond maturing in τ periods, $z[r(t), \tau]$, can then be written as an affine function of the short rate:

$$z[r(t), \tau] = -\frac{A(t, \tau)}{\tau} + \frac{B(\tau)}{\tau} r(t), \tag{10}$$

where

$$\begin{aligned} B(\tau) &= \frac{1}{\kappa^*}(1 - e^{-\kappa^*\tau}), \\ A(t, \tau) &= \frac{\gamma(B(\tau) - \tau)}{(\kappa^*)^2} - \frac{\sigma^2 B(\tau)^2}{4\kappa^*}, \\ \gamma &= (\kappa^*)^2\theta^* - \frac{\sigma^2}{2}. \end{aligned}$$

We use daily fitted zero-coupon yields to calibrate the parameters of the model, sampled at 15-day intervals. The fitted rates rely on data that do not include extremely short-term instruments, so we use the three-month rate as the short-term rate. The parameters σ, κ, and θ, which parameterize the short rate under the physical measure, and can be matched to time series moments of the short rates. We set σ to match the volatility of the short-term rate:

$$\hat{\sigma}^2 = \sum_{i=0}^{N-1} \frac{[r(t_{i+1}) - r(t_i)]^2}{N\Delta t}, \tag{11}$$

and calibrate κ using the first-order autocorrelation of the short rate ρ_r,

$$\hat{\kappa} = (1 - \rho_r)/\Delta t. \tag{12}$$

Finally, θ can be set to the average level of the short rate.

We use the average yield spreads and differences in volatility to calibrate the market price of risk, the parameters λ_0 and λ_1. We use the ten-year yield. Since the linear specification for the market price of risk preserves the linearity of yields in the short rate, given the other parameters, we can write

$$z[r(t), \tau] = f_0(\tau, \lambda_0, \lambda_1) + f_1(\tau, \lambda_1) r(t),$$

and we can solve for λ_1 to match the differences in variance:

$$\mathrm{Var}(z[r(t), \tau]) = f_1(\lambda_1)^2 \mathrm{Var}[r(t)], \tag{13}$$

and then solve for λ_0 from the average spread:

$$E(z[r(t), \tau]) = f_0(\tau, \lambda_0, \lambda_1) + f_1(\tau, \lambda_1) E[r(t)], \tag{14}$$

using the sample analogues to compute estimates.

We calibrate the parameters $\Theta = (\kappa, \theta, \sigma, \lambda_0, \lambda_1)$ using the whole sample period, 1995-2013. Table 3 reports the parameter values we calibrated in this manner, along with alternative values based on subperiods. The long-run mean, θ, is quite sensitive to the sample period employed, since our sample was a period of gradually declining interest rates. (See the third panel of Figure 2.) The estimates of the option values we obtain are, in turn, fairly sensitive to the value of θ we choose. This is not surprising. If current rates, and expectations about future rates, are low relative to the historical average over the sample period, our estimates of the put option values will be misleading, although the direction of the effect may depend on the strength of the mean-reversion parameter.

Accordingly, we also use the Hull and White (1990) model, which has a time-varying long-term mean parameter:

$$dr(t) = \kappa(\theta(t) - r(t))dt + \sigma dW(t), \tag{15}$$

which is similar to equation (6), except the central tendency parameter, $\theta(t)$, is now a deterministic function of time. Bond yields can still be written as an affine function of the short rate as in equation (10), except $A(t, \tau)$ now satisfies

$$A(t, \tau) = -\int_t^\tau \kappa B(t)\theta(t)dt + \frac{\sigma^2}{2\kappa^2}\left(\tau + \frac{1 - e^{-2\kappa\tau}}{2\kappa} - 2B(t)\right).$$

In the Hull and White (1990) model, we estimate σ and κ by matching the three-month volatility and standard deviation (see equations (11) and (12)). Note that given κ and σ, we only need to know $\theta(t)$ in order to get bond price. The time-varying central tendency parameter, $\theta(t)$ is calibrated assuming that today is time 0 and we choose the path of θ_t to match the current term structure. Thus, $\theta(t)$ represents a vector of values corresponding to each maturity, which changes over time. We assume the mean-reversion target is piecewise linear and changes once per year. We iteratively calibrate $\theta(1)$, $\theta(2)$ up to $\theta(30)$. In particular, we first match the one-year zero-coupon bond market price with model implied zero coupon bond price to get $\theta(1)$. Given $\theta(1)$, we then match the two year zero-coupon bond market price with model implied price to get $\theta(2)$ and so on. We continute this procedure until we match the 30-year zero coupon bond market price with the model-implied price to get $\theta(30)$.

4.2 Option Valuation

In a one-factor term structure model, options on zero-coupon bonds have known closed-form solutions. Define $P[r(t),\tau]$ as the price of a zero-coupon bond with maturity τ, $P[r(t),\tau] = A(t,\tau) - B(\tau)r(t)$. The price of a European put option on $P[r(t),\tau]$ with maturity T and strike price K is given by

$$\text{Put}[r(t),T,K] = KP[r(t),\tau]N(-h+\sigma_P) - P[r(t),\tau]N(-h), \tag{16}$$

where

$$\begin{aligned} \sigma_P &= \frac{\sigma}{\kappa}[1-\exp(-\kappa(\tau-T))]\sqrt{\frac{1-e^{-2\kappa T}}{2\kappa}}, \\ h &= \frac{1}{\sigma_P}\ln\frac{P[r(t),\tau]}{KP[r(t),T]} + \frac{1}{2}\sigma_P, \end{aligned}$$

and $N(\cdot)$ is the cumulative normal distribution.

An option on a coupon bond, however, can be viewed as an option on a portfolio of zero-coupon bonds. Suppose there are N payments remaining after the exercise date for the option, and these occur at times (measured from the current date), $\tau_i, i = 1,\ldots,N$. Then we can write the value of the coupon bond, $V[r(t)]$, as a function of the short rate:

$$V[r(t)] = \sum_{i=1}^{N-1} C \cdot P[r(t), \tau_i] + [100 + C]P[r(t), \tau_N]. \tag{17}$$

Jamshidian (1989) takes advantage of the fact that each zero-coupon bond, $P[r(t), \tau_i]$, is monotonic in the short rate under the Vasicek (or any other single-factor) model to derive the value of an option on a coupon bond. We can define a critical interest rate, r^*, such that $V[r^*] = K$: the value of the coupon bond equals the stike price. Now define $K_i \equiv P(r^*, \tau_i)$. We know by monotonicity that $V[r(t)] > K$ if and only if $P(r^*, \tau_i) > K_i$, for all i. Thus, we can treat the option on the coupon bond as a portfolio of options on the zeroes, each with an appropriately chosen exercise price. It is a simple matter to find r^* iteratively. It can then be used to find K_i for each coupon maturity, τ_i. The value of each option on each zero can then be computed using the close-form solution in equation (16), and the value of the option on the coupon bond is the sum of these options on the zeroes times the payments at those dates.

5 Losses from Advance Refunding

The option value lost to the issuer in an advance refunding is the value of a put option on the coupon bond expiring on the call date. We compute the option value lost for each of the 203,207 separate advance refunded CUSIPS for which we have sufficient data during our sample period over 1995-2013 using the Vasicek (1977) model with time-varying prices of risk and the Hull and White (1993) model.[16]

[16]Since some option value is lost for with any pre-commitment to exercise, where appropriate we report in footnotes the lost option value associated with the 31,507 current refundings in our sample as well and provide tabulated results in the appendix.

