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**Abstract**

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### Abstract

The market for Auction Rate Securities (ARS) made headlines during the second week of February 2008 when auctions, at which the bonds interest rates are reset, experienced a wave of "failures." Contrary to headlines that attribute the failures to a "frozen" market and/or to "irrationality" on the part of market participants, we find that (1) even at their height, less than 50% of ARS bonds experienced auction failures, (2) the likelihood of auction failure was directly related to the level of the bonds "maximum auction rates" that cap the bond yields, and (3) using an empirical model of market clearing yields, the implied market clearing yields of bonds with failed auctions were significantly above their maximum auction rates. We interpret this evidence to mean that auctions failed because investors rationally declined to bid for bonds for which required market yields exceeded their maximum auction rates. We further find that ARS yields were generally higher than yields of various cash equivalent investment alternatives including treasury bills (T-bill), certificates of deposits (CD), money market funds (MMF), and Variable Rate Demand Obligations (VRDO). We interpret this latter evidence to mean that investors priced the possibility of auction failure into ARS yields.

# 1. Introduction

Auction Rate Securities (ARS) are long-term bonds and preferred stocks with coupon rates that reset at regular intervals by means of open-market auctions. At each auction, buyers pay, and sellers receive, par value for the securities. Given that the securities must trade at par, potential buyers submit bids in terms of the coupon rate they require to hold the securities until the next auction. Thus, the market-clearing "price" for an issue is the lowest coupon rate at which the cumulative dollar amount of the security demanded at or below that rate equals the total dollar amount outstanding.

ARS were much in the news during the first half of 2008 due to a wave of auction "failures." The typical headline story attributed the failed auctions to investors who "abandoned" the "frozen" market, and hint that investors, perhaps irrationally, were unwilling to bid for the securities at any price:[1]

> The failure of a string of short-term funding auctions this week is a reminder that not only is the credit crunch not over — it's taken a further step into the realm of the irrational. (Barrett (February 13, 2008) Auctions fail on fear of fear itself, *Dow Jones Capital Markets Reports*, 27-29).

And later:

> Much of the $350 billion market for auction-rate securities... has been frozen since February, when auction failures became widespread. That has left many investors without the ability to sell. (Rappaport, Scannell, and Smith (July 16, 2008) UBS to buy back up to $3.5 billion in securities, *The Wall Street Journal*, C.15).

Against this background, we undertake an empirical investigation of the ARS market over the months leading up to and during the epical first half of 2008. In particular, we investigate whether auction failures can be attributed to factors other than irrationality on the part of market participants.

One item missing from the headline stories is that, as with most floating rate securities, ARS periodic reset rates are capped by contractually specified maximum rates. With ARS, however, because the securities trade at par, the maximum rates play a critical role in the market clearing process. Indeed, an auction is deemed to have failed when there

[1] Rappaport and Karmin (February 14, 2008), Reason (February 22, 2008), and Cowen (March 23, 2008).

are not sufficient bids to clear the market at a rate less than a security's maximum rate. In official parlance, the rate caps are "maximum auction rates." In Wall Street parlance, "maximum auction rate" is often shortened to "max rate." We use the terms "maximum auction rate" and "max rate" interchangeably throughout the paper.

An alternative explanation to irrationality on the part of investors is that the failed auctions occurred because the market yields that investors required to hold the securities lay above their maximum auction rates. When this occurred, market participants rationally declined to bid at the auctions. Thus, the missing market participants were investors who quite reasonably decided not to bid.

As a preliminary analysis, we calculate the fraction of auctions that failed, by week, beginning with the first week of January 2003 and ending with the third week of July of 2008. Contrary to the impression given by news stories that refer to the frozen ARS market, we find that, even at the peak of auction failures, not all auctions failed.[2] Indeed, at its peak, in the sample of 793 bonds that we analyze, the overall auction failure rate was only 46%.

This observation naturally gives rise to the question of whether auction failures can be explained by the characteristics of the bonds that were being auctioned. We propose that failed auctions were systematically and negatively related to the level of the bonds maximum auction rates. We test this conjecture against the null hypothesis that auction failures were unrelated to the bonds maximum auction rates.

Our test has three components. First, we estimate the parameters of a logistic model of auction failures. We find that the probability of auction failure is negatively and significantly related to the level of bonds maximum auction rates — lower max rates are associated with a higher probability of auction failure.

Second, we observe that there are two generic types of maximum auction rates: fixed and floating. Because the levels of floating maximum auction rates are typically much lower than the levels of fixed maximum auction rates, the type of maximum auction rate can serve as a proxy for the levels of the rates and allows a natural dichotomization of the sample. When we classify ARS by the type of max rate, we find that auctions for those with floating max rates failed at a much higher frequency than did auctions for bonds with fixed max rates. For example, during the tumultuous second week of February 2008, when the rate of auction failures in our sample jumped from 18% to 41%, the rate of

[2] Kim and Anand (February 21, 2008).

auction failures for bonds with floating maximum auction rates was 93%, while the rate of auction failures for bonds with fixed maximum auction rates was 13.4%. Using a logit model, we find that the probability of auction failure is significantly related to the type of maximum auction rate — ARS with floating max rates were significantly more likely to have experienced auction failures than were those with fixed max rates.

Third, using bonds with successful auctions, we estimate cross-sectional and panel regression models of market clearing yields based on bond characteristics and market-wide data. For bonds with failed auctions, we compare the market clearing yields implied by the models with the bonds maximum auction rates. We find that the market clearing yields implied by the models are significantly higher than the bonds maximum auction rates.

Thus, the data soundly reject the null hypothesis of no relation between the level of maximum auction rates and auction failures and solidly support the alternative that auction failures were directly related to the level of maximum auction rates. Rather than being irrational, investors appear to have prudently distinguished among ARS and chose to bid on those for which the market required yields were less than their maximum auction rates.

We then investigate two questions intertwined with the auction failures. The first is whether investors were "compensated" for the risk of auction failure. The second is whether the observed increase in ARS yields during the first half of 2008 is attributable to a "spillover" or "contagion" from the difficulties that were being experienced in the subprime mortgage market.

The first of these questions has its origins in the official inquiries and lawsuits that followed shortly on the heels of the failed auctions.[3] One of the focal points of the inquiries and lawsuits is the allegation that ARS investors were duped into buying securities that were "cash equivalents." We investigate this allegation, albeit inferentially, in two ways. We first we compare ARS yields with yields of certain cash equivalent investment alternatives including and money market funds (MMF), treasury bills (T-bill), certificates of deposit (CD).

In a multivariate regression analysis, we find that ARS provided average returns that were significantly greater than the various cash equivalent alternatives. For example, over the period January 2003 through the mid-January 2008, ARS bonds provided an average

[3]Scheer (January 18, 2008), Bajaj (April 18, 2008), and Morgenson (June 27, 2008).

annual return of 26 basis points above the return of MMF. Over the period of September 2007, when the first auction failure in our sample occurred, through the second week of January 2008, the week just prior to the ramp-up in auction failures of 2008, the spread between ARS and MMF increased to approximately 48 basis points.

We then compare ARS yields with yields of Variable Rate Demand Obligations (VRDO). VRDO are a second useful benchmark for this comparison because of a key distinction between ARS and VRDO. Like ARS, VRDO are long-term bonds whose yields are reset at periodic intervals. Further, buyers pay and sellers receive par value for the securities at each interest reset date. However, rather than an auction, the bond yields are determined by re-marketing agents who canvass the market for buyers and sellers.

The key distinction between ARS and VRDO has to do with the market clearing process. With an ARS, if there are insufficient buyers to clear the market, investors who hold the security prior to the auction are "stuck" with the security at least until the next auction and possibly much longer if subsequent auctions also fail. And, based on our analysis of auction failures, they are stuck holding securities that are providing below market yields.