5.1 Value of the Put Option

Table 4 summarizes the distribution of the put option values: the value lost per $100 face value and the total value lost for each CUSIP and deal. As we can see from the large differences between the means and medians, the distributions of the value lost are extremely skewed for both CUSIPs and deals. The majority of advance refundings are relatively innocuous in terms of the option value surrendered. These are cases where the call option is deep in the money or the bond is relatively close to the call date. Using the Vasicek (1977) model, the average advance refunding deal costs 85 cents in option value per $100 of par value, representing a loss of $35,556 per CUSIP refunded. The mean loss per deal is $547,287. Because of the large skewness, the median losses are much lower: 42 cents per $100 of par value, $2,627 per bond, and $116,968 per deal. The estimates for the Hull-White model, in Panel B, are similar in terms of means but display even more skewness.[17]

There are, however, some extremely large and very bad deals. On July 7, 2005, the Triborough Bridge and Tunnel Authority advance refunded five bonds in our sample. One of these was the largest pre-refunded bond in our sample by par value, $584,155,000. Our Hull-White estimates (the more conservative in this case) suggest refunding this bond cost more option value than any other bond in our sample, with a loss of $28.183 million. The other bonds pre-refunded in the deal involved $5.0 million, $2.9 million, $0.5 million and $0.2 in option value destroyed. At the end of March 2007, the state of California advance refunded 136 different CUSIPs. Only eleven of these had less than a year to call. The total par value of these bonds was $3.920 billion, and we estimate the lost option value to California to be $122 million (again, using the Hull-White model).

Table 5, Panel A reports our estimates of the total option value lost in the advance refundings in our sample. In total, the option value surrendered is approximately 1.25%

[17] Table A-2 in the appendix reports results including current refundings in the dataset. This lowers slightly the average put values.

(Vasicek) or 1.59% (Hull-White) of the par value of the bonds that are pre-refunded. Since there are a great many bonds, however, the losses total over $7 billion for the Vasicek (1977) model and over $9 billion using the Hull and White (1990) model.

Most of the value lost is due to a small fraction of the transactions. The pre-refundings that generate losses in excess of the 95th percentile account for almost $5.1 billion of the $7.2 billion in estimated losses for the Vasicek model, while the skewness is even more extreme for the Hull-White estimates. The most value destructive deals tend to be CUSIPs with large par value outstanding, which are issued by large public entities. The correlation between issue size and total option value lost is 0.69 and the correlation between total value lost and years to call is 0.17. The distribution of option value lost, however, is more skewed than that of issue size. The largest 5% of CUSIPs account for 49.4% of total par value in our sample.[18]

There are some smaller pre-refundings that destroy large fractions of the par value refunded. Indeed, some of the refundings that have high put option values per $100 face value would be poor candidates even for a current refunding. For example, on December 14, 2006, the New Jersey State Education Facility advance refunded two bonds that had originally been issued at par value with coupons of 3.875%. The bonds would have matured in 2028. Our estimate of the zero-coupon municipal interest rates for all maturities beyond 10 years on that date exceed 4%. The bonds were advance refunded along with a large number of other maturities that had been originally issued in the same offering. Apparently, the issuer chose to pre-refund the whole series, rather than to selectively pick and choose, despite the fact that new bonds were being issued at higher rates than some of the bonds being defeased. In some cases, this may be motivated by bond indentures that apply to the entire series, and these indenture restrictions can only be lifted by defeasing all the bonds.

Of course, because interest rates fell over the sample period, realized ex-poste losses were

[18]Table A-3 in the appendix shows that including the current refundings in the sample slightly increases the aggregate value lost, but has little effect on the qualitative features of these aggregates.

substantially less than the option value surrendered through pre-refundings. Municipalities got lucky.

5.2 Estimate of Fees

The fees associated with advance refundings are numerous: there are fees paid to underwriters, rating agencies, lawyers, municipal debt advisors, swap advisors in cases where derivatives are used in the financing arrangements associated with the refunding deal, and other miscellaneous fees. Furthermore, the vast majority of advance refundings are sold via negotiated sale (see Wood, 2008). Robbins (2002) and McCaskill (2005) estimate the cost of nontendered offerings are 20-35 basis points higher than competitive auctions. The cost of advance refundings is unknown, especially when derivatives are used as part of the refunding issue. Nevertheless, estimates of fees paid range from 0.375% in Kalotay, Yang and Fabozzi (2007) to 3-10% by the GFOA. The GFOA states fees of 0.5% to 1.0% for issuance fees, 0.5% to 1.0% for the underwriter's discount, 2.0% to 3.0% for the redemption premium, 0.5% to 1.0% for bond insurance, and 1.0% to 3.0% associated with the negative carry in the trust created to defease the refunded issue.[19]

Table 6 gives estimates the fees paid with advance refundings. We use a range of values from 0.375% to 5% as a fraction of the value of the bond being refunded. In general, we do not observe the actual market value of the callable bond at the time of the pre-refunding deal. This value, which will generally be at a premium over par, will determine the size of the trust required to fund the remaining payments. To estimate it, we value a straight bond with the same coupon rate and same maturity as the refunded bond. This approximation will overestimate the callable bond value because the callable bonds should have a lower price than the comparable straight bond. Under the lowest fee assumption of 0.375%, the total fees paid amount to $2.352 billion. The total fees paid exceed $6 billion dollars with an

[19]Numbers are from "Analysis of a Refunding," Government Finance Officers Association, 2007.

assumed 1% fee structure. With a 2% fee, the total fee paid is over $12 billion, representing 2.17% of total par value. Thus the “de-fees-ance” fees are as much, and probably larger, than the total option value lost of $7-$9 billion.

We note that the fees paid in an advance refunding cannot all be viewed as incremental to the transaction. If the bond is not advance refunded, it is likely that in most cases the call option would be in the money eventually, and the bond refunded at that point. Only in those cases where the original bond issue would be allowed to mature would the fees be avoided completely. Thus, the estimates above should be viewed as costs that could either be avoided or deferred by choosing not to advance refund.

5.3 Implicit Borrowing

Along with destroying part of the value of the issuer’s call option, advance refunding immediately reduces interest expense to the issuer at the expense of expected higher interest payments after the call date. In effect, the issuer is borrowing against anticipated future interest savings. In this section, we attempt to measure this implicit borrowing.

As with the option value destroyed, the amount of borrowing implicit in an advance refunding increases with the time to call. Unlike the lost option value, however, the amount of implicit borrowing increases the more interest rates have dropped since the bonds were issued. In these situations, because the chances the call will expire out of the money are low, the lost option value is small even though the amount of implicit borrowing may be significant.

The example in Section 2.1 illustrates that the amount of borrowing against expected future interest savings is the present value of the difference, up to the call date, between the coupon on the old debt and the coupon payments on the new debt issued to fund the trust. The latter reflects both the lower interest rates on a new par issue and the higher par value amount required to fund the trust for the remaining payments up to call. Assuming interest rates have fallen since the original issue date, the old debt will be at a premium, so the value of the trust exceeds the par amount of the issue.

Given information about the municipal term structure on the date of the advance refunding, calculating the amount of implicit borrowing for a given CUSIP or deal would be straightforward if we could observe the amount put in trust and the coupon rates on the newly issued debt. For a given CUSIP, this information is available in the official statements (analogous to a prospectus for municipals) associated with the new debt. Formats are not standardized, however, and the new debt issue may involve purposes in addition to the advance refunding. There may also be derivatives associated with the advance refunding, which may not be reported in the official statements. In any case, the official statements are available, at best, only as pdf documents online through the EMMA system of the MSRB and have been disseminated only recently.[20] Our large sample of over 200 thousand bonds precludes gathering this data by hand.

Accordingly, we attempt to approximate the magnitudes involved using information from the term structure to estimate the coupon rates at which debt could be issued on the pre-refunding date. Using the fitted zero-coupon municipal yields, we first calculate the present value of coupon payments that remain until the call date, and of the call price. This we treat as the size of the trust and the par value of new debt that must be issued to fund it. Let F denote this funding requirement, per \$100 par value. Since typically interest rates will have fallen, we will generally have $F > 100$. The same fitted zero-coupon yields can be used to approximate the coupon on a new par bond with a maturity equal to that of the old bond. If d_t is the zero-coupon price for a zero that pays \$1 in t periods, and the original bond has

[20]Between May 2011 and September 2012, there were more than 21,000 new municipal issues. But there were only 62 pre-sale documents filed through EMMA. See "MSRB Wants Dealers to Post POS on EMMA Site," by Jonathan Hemmerdinger, *The Bond Buyer*, July 29, 2013.

T periods to maturity, then the coupon of a par bond solves:

$$100 = C^* \sum_{t=1}^{T} d_t + 100 d_T. \tag{18}$$

The per period reduction in interest cost is then $C - FC^*$, where C is the coupon on the bond being advance refunded. The present value of this difference, up to the call date, times the total par value outstanding of the pre-refunded issue, is our estimate of the present value of interest savings that are accelerated, or borrowed, through the transaction.

Table 7 reports summary information on the cross-sectional distribution of the implicit borrowing associated with advance refundings. It reports statistics for both individual CUSIPs and deals as the unit of observation. As in the case for lost option value, the distribution is extremely skewed; there are dramatic differences between means and medians for both deals and CUSIPs. The present value of accelerated interest deductions is only \$12,740 for the median CUSIP and \$116,968 for the median deal. The corresponding means are \$60,845 and \$546,255, respectively. Most of the implicit borrowing is associated with a small number of very large deals. In total, the advance refundings in our sample give issuers over \$12 billion worth of estimated accelerated interest savings. This represents 2.14% of the par value of pre-refunded bonds. Almost 60% of the total, however, comes from only 5% of the CUSIPs or deals.

The CUSIP that triggered the most implicit borrowing is a New Jersey Tobacco Settlement bond that was pre-refunded in January of 2007, one of 15 such CUSIPs in what is also the deal for which implicit borrowing was the largest. The deal involved \$3.289 billion in par value with an average time to call of over five years. This deal was also in the top ten in terms of estimated option value lost (\$33.6 million). As noted earlier, however, this need not be the case, because deals for which the call is deep in the money will involve a large amount of implicit borrowing, but relatively little destruction of option value. Indeed, while the correlation between implicit borrowing and option value lost is 10.2% at the deal level, it is slightly negative (-1.21%) when the unit of observation is the individual CUSIP.

5.4 Subsidy for the Hedge

For each advance refunded bond in our sample, we estimate the value of the subsidy to the hedge embedded in the advance refunding. Hedging future borrowing rates involves borrowing long term and lending short term. The lending side of the position is associated with the assets of the trust that funds payments on the refunded bond up to and including the call. Let $\{C_t\}_t^\tau$ represent these remaining payments, and let r_{mt} be the short-term municipal rate for maturity t at the date of the pre-refunding. We estimate the latter with a fitted zero-coupon yield curve, as noted in the previous section. The "subsidized" lending rates are the capped yields on the trust assets, denoted:

$$r_{st} = \min\{y_T, r_t^{SLGS}\}. \tag{19}$$

The first argument of the min function above is the yield on the new bonds issued to refund the issue, which will have the same maturity as the old bond. We do not observe this rate, but as described in the previous section we estimate it as the yield on a par bond calculated in equation 18 using the fitted zero curve to determine the discount factors. We obtained the SLGS rates on a daily basis through a Freedom of Information request from the Treasury.

The total subsidy to the hedge, then, can be calculated as the present value of remaining payments at the municipal rates less their present value using the subsidized rates.

$$\sum_{t=1}^{\tau} \frac{C_t}{(1+r_{mt})^t} - \sum_{t=1}^{\tau} \frac{C_t}{(1+r_{st})^t} \tag{20}$$

This is the present value saved by funding the trust at the higher rates.

Table 8 provides descriptive information about this quantity for the CUSIPs and deals in our sample. While the means are of an order of magnitude similar to the put option values, it is evident from the table that a substantial portion of the sample involves negative "subsidies." The mean of the subsidy minus the put option value, indeed, is significantly negative: -0.475 per 100 par, with a t-statistic of -116.3. Consideration of how the subsidy is evolving over time makes clear that the negative values are due to recent experience. Figure 3 plots mean values of the subsidy on a quarterly basis, along with 10th and 90th percentiles. While substantial, and positive, during the early periods, the mean and both deciles have been consistently negative since the financial crisis. Nevertheless, as noted in our earlier discussion of the subsidized hedge, advance refunding continues to be a popular transaction. This leads us to question whether the subsidy to the hedge is a motive for advance refunding of first-order importance.

5.5 Which Municipalities do the Worst Deals?

Table 9 provides some descriptive information on the municipalities destroying the most value in advance refundings. For the 22,634 deals in our sample, we sort the deals on the basis of amount of estimated option value destroyed and value destroyed per $100 par value, both using the Vasicek (1977) model, as well as par value of the deal and the estimated amount of implicit borrowing. Then, based on the name of the issuing entity, we categorize the 50 extreme deals by the type of issuer.[21] For the three criteria where size is obviously important (total par value, total put value, and implicit borrowing), states and transportation authorities dominate the distribution. Indeed, universities, water authorities, and development authorities that appear in these sets tend to be state-wide or state-affiliated. In contrast, the deals that are most destructive of value in percentage terms are primarily small and,

[21] The categorization is admittedly subjective, since the names are sometimes ambiguous and the categories overlapp. It is intended to give a general idea of the types of issuers, rather than a precise taxonomy.

presumably, relatively unsophisticated issuers. Here 30 of the worst 50 deals were done by school districts.

A full cross sectional analysis is difficult to perform given the limited data available on the individual issuers.[22] While information at the level of individual issuers is highly incomplete, we do have information about the states. This information is certainly relevant since state law, rather than the federal law, ultimately governs the behavior of municipal bond issuers. Standards of transparency and governance are therefore likely to be shared by issuers within a state.

Table 10 reports regression results using state and bond specific characteristics to explain the amount of option value lost. In the top panel, we focus on the put value per $100 face value as the independent variable, measured with the Vasicek (1977) model. The bottom panel reports results for the option value lost per CUSIP refunded. The regressions in the top panel capture factors that lead municipalities to do worse deals in percentage terms. A small school district, in this specification, gets the same weight as the State of California. The regressions in the bottom panel highlight factors that lead to large losses of option value in absolute terms, and so factors that encourage bigger deals will have more influence.

The independent variables include the bond's S&P rating, scored 10 for a AAA rating, to 3 for a D rating, 2 for not rated, and 1 for "other." We include several measures of state-wide economic and demographic characteristics: unemployment rate, nominal state GDP growth, population growth, median real income, and state population. Two other variables provide information about the quality and transparency of municipal and state governance within the state. The state government's debt per capita can be viewed as a measure of the quality of a state's fiscal governance. The variable "Convictions" is the number of public officials

[22] The only two studies empirically examining municipal refundings also use limited samples. Vijayakumar (1995) examines only 102 general obligation bonds called between 1977 and 1988. Moldogaziev and Luby (2012) examine only bonds refunded in California between 2000 and 2007. Both of these studies do not distinguish between current refundings and pre-refundings. They also do not take into account the option value lost by early refunding.

convicted divided by the state's population. This is available on an annual basis on the U.S. Department of Justice's web site. We report results using both annual and quarterly fixed effects.

We include two variables that capture the interest-rate environment. A long-term municipal bond rate, accounts for the fact, evident in Figure 2, that there are more refundings when interest rates fall. The variable "Subsidy" captures the size of the subsidy to the forward hedge provided by the spread between the return on the escrow that pays off the pre-refunded bonds, and and short-term municipal rates. This is calculated on a bond-by-bond basis as described in Section 5.4.

The interest rate variables are significant in all specifications. It is not surprising that municipalities are more anxious to refund their debt in low-rate environments, and therefore are willing to sacrifice more option value in either percentage or absolute terms. Practitioners point to the subsidized hedge in justifying the practice, and it appears that when this is large, it does encourage more value-destructive advance refundings.