Investors are stuck because they have, in essence, sold a put option to the bond issuer such that the issuer has the right to "put" the bond to the investor at par at each auction date should the auction fail to clear. In contrast, with a VRDO, if the re-marketing agent is unable to find sufficient buyers for the security, the investor has the right to "sell" the bond at par back to the re-marketing agent at each interest reset date. Thus, VRDO eliminate the possibility that the investor will be stuck with a security that is providing a below market yield.

By comparing ARS yields with VRDO yields, we are testing whether the "put" option embedded in the ARS structure was priced into ARS yields. After controlling for differences in bond characteristics in a multivariate regression, we find that, prior to September 2007, ARS yields were not greater than VRDO yields. However, beginning in September 2007, ARS yields began to increase relative to VRDO yields such that the spread between the two had widened to 99 basis points by the end of December 2007 and increased further into January of 2008.

One interpretation of this finding is that, prior to September of 2007, investors viewed the possibility of being stuck with an ARS as remote. Such a premise on the part of investors may well have been reasonable given that only a handful, if any, failures occurred between 1985, when the first ARS was issued, and September of 2007. However, as the prospect of auction failure increased during the fall of 2007, investors began to demand compensation for the possibility of being stuck with a security providing a below market yield. On that basis, ARS yields did incorporate a price for the put option embedded in the bonds, but only as the likelihood of auction failure increased during the fall of 2007.

We cannot answer the question of whether individual investors were duped into buying ARS under the false impression that auctions would never fail. However, the data indicate that ARS were not being priced by market participants as if the securities were cash equivalents and they were not priced as if auction failure could not occur once the possibility of failure became manifest during the fall of 2007.

We then turn to the question of whether the increase in ARS yields that occurred during the first half of 2008 can be ascribed to a “spillover” or “contagion” effect that spread from the subprime mortgage market into the ARS market and/or to a wider concern with credit risk that may have affected debt markets in general.

To examine this issue, we use the framework proposed by Longstaff (2008b). In particular, we estimate time series regressions to examine the extent to which changes in ARS yields are predicted by changes in subprime asset backed index prices (i.e., ABX) and/or changes in credit default swap index spreads (i.e., CDX). We find that during 2007, ABX indexes did have predictive power for ARS yields. However, during the first half of 2008, when the ARS auction failures were occurring, ABX indexes had no predictive power for ARS yields. On this basis, auction failures do not appear to be a result of a contagion spreading from the subprime asset backed securities market to the ARS market. In contrast, changes in CDX spreads have no predictive power for ARS yields during 2007, but do have predictive power during 2008 when ARS auctions were failing. These results suggest that ARS auction failures came about as a result of an increase in concerns about credit risk more broadly.

Given that ARS bonds are issued by government-related entities and many receive tax-exempt status as a result, our study is related, albeit tangentially, to an extensive literature on the issuance and pricing of municipal bonds, including but not limited to, Miller (1977), Benson, Kidwell, Koch, and Rogowski (1981), Trzcinka (1982), Skelton (1983), Buser and Hess (1986), Green (1993), Chalmers (1998), Downing and Zhang (2004), Nanda and Singh (2004), Neis (2006), Green, Hollifield, and Schurhoff (2007), Ang, Bhansali, and Xing (2008), and Longstaff (2008a).

It is also related tangentially to a literature that considers the pricing of floating rate securities and interest rate caps, including, but not limited to, Cox, Ingersoll, and

Ross (1980), Ramaswamy and Sundaresan (1986), McConnell and Singh (1991), Kau, Keenan, Muller, and Epperson (1993),Longstaff, Santa-Clara, and Schwartz (2001), Dai and Singleton (2003), Driessen, Klaassen, and Melenberg (2003), Jagannathan, Kaplin, and Sun (2003), and Han (2007).

Finally, the paper is related, again tangentially, to a literature that considers financial market contagions, including, but not limited to, James (1987), Lang and Stulz (1992), Docking, Hirschey, and Jones (1997), Laux, Starks, and Yoon (1998), Slovin, Sushka, and Polonchek (1999), Allen and Gale (2000), Kyle and Xiong (2001), Kiyotaki and Moore (2002), Kodres and Pritsker (2002), Allen and Gale (2004), Jorion and Zhang (2007), Brunnermeier and Pedersen (2008), and Longstaff (2008b).

The remainder of the paper proceeds as follows. The next section provides a detailed description of ARS and their contractually specified maximum auction rates. Section 3 gives a narrative of the events that transpired in the months leading up to and including the wave of ARS auction failures that occurred during the first six months of 2008. Section 4 describes the data used in our tests. Section 5 presents the results of our tests of whether auction failures can reasonably be attributed to factors other than irrationality on the part of market participants and specifically whether auction failures can reasonably be attributed to the maximum auction rates in the ARS bonds. Section 6 considers the related issues of whether ARS provided yields above those of various cash equivalent investment alternatives and whether the auction failures that occurred during the winter and spring of 2008 were the result of a contagion spilling over from subprime asset backed securities. Section 8 concludes.

## 2. Auction Rate Securities

ARS are long term floating rate bonds and preferred stocks. In this study, we focus on ARS bonds.[4] Such bonds can be either taxable or tax exempt and because they are issued by government-related entities, they are often characterized as "munis." The rates paid on ARS are determined by market participants through periodic auctions. In principle, the interval between auctions can be of any length. However, popular auction intervals have been 7, 28, and 35 days with some securities resetting through daily auctions.

[4] Auction rate preferred stocks (ARPS) are similar to ARS bonds. The key differences are that ARPS are not issued by government-related issuers, are not insured, and contain greater risk of default. Auctions for ARPS failed at rates equal to or greater than did those for ARS bonds. Based on some very preliminary analyses, the results for ARS bonds appear to apply to ARPS as well. We focus on bonds because they comprise roughly 80% of the ARS market.

Buyers must pay face or par value for securities purchased at auction. At each auction, the auction agent accepts bids from potential investors. Each bid indicates the yield that the bidder requires to hold the security over the interval until the subsequent auction. Bidders submit dollar amounts along with their required yields. Thus, in their bids, potential investors specify an amount at par value and a required periodic yield. At each auction, the market clearing bid is the lowest yield such that the cumulative dollar amount of bids with lower yields equals the total outstanding dollar amount of the issue at par value. The market clearing yield is the yield that all holders of the security earn over the interval until the subsequent auction.

Market participants who already hold a particular security may submit one of three types of bids. Those who wish to sell the security regardless of the market clearing yield can submit a sell order. Those who wish to maintain their positions regardless of the market clearing yield can submit a "hold at market" order. Those who wish to submit a specific bid at the auction can do so. If that bid is below the market clearing yield, the investor continues to hold his position. If that bid turns out to be above the market clearing yield, the bidder is deemed to have sold his position.

A market participant who does not hold the security and wishes to do so can submit a buy order that specifies a dollar amount and a yield. If the bid is less than or equal to the market clearing yield, the bidder receives the security. All market participants submit their bids to brokers who, in turn, submit the bids to the auction agent. It is the auction agent's responsibility to determine the market clearing yield by matching orders among holders and potential new investors.

In clearing the market, the auction agent is constrained by a maximum auction rate that limits the interest rate that the issuer can be required to pay on the bond. The maximum auction rates, which are specified in each bond indenture, come in one of two varieties: fixed rate or floating rate. As implied by their name, fixed maximum auction rates are straightforward, albeit, across securities, there is a wide range of observed fixed maximum auction rates with a low of 9% and a high of 25% for the bonds in our sample.