Convictions of public officials is significant across both specifications for percentage losses, suggesting municipalities in states with governance problems are also more willing to sacrifice financial value to achieve other objectives. States in which public officials are irresponsible to the point of criminal culpability are also states where municipal officials will destroy more value in advance refundings, possibly to achieve short-term budget relief at the expense of higher interest payments in the future. This result is reminiscent of Butler, Fauver and Mortal's (2009) findings that states with more corruption have higher borrowing costs. This variable is insignificant when the dependent variable is option value losses per CUSIP. This is presumably because bigger states, which are doing the bigger deals, are less likely to have severe governance issues. Credit ratings are positively associated with the destruction of option value in all specifications. Perhaps, by facilitating access to financial markets at attractive rates, municipalities are encouraged to refinance even when it is suboptimal to do so from a financial standpoint.

State median income is associated with better deals in percentage terms. Wealthier states, it appears, have better financial management. These are also likely to be large states, so the effect disappears in the bottom panel, where the dependent variable is measured in absolute rather than percentage terms.

Figure 4 plots the estimated coefficients for the annual fixed effects (top panel) and quarterly fixed effects (bottom panel) from the regressions in the top panel of Table 10. Note that the regressions already include a long-term municipal bond rate and the subsidy variable, which should capture increases in refunding activities due to changing interest rates. Thus, the fixed effects capture increases in value-destructive pre-refundings through time that are not due to interest rate declines. All of the annual fixed effects, except for 1995, are significant at conventional levels. All of the quarterly fixed effects are highly significant after the first eleven quarters, except for 3-1999, and 1-2002 to 2-2002. The estimated fixed effects show clear patterns. Issuers were doing worse deals, controlling for interest rates, in periods associated with high liquidity, easy credit, and high volumes of financial activity generally. Perhaps it is easier to convince issuers to employ solutions involving financial engineering in periods when “Wall Street is booming” more generally.

6 Conclusions and Policy Implications

The widespread practice of advance refunding of municipal bonds is, at best, zero net present value, though wasteful of fees. If there is any chance that the bonds would otherwise not be called, or any risk of default, the transaction destroys present value for the issuer and its taxpayers. Advance refunding does allow the municipality to realize interest savings prior to the call date, at the expense of savings that would otherwise be realized afterwards. While this can relieve pressure on current operating budgets, it increases interest costs in the future and thus circumvents restrictions prohibiting municipalities from borrowing to fund operating activities.

Nevertheless, the practice is widespread. In our discussions with industry professionals and issuers a number of rationales for the practice are offered, which we have addressed implicitly or explicitly in the paper. We now briefly summarize these and speak to each directly:[23]

1. To realize interest savings.

   Our analysis has shown that there are no interest savings realized through advance refunding in the sense of present value. While the coupon payments associated with the refunded issue are lower than the original bond, the municipality is giving up higher expected payments after the call date along with the optionality of the call option. With no uncertainty, the advance refunding is zero net present value.

2. To restructure debt, typically to extend the payments of principal and interest.

   Advance refunding does enable a municipality to reduce interest expense immediately, but at the cost of increasing expected interest payments after the call date. Thus, advance refunding accelerates interest savings at the expense of future savings. Our estimates are that for the bonds in our sample, advance refundings implicitly gave issuers over $13 billion of borrowings that need to be paid back in the future. This additional debt bypasses restrictions aimed at keeping municipalities from borrowing to fund current operating expenses.

3. To monetize the call option today.

   The call option is certainly an asset of the municipality. Kalotay and May (1998) argue that the option is similar to an illiquid employee stock option, which the holder

[23]Items 1, 2, and 5 are from Wood (2008). Item 3 is from Kalotay and May (1998) and Brooks (1999). Item 4 is from Kalotay (2013).

may choose to exercise to extract some of its value, even though it is not extracting the full value. Some practitioners argue that call option can be exercised when the municipality wishes to "lock in" interest rate savings today. Both of these arguments are problematic. First, as detailed in Section 2.1, a swap that lowers payments today for higher payments after the call date can achieve the same cash flows more efficiently and transparently, while preserving the option on the original bond. Second, the option value incorporates the predictability of interest rates (and predictable deviations from the Expectations Hypothesis captured by time-varying prices of risk as shown by Dai and Singleton, 2002). Betting on future interest rate movements by advance refunding presupposes superior market foresight, and it seems questionable that municipal issuers, or their advisors, have a competitive advantage over other market participants in this regard.

4. Any exercise of an American call before expiration destroys some time value.

   This point is often advanced to argue that there is nothing special about the pre-committing to call in an advanced refunding. It is certainly the case that the call provisions on municipal bonds are generally American. Call protection typically lasts for ten years, and the bond can then be called any time after this up to maturity. It is therefore not always the case that it will be optimal to call as soon as call protection expires. This depends on the tradeoff between the interest savings achieved over the next period and the time value lost on the option. Committing to call through an advanced refunding is qualitatively different. While calling at the first call date may or may not be optimal, committing to call before that date cannot be optimal, because there are no real interest savings associated with doing so. The apparent interest savings before the call date are really the result of borrowing against expected savings after the call date. The old bonds remain in place, and interest on them must be paid.

5. To amend bond covenants.

   This is clearly one economically sensible argument rationale for the transaction. Any improvement in bond covenants that a municipality can negotiate in the refunding issue, however, should be carefully balanced against the costs that our analysis highlights.

6. The hedge against higher future interest rates in an advance refunding is "subsidized" due to the steeper slope of the municipal yield curve.

   This argument was discussed in detail in Section 2.4, where we estimate the present value of the subsidy for every bond in our sample. This subsidy has been negative for almost the entire sample period since the financial crisis, and yet tens of thousands of municipal bonds have been advance refunded, suggesting this is unlikely to be a primary motive.

Using a large sample of municipal bonds over 1995 to 2013 that have been advance refunded, we estimate both the option value destroyed and the amount of borrowing implicit in the transactions. In aggregate, advance refunding loses approximately 1% of the par value of the original bond, which represents at least $7 billion over the sample. The aggregate amount of implicit borrowing is over $13 billion. However, both the option value and the implicit borrowing quantities are highly skewed. For the majority of advance refundings, the option value lost is small. For the median CUSIP, the practice of advance refunding results in an option value lost of approximately 26 cents per $100 of par value. There are some deals which result in extremely large destruction of value. The option value lost in the top 5% of CUSIPS is over $2.98 per $100 of par value. Advance refunding allows municipalities to implicitly borrow over $5.76 per $100 par value in the top 5% of cases. Fees lost in the transaction, around 2% of the refunded issue value, further increase the cost of this practice to issuers.

We find that issuers in states with the most problematic governance tend to engage in advance refundings that destroy more value. This is consistent with municipalities treating advance refunding as a non-transparent way to borrow money. The borrowings result in temporarily lower interest payments, but at the expense of future potential interest savings. While municipal borrowings are often restricted to fund capital projects, there are typically no restrictions on advance refunding borrowings which can be used for operating budgets. Advance refunding, then, can be interpreted as "shrouded" borrowing, which is not unlike the true costs of public pension obligations which are often hidden by misleading accounting and are difficult for taxpayers to calculate (see Novy-Marx and Rauh, 2009; Glaeser and Ponzetto, 2013).

The Federal government already limits the number of advance refundings: bonds issued after the 1986 Tax Reform Act are entitled to only one advance refunding.[24] The U.S. Treasury already provides one tax exemption for the original municipal bond issue, which funds a new investment project, and the limit means that the U.S. Treasury gives a double subsidy when the advance refunding occurs. Given the economic losses imposed on taxpayers by advance refunding, Federal authorities should carefully consider the tax-exempt status of *any* advance refunding.

While we used a single-factor model to value the option value lost by advanced refunding, we expect our results will be robust to using other multi-factor models. In particular, given the underlying patterns of remaining time to call and of the par value of bond issues, which are highly skewed, we expect that more sophisticated option valuation will still produce a highly skewed distribution of the losses incurred through advance refunding where the worst deals involve egregious destruction of present value.

[24]New money bonds issued before January 1, 1986, can be advance refunded a maximum of two times.