In contrast to the straightforward fixed max rates, floating max rates exhibit significant heterogeneity in their composition. To begin, each floating max rate is tied to a floating reference rate. The floating max rates are either tied to the reference rate as of the date of the auction or to a moving average of the reference rate over some pre-specified period of time prior to the auction. In either case, a floating max rate can be specified as the reference rate times a multiplier or the reference rate plus a spread. Additionally the magnitude of the multiplier or the additive spread depends on the credit rating of the security as of the date of the auction. Further, in some instances, the floating max rate is specified as the minimum of two rates, one of which is the reference rate times a multiplier and the other of which is the reference rate plus a spread.

Reference rates include the one-month London Interbank Offer Rate (LIBOR), the 30-day AA Non-Financial Commercial Paper rate, the 30-day AA Financial Commercial Paper rate, the Kenny S&P High Grade Municipal Bond Index, and the Securities Industry and Financial Market Association (SIFMA) Municipal Swap Index rate. Further, the reference rate multipliers vary significantly across ARS ranging from a low of 125% to a high of 500%. Similar variability occurs in additive spreads that range from 1% to 3.5%.

One example of a floating maximum auction rate comes from the 2007 series C bond issued by the Michigan Housing Development Authority: if the rating of the issue is AAA- or higher as of the auction date, the max rate is 150% of the one-month LIBOR as of that date; if the rating of the bond is AA+ to AA- as of the auction date, the max rate is 175% of the one-month LIBOR; if the rating of the bond is A- to A+ as of the auction date, the max rate is 200% of the one-month LIBOR; if the rating is BBB- to BBB, the max rate is 225% of the one-month LIBOR; and if the rating is below BBB-, the max rate is 250% of the one-month LIBOR. The bond is tax exempt and is insured by Financial Security Assurance Incorporated.

A second example of a floating maximum auction rate comes from the Student Loan Revenue Senior Bond issued by the Brazos Education Authority in 2006: if the rating of the issue is AA- or better as of the auction date, the max rate is one-month LIBOR as of that date plus 1.5%; if the rating of the issue is between A+ and A- as of the auction date, the max rate is one-month LIBOR plus 2.5%; and if the rating of the issue is below A-, the max rate is one-month LIBOR plus 3.5%. The bond is tax exempt and is guaranteed by the Brazos Education Authority, but has no other form of insurance.

A third example is from the Higher Education Assistance bond issued by the Pennsylvania Education Authority in 2007: if the bond rating is above AA-, the max rate is the rate that taken together with the reset rates over the previous year equals the sum of the 91-day T-bill yields as of the same auction dates plus 1.2%; and if the bond rating is below AA-, the max rate is the rate that taken together with the reset rates over the previous year equals the sum of the 91-day T-bill yields as of the same auction date plus 1.5%. The bond is not tax exempt and is guaranteed by the Pennsylvania Education Authority, but has no other form of insurance.

The examples illustrate, but do not exhaust, the many variations in maximum auction rates across ARS. The examples also illustrate that some bonds are tax exempt and others are not, and that some are self-insured while others are insured by third-party insurers. The third-party insurers are the so-called monoline insurers whose sole business line is insuring bond issues.

A further characteristic of ARS bonds with floating max rates is that all of them also have fixed max rates. At each auction, the binding max rate is the minimum of the two as of the auction date. An auction succeeds when there are sufficient bids at or below the maximum auction rate such that the cumulative dollar amount bid is at least equal to the dollar amount outstanding at par value. It is conceivable that all current investors will submit hold orders. In that circumstance, the security's yield is set to a, typically small, fraction of the reference rate. In our sample these fractions range from 0.45 to 0.90. This rate is called the "all hold rate."[5]

For our purposes, the more important outcome occurs when there are not sufficient bids to clear the market at a rate less than the bonds max rate. These are the failed auctions that were much in the headlines during the first six months of 2008. In the instance of a failed auction, current holders of the ARS continue to hold the security regardless of their orders. The problematic investor is the holder who wishes to extricate himself from his position. This investor is stuck, at least until the next auction, and possibly much longer. Indeed, this investor is stuck until the next successful auction and, in the meantime, receives the contractually specified maximum auction rate. Assuming that the bonds maximum auction rate is below the "market required" rate, investors are stuck with a security that is providing a below market return.

## 3. A Narrative of the ARS Market

The first ARS bond was issued in 1985 by Warrick County (Indiana) to finance the Southern Indiana Gas and Electric Company. Seven ARS bonds were issued in 1985 with another 34 issued between 1986 and 1990. Issuances began to gather steam in 1991 with 81 issues and another 129 in 1992. Over the following 16 years, the number of issuances of ARS bonds ebbed and flowed as capital market activity underwent cycles of expansion and contraction, but ARS bonds, with 603 issued in 2007, had remarkable staying power

[5]Arguably, the "low" all-hold rate that prevails in the event of all investors submitting hold bids is to motivate current investors to submit specific bids. In general, the issuer prefers more specific bids so as to reduce the likelihood that the market will clear at a single "high" specific bid. That is, greater competition among bidders is likely to lead to a lower yield for the issuer. Of course, all of this takes us into the realm of auction theory and strategic bidding. A realm that we do not propose to enter here.

at least until 2008. However, the first six months of 2008 witnessed the issuance of only 12 ARS bonds.[6]

From their inception, it was recognized that ARS auction failures could occur. However, auction failures with any type of ARS were few and far between. According to *Moody's*, between 1984 (when the first preferred stock ARS was issued) and the end of 2006, ARS bonds and preferred stocks together experienced a total of only 13 auction failures out of over 100,000 auctions.[7] The landscape began to shift in late 2007 and erupted dramatically during the first quarter of 2008.

For the 793 ARS bonds in our sample, which we describe in greater detail in Section 4, the first auction failure of 2007 occurred in the first week of September. Another four occurred during the remainder of September and through the end of November for a total of five failures from over 13,000 auctions. December witnessed 22 auction failures. The level of auction failures picked up further during January 2008 and into the first week of February, with 158 failures in January and 104 failures in the first week of February. It was during the second week of February that the auction failures surged along with the headline stories. Those stories paint a dire picture for the ARS market:

> "Goldman, Lehman Brothers, Merrill Lynch and other banks have been telling investors the market for these securities [ARS] is frozen — and so is their cash." (Anderson and Bajaj (February 15, 2008) New trouble in auction-rate securities, *The New York Times*, C.6).

And further:

> "Auction rate securities are the latest corner of the debt market to lock up. Some investors can't sell because no one is bidding." (Maxey (February 20, 2008) Discount sales can be boon for investors, *The Wall Street Journal*, C.3).

Thereafter, news stories regularly appeared at least through mid-July of 2008 describing the ARS market as "frozen" and telling the tale of investors who were holding securities for which there was no market.[8]

[6] As best we can determine, there were no further issuances of ARS bonds in the second half of 2008.

[7] Prolonged disruption of the auction rate market could have negative impact on some ratings; absence of liquidity jars market's orderly functioning, *Special Report, Moody's Investors Service*, February 20, 2008.

[8] Maxey (February 20, 2008) and Kim and Anand (February 21, 2008).

A number of themes flow through the popular press reporting of the auction failures. One of those themes is that market participants were acting "irrationally." A variation on that theme is that investors had abandoned the market and/or that investors were unwilling to bid at any price leading to a "frozen" market.[9]

The second theme is that the auction failures stemmed from a "spill-over" or "contagion" from the defaults and write-downs that were being experienced in the subprime mortgage market. News stories regularly referred to the ARS market as being "the latest casualty" as fear from the subprime "crisis" spread to other sectors of the credit market.[10]

A further well-reported set of events were the official government inquiries into the ARS auction failures and the related lawsuits filed by ARS investors. The most publicized of the official inquiries were those led by the Attorney General of the Commonwealth of Massachusetts and the Attorney General of the State of New York.[11] The most widely-reported of the civil lawsuits, but it was only one of many, is that by Maher Terminal Holdings, Inc.[12] A common allegation of the inquires and lawsuits is that investors were misled by their brokers and bankers into believing that ARS were "cash equivalents" that could readily be converted to cash at their par values at any time.