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Table 1
Numerical Example of Advance Refunding. Assume there is an existing bond with annual 6% coupon payments with six years to maturity, but is callable at the end of three years at a price of $100 per face value. Interest rates are currently 4% across all maturities. The first row gives the cashflows of this existing bond. In the rows under "Pre-Refund," we consider the case where the municipality issues new debt with a maturity of six years, with a face value of $105.55 and an annual coupon of $4.22. The proceeds of the new issue go into a trust, which pays the $6 coupons of the original debt for the next three years and the call price of $100. The rows under "Wait to Call" list the cashflows of the case where the municipality waits three years, and then calls the original bond. The final line shows that the interest savings associated with pre-refunding are equal to the savings associated with waiting to call.

Periods	1	2	3	4	5	6
Original Bond Payments (PV=110.48)	6	6	6	6	6	106
Pre-Refund						
Trust (PV=105.55)	6	6	106	0	0	0
New Bond Payments (PV=105.55)	4.22	4.22	4.22	4.22	4.22	109.77
Savings (PV=4.94)	1.78	1.78	1.78	1.78	1.78	-3.77
Wait to Call						
Payments (PV=105.55)	6	6	6	4	4	104
Savings (PV=4.94)	0	0	0	2	2	2
Difference in Savings (PV=4.94-4.94=0)	1.78	1.78	1.78	-0.22	-0.22	- 5.77

Table 2
Comparison of Included and Excluded Data. The table lists characteristics—number of CUSIPs, par value, coupon, maturity, and years to call—of bonds included in our sample (Panel B) compared to the excluded universe of refunded issues (Panel A) due to incomplete data. Years to call is not available for most excluded bonds, because of missing information on the date of the refunding. The sample of advance refunded bonds (Panel C) further excludes bonds with less than 90 days to call, which are treated by the IRS as current refundings. Bonds in a series that were refunded in a single transaction are aggregated into deals in Panel D.

Characteristic	Number of Observations	Mean	Lower Quartile	Upper Quartile
Panel A: Excluded Bonds				
Number of CUSIPs	127,482			
Par Value ($)	103,951	2,926,037	300,000	2,090,000
Coupon (%)	127,290	5.28	4.65	5.80
Maturity Year	127,482	2014	2009	2019
Panel B: Included Bonds				
Number of CUSIPs	234,714			
Par Value ($)	234,714	2,850,541	295,000	2,095,000
Coupon (%)	234,714	5.00	4.55	5.37
Maturity Year	234,714	2015	2011	2019
Yrs. to Call	234,714	2.27	0.58	3.34
Panel C: Advance Refunded				
Number of CUSIPs	203,207			
Par Value ($)	203,207	2,839,214	300,000	2,150,000
Coupon (%)	203,207	5.02	4.60	5.40
Maturity Year	203,207	2016	2012	2020
Yrs. to Call	203,207	2.59	3.00	3.34
Panel D: Advance Refunded Deals				
Number of CUSIPs	22,633			
Par Value ($)	22,633	25,491,456	3,060,000	19,220,000
Ave. Old Coupon (%)	22,633	5.17	4.70	5.51
Ave. Yrs. to Call	22,633	2.54	1.00	3.69
No. CUSIPs	22,633	8.99	4.00	11.00

Table 3
Calibrated Parameter Values. We estimate a Vasicek (1977) model with short rate given in equation (6) and time-varying prices of risk in equation (8). We estimate σ and κ by matching the three-month volatility and autocorrelation. To calibrate θ, we match the sample three-month rate. The price of risk parameters, λ_0 and λ_1, are pinned down by matching the average long-term yield spread and volatility using the ten-year yield.

	Parameters				
	σ	θ	κ	λ_0	λ_1
Whole Sample					
1996-2013	0.0127	0.0267	0.3619	-0.0043	-15.6445
Subsamples					
1996-2002	0.0128	0.0385	0.8774	1.7272	-52.8134
2003-2013	0.0126	0.0177	0.5858	0.0208	-32.3594

Table 4
Distribution of Value Lost from Advance Refunding. The value lost in an advance refunding is equal to the value of a put option on the coupon bond expiring on the call date. We value the put option using a Vasicek (1977) model with time-varying prices of risk and the Hull and White (1990) model. In both cases, we use the closed-form method of Jamshidian (1989) to compute the value of the put option. Put option values are computed for 203,207 separate CUSIPs in 22,633 deals.

	Put Value Per $100 Par	Put Value Per CUSIP	Put Value Per Deal
Vasicek (1977) Model			
Mean	0.852	35,556	546,287
Standard Deviation	1.100	249,488	2,190,046
Quantiles			
30%	0.082	432	45,637
50%	0.420	2,627	116,968
90%	2.306	55,877	1,196,400
95%	3.128	122,340	2,415,683
Maximum	41.827	29,443,000	137,953,205
Hull and White (1990) Model			
Mean	0.820	45,222	406,020
Standard Deviation	1.408	390,580	2,539,438
Quantiles			
30%	0.045	242	3,527
50%	0.304	1,760	25,276
90%	2.180	54,282	605,623
95%	3.268	131,957	1,421,615
Maximum	50.01	40,309,000	145,349,054

Table 5
Aggregate Losses of Option Value From Advance Refudings. The put option is valued using the Vasicek (1977) model with time-varying prices of risk or the Hull and White (1990) model. All figures are in $ billions except percent of par lost.

	Vasicek	Hull-White
Total Option Value Lost	7.225	9.189
Total Par Value Pre-Refunded	576.948	576.948
Percent of Par Lost	1.252	1.593
Total Value Lost From CUSIPs below 95% Quantile	2.113	1.957
Total Value Lost From CUSIPs above 95% Quantile	5.112	7.233

Table 6
Aggregate Fees Paid in Advance Refundings. We estimate the fees associated with advance refunding. We sum all fees assuming transaction costs ranging from 0.375% to 5% as a fraction of the value of the bond that is pre-refunded. All figures are in $ billions except where percentages are reported.

	Transaction Costs			
	0.375%	1%	2%	5%
Total Fees Paid ($ Billions)	2.352	6.273	12.546	31.364
Total Fees Paid as a Percent of Par	0.408%	1.080%	2.174%	5.436%
Total Fees Paid from CUSIPS below 95% Quantile	1.834	3.156	6.312	15.781
Total Fees Paid from CUSIPS above 95% Quantile	1.169	3.117	6.233	15.583

Table 7
Distribution of Implicit Borrowing in Advance Refundings. We estimate the size of the trust, F, required at the pre-refunding date and the coupon of the par bond required to fund it, C^* (see equation (18)). The per period reduction in interest cost is then $C - FC^*$, where C is the coupon on the bond being advanced refunded. The present value of this difference, up to the call date, times the total par value of the pre-refunded issue is our estimate of the present value of interest savings that are being accelerated in the advance refunding transaction. The table reports summary statistics of the distribution of these quantities for individual CUSIPs and deals. There are 203,207 CUSIPs and 22,632 deals.

	Per \$100 Par	Per CUSIP	Per Deal
Mean	2.357	60,845	546,287
Standard Deviation	2.018	292,451	2,190,046
Quantiles			
30% Quantile	1.212	4,995	45,637
50% Quantile	2.053	12,740	116,968
90% Quantile	4.911	149,225	1,196,400
95% Quantile	5.982	283,611	2,415,683
Maximum	27.431	34,112,482	137,953,205
Total Implicit Borrowing	–	12,364,114,816	12,364,114,816
Total Above 95th percentile	–	7,185,251,258	7,250,279,678

Table 8
Distribution of Subsidy to Hedge in Advance Refundings. The subsidy to the hedge is the difference in present value of the payments on the refunded bond up to the call date, discounting at fitted zero-coupon municipal rates, and at the "subsidized" rates allowed for the excrow accounts. The latter are the minimum of estimates of the Treasury's borrowing costs for a particular maturity and our estimates of the par yield on new bonds issued at the date of refunding. The table reports summary statistics of the distribution of these quantities for the 203,207 CUSIPs and 22,633 deals in our sample.

	Per $100 Par	Per CUSIP	Per Deal
Mean	0.345	22,930	205,872
Standard Deviation	1.736	309,151	2,257,412
Minimum	-18.381	-11,328,937	-23,775,566
10% Quantile	-1.725	-27,501	-219,953
30% Quantile	-0.613	-2,845	-23,789
50% Quantile	0.104	270	3,094
70% Quantile	1.315	7,106	87,643
90% Quantile	2.644	61,825	609,573
Maximum	9.213	31,269,611	150,204,336
Total Subsidy to Hedge	–	4,659,504,216	4,659,504,216

Table 9

Distribution of Types of Issuers for Top Worst Deals. The entries in the table represent the number of issuers of the 50 deals with the largest observations for each quantity listed at the top of the table. That is, they are the 50 worst deals subdivided by the type of issuer, in terms of par value destroyed, the total put value, and the amount of implicit borrowing being done in the advance refunding. There are a total of 26,500 deals.

Issuer Type	Par Value Total	Put Value Total	Implicit Borrowing	Put Value Per $100 Par
State	17	8	24	3
City	5	4	5	2
County	0	2	2	2
Town, Borough	0	0	0	6
Highway, Airport, Public Transit	11	16	11	1
Utility, Water	8	8	4	2
Development Authority	5	4	2	3
University	3	4	1	0
Health Care	0	0	0	1
School District	1	4	1	30
Total	50	50	50	50

Table 10

Which Municipalities Destroy the Most Value? We run pooled cross-sectional regression where the dependent variable is the amount of option value lost per $100 par value (Panel A) or the total option value lost for that CUSIP, as measured using the Vasicek (1977) model. The table lists the coefficients and t-statistics with year or quarterly fixed effects. The unit of observation is the CUSIP. There are 157,306 observations for which we were able to identify the state of the issuer over the period coincident with the data on the states. T-statistics are computed using clustered standard errors.

Coefficient	t-statistic	Coefficient	t-statistic	
Panel A: Put Value Per 100				
Long Muni Rate	-0.166	-3.44	-0.109	-1.80
Subsidy	0.315	13.49	0.340	14.58
Number of Convictions	0.026	2.33	0.025	2.34
S&P Rating	0.012	1.98	0.013	2.23
State Unemployment	-0.028	-1.70	-0.027	-1.56
State GDP Growth	-1.479	-1.81	-1.383	-1.80
State Debt Per Capita	0.036	0.30	0.050	0.43
State Population Growth	-5.173	-1.30	-4.500	-1.36
State Median Income/1,000	-0.006	-4.60	-0.005	-3.95
State Population	0.021	1.94	0.022	1.94
R^2	43.15%		44.79%	
Time Fixed Effects	Each Year		Each Quarter	
Panel A: Put Value Per CUSIP				
Long Muni Rate	-18.748	-3.18	-17.313	-2.20
Subsidy	0.5315	7.28	0.533	7.25
Number of Convictions	-0.749	-1.19	-0.735	-1.16
S&P Rating	2.855	6.12	2.864	6.25
State Unemployment	-1.486	-1.25	-1.363	-1.14
State GDP Growth	-114.538	-2.06	-115.247	-2.04
State Debt Per Capita	0.799	0.13	1.462	0.24
State Population Growth	-230.801	-0.79	-215.173	-0.76
State Median Income/1,000	-0.058	-0.40	-0.017	-0.12
State Population	0.649	0.48	0.823	0.62
R^2	42.42%		42.58%	
Time Fixed Effects	Each Year		Each Quarter	

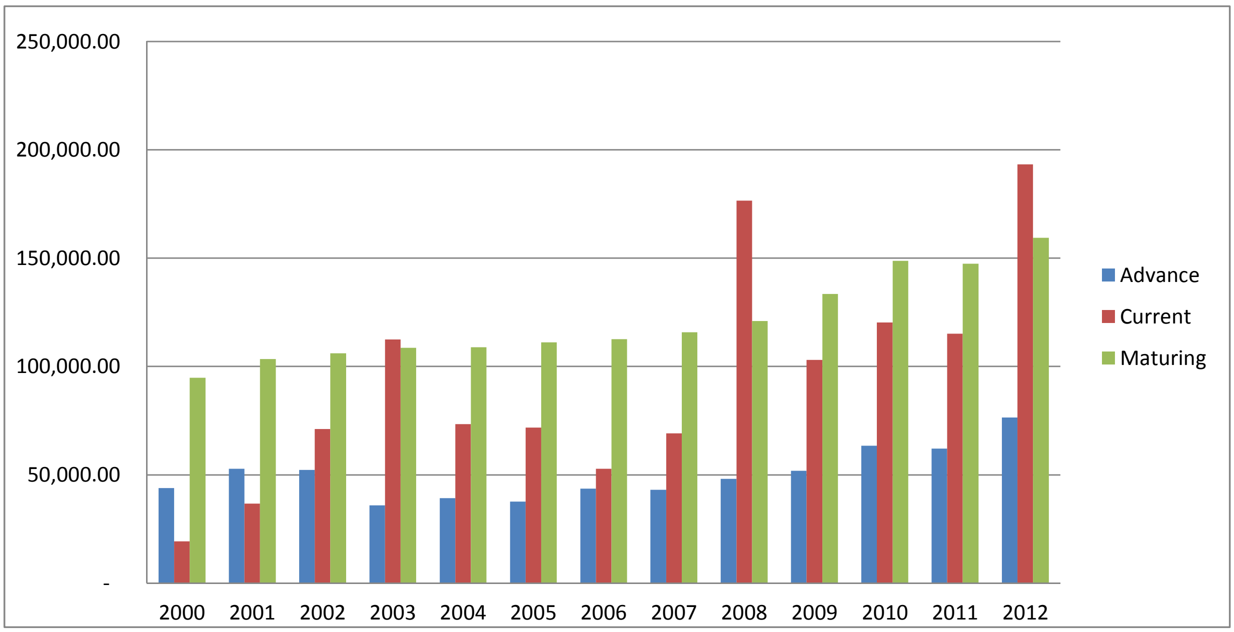

Figure 1

Redemptions of Municipal Bonds by Year. The plot shows the par value (in millions) of municipal bonds redeemed in each year through reaching maturity, through exercise of a call provision in a current refunding, and through exercise of a call provision after having been previously advance refunded. Source: Bondbuyer Statistical Yearbooks and Annual Statistical Review.

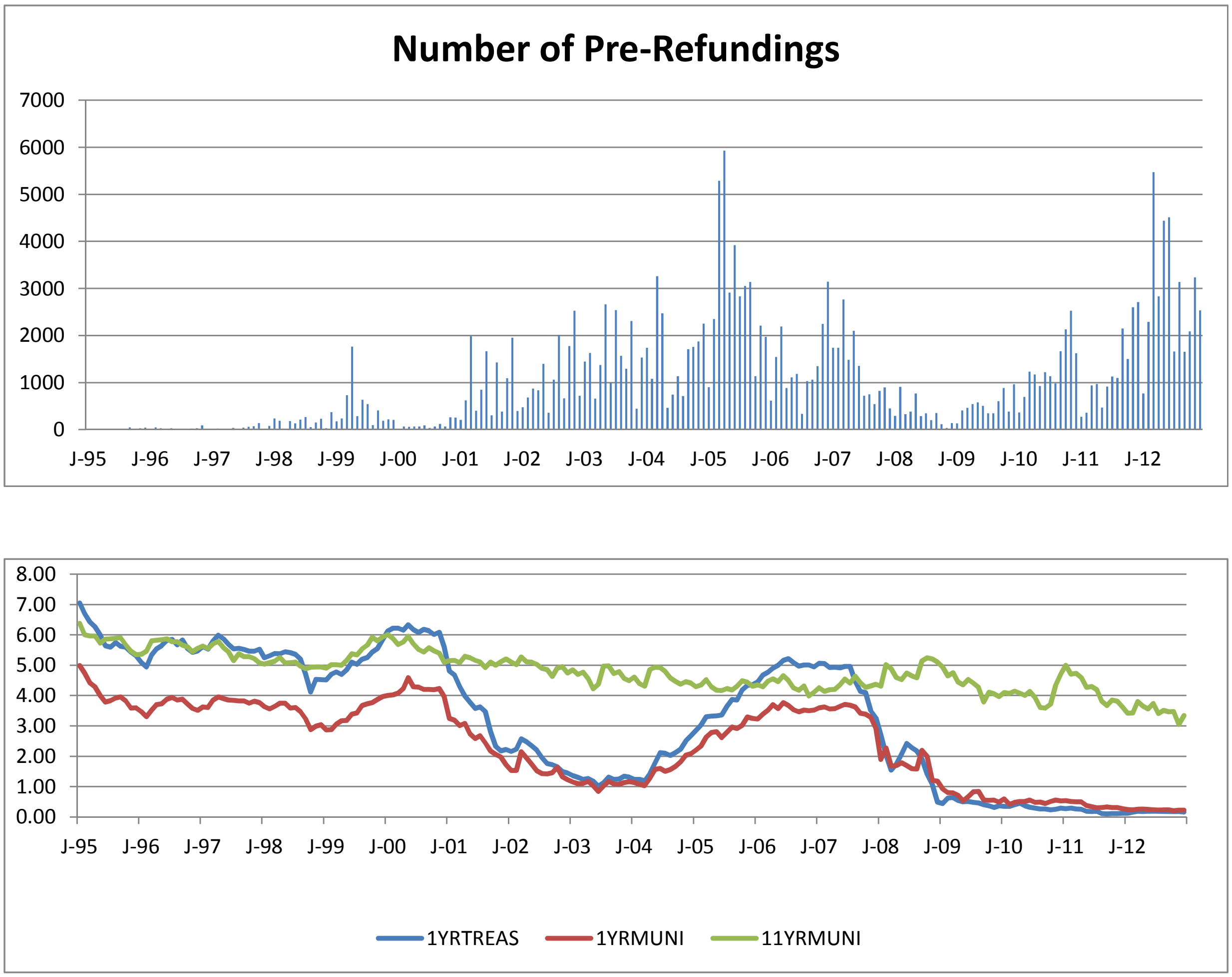

Figure 2
Advanced Refundings Over Time. We plot the number of pre-refundings in each month(top panel), monthly interest rate series (bottom panel) The “arbitrage spread” is the minimum of the short Treasury rate and the long municipal rate, less the short-term municipal rate. The figure shows it became negative after the crisis in 2008.

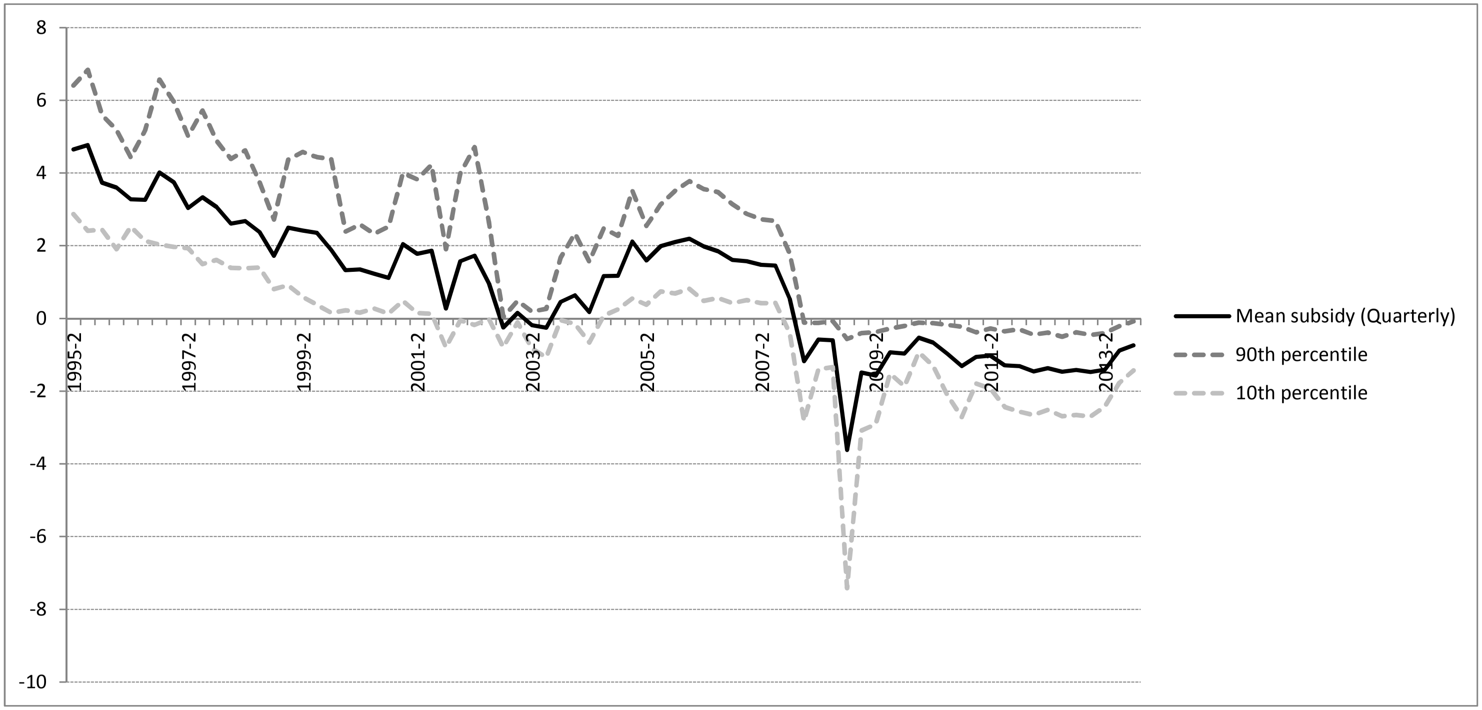

Figure 3
Implicit Subsidy For Hedge. The plot shows the quarterly mean of the subsidy per 100 par value, as well as the 10th and 90th percentiles of this variable. While substantial in the early years of the sample, the subsidy to the hedge embedded in advance refundings has been negative since the financial crisis.

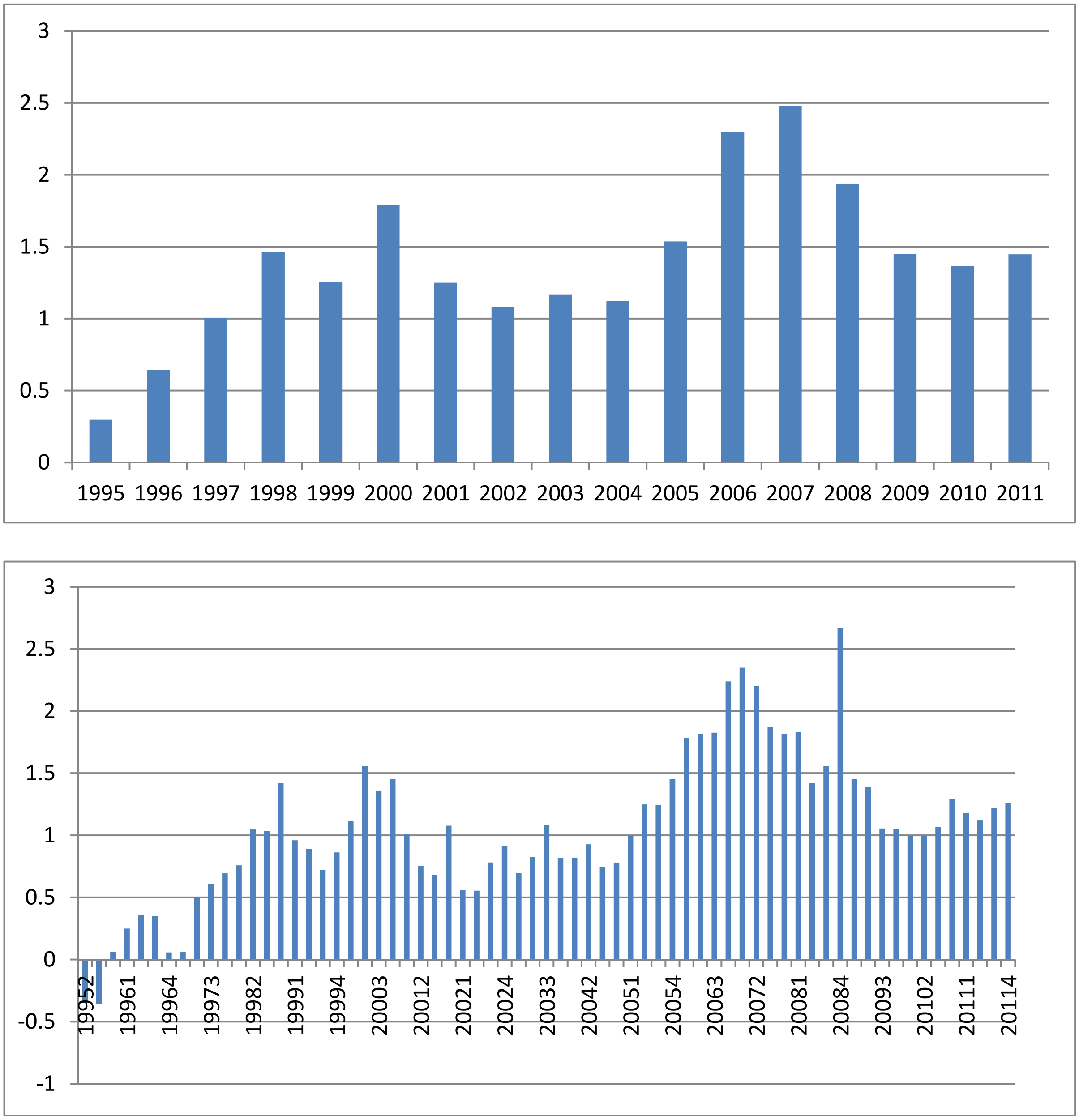

Figure 4
Time Fixed Effects. We show estimated coefficients on fixed effects for years (top panel) and quarters (bottom panel) from the cross-sectional regressions reported in the upper panel of Table 10, explaining the magnitude of advance refunding losses per 100 par. All annual fixed effects except for 1995 are associated with p-values of less than 0.001. Quarterly fixed effects other than 2-1995 to 4-1997, 3-1999, and 1-2002 to 2-2002 have p-values less than 0.05.

Table A-1
Aggregate value lost by state. This table lists the total value lost by each state using the Vasicek (1977) model.

	Total par amount of prerefunded bonds	Value Lost (vasicek model)
AK	1,760,010,000	22,873,384
AL	8,983,415,000	162,138,683
AR	3,842,100,385	26,826,668
AZ	14,267,315,000	125,360,051
CA	89,148,340,124	1,128,854,803
CO	14,918,336,000	150,574,368
CT	9,336,649,000	101,556,252
DC	2,383,975,000	39,775,198
DE	2,032,085,000	16,860,656
FL	33,084,637,000	293,481,715
GA	11,639,615,000	172,417,010
HI	4,653,135,000	40,794,431
IA	2,262,300,000	14,380,991
ID	1,313,145,000	11,435,035
IL	22,918,110,000	267,616,119
IN	12,433,263,000	169,345,955
KS	6,365,697,100	47,740,071
KY	6,386,841,000	54,340,590
LA	6,571,108,000	69,689,327
MA	21,785,435,000	294,770,301
MD	10,099,935,000	91,446,199
ME	1,439,445,000	9,585,318
MI	22,613,534,000	262,195,764
MN	7,689,047,500	56,494,062
MO	9,473,874,500	103,651,330
MS	2,845,220,000	28,882,883
MT	599,130,000	5,496,600
NC	14,721,150,000	172,470,762
ND	597,825,000	2,664,318
NE	5,083,542,000	52,393,325
NH	1,934,471,400	17,877,724
NJ	34,133,359,750	398,015,967
NM	2,462,980,000	15,068,125
NV	8,521,310,000	105,344,191
NY	68,043,559,988	697,401,723
OH	22,748,415,000	280,591,311
OK	3,227,815,000	35,501,273
OR	7,640,455,000	85,614,631
PA	32,504,874,000	389,206,413
RI	1,930,010,000	12,625,317
SC	10,801,360,000	82,690,992
SD	632,110,000	3,097,400
TN	9,038,015,000	110,045,133
TX	58,024,054,395	617,294,053
UT	4,847,250,000	47,937,404
VA	16,419,891,000	155,353,487
VT	920,230,000	6,268,146
WA	24,419,117,379	135,370,003
WI	7,83[illegible],941,000	65,648,517
WV	1,547,080,000	11,889,620
WY	177,445,000	279,331

Table A-2
Distribution of Option Value Lost Including Current Refundings. The value lost in an pre-committing to excercise is equal to the value of a put option on the coupon bond expiring on the call date. We value the put option using a Vasicek (1977) model with time-varying prices of risk and the Hull and White (1990) model. In both cases, we use the closed-form method of Jamshidian (1989) to compute the value of the put option.

	Put Value Per $100 Par	Put Value Per CUSIP	Put Value Per Deal
Vasicek (1977) Model			
Mean	0.742	30,970	274,310
Standard Deviation	1.067	233,248	1,662,755
Quantiles			
30%	0.019	93	639
50%	0.259	1,503	12,432
90%	2.139	46,730	446,316
95%	2.976	105,060	1,008,767
Maximum	41.827	29,443,000	160,313,591
Hull and White (1990) Model			
Mean	0.717	39,427	349,212
Standard Deviation	1.350	364,999	2,353,499
Quantiles			
30%	0.010	53	801
50%	0.174	942	12,774
90%	1.993	44,577	500,027
95%	3.050	112,320	1,183,307
Maximum	50.01	40,309,000	145,349,054

Table A-3

Aggregate Losses From Early Exercise Including Current Refundings. The put is valued using the Vasicek (1977) model with time-varying prices of risk or the Hull and White (1990) model. All figures are in $ billions except percent of par lost.

	Vasicek	Hull-White
Total Option Value Lost ($ Billions)	7.269	9.254
Total Par Value Pre-Refunded	669.061	669.061
Percent of Par Lost	1.086	1.383
Total Value Lost From CUSIPs below 95% Quantile	1.949	1.785
Total Value Lost From CUSIPs above 95% Quantile	5.320	7.469

Table A-4

Distribution of Implicit Borrowing Including Current Refundings. We estimate the size of the trust, F, required at the pre-refunding date and the coupon of the par bond required to fund it, C^* (see equation (18)). The per period reduction in interest cost is then $C - FC^*$, where C is the coupon on the bond being advanced refunded. The present value of this difference, up to the call date, times the total par value of the pre-refunded issue is our estimate of the present value of interest savings that are being accelerated in the advance refunding transaction. The table reports summary statistics of the distribution of this implicit borrowing for individual CUSIPs and deals. There are 234,714 CUSIPs and 26,6500 deals.

	Implicit Borrowing Per $100 Par	Implicit Borrowing Per CUSIP	Implicit Borrowing Per Deal
Mean	2.148	55,416	490,832
Standard Deviation	1.959	273,457	2,042,474
Quantiles			
30% Quantile	1.008	4,188	37,878
50% Quantile	1.732	10,916	98,871
90% Quantile	4.687	133,961	1,053,476
95% Quantile	5.756	258,673	2,126,734
Maximum	27.430	34,112,482	137,953,205
Total Implicit Borrowing	–	13,007,057,515	13,007,057,515
Total Above 95th percentile	–	7,683,348,902	7,773,638,609