## 4. Data

The data used in our analyses are retrieved from *Bloomberg*. To identify ARS, we search the universe of municipal bonds for those for which the interest rate reset mode is classified as "auction" as of March 15, 2008.[13] For each security, we retrieve the name of the issuer, the issue date, the maturity date, the dollar amount of the issue, the auction interval, the tax status, and whether the issue was insured.

We also obtain the Official Statement for each bond from *Bloomberg* along with the periodic clearing yields. We then read each Official Statement to determine the structure of the maximum auction rate. We obtain time series of credit ratings from *Standard & Poors (S&P)*. We also obtain time series of LIBOR, constant maturity T-bill rates, AA Non-Financial Commercial Paper rates, AA Financial Commercial Paper rates, and

[9]Chasan (January 24, 2008), Norris (February 8, 2008), Rappaport and Scannell (February 22, 2008), and Forsyth (March, 3, 2008).

[10]Mackenzie and Van Duyn (February 13, 2008) and Krugman (February 15, 2008).

[11]Bajaj (April 18, 2008) and Story (July 25, 2008).

[12]Frank (February 14, 2008) and Henry (February 18, 2008).

[13]Municipalities and government-related entities are exempt from SEC filing requirements. Thus, it is not possible to construct a precise history of ARS bond issuances. The list that we obtain from *Bloomberg* is comprehensive only of issues that were outstanding as of March 15, 2008.

MMF yields from *Bloomberg*. We obtain the SIFMA Municipal Swap Index rate from the SIFMA website. We assemble data for VRDO from the same sources. By convention, all yields are expressed in annualized terms.

We obtain AAA, AA, A, BBB, and BBB- ABX index prices from an asset management firm. The index prices are maintained by Markit Group Ltd. We construct continuous weekly time series of log price changes of the indexes as in Longstaff (2008b). We obtain six series of CDX index prices from *Bloomberg*. The indexes are compiled from credit default swap (CDS) spreads for investment grade entities. We construct continuous weekly time series of log price changes of the CDX indexes in the same way as we construct the continuous time series of ABX price changes.

We first present descriptive data for the ARS bond market as of March 15, 2008. Table 1 presents bonds by year of issuance from 1985 through March 2008. The total number of issues outstanding was 5,636 with an aggregate face amount of $266.5 billion, an average face amount of $47.3 million, and an average term to maturity of 27.2 years. When classified according to auction interval, roughly 40% reset every seven days, 20% reset every 28 days, and 40% reset with an interval of 35 days or longer. The remainder, a tiny 0.01%, reset daily. As for tax status, 79% are exempt from federal taxation, 67% are exempt from the calculation of the federal alternative minimum tax (AMT), and 87% are exempt from state taxation for investors who reside in the home state of the issuer. Finally, 65% of the bonds are insured by one of the so-called monoline insurers. All of the bonds are issued by some form of government-related entity.

Because our analyses require time series of bond ratings which are not available in *Bloomberg*, these were purchased from *S&P*. To keep the cost within reasonable bounds, we use a subset of the outstanding ARS bonds in our analyses. In certain of our empirical analyses, we compare the yields of ARS with the yields of VRDO. To facilitate this analysis, we select ARS bonds issued by an issuer that also has at least one VRDO outstanding. As a final criterion, we include only ARS and VRDO that are identified by *Bloomberg* as having an auction interval of seven days.[14] This requirement allows us to "line up" ARS auctions with VRDO reset intervals for purposes of comparability. The subset of ARS includes 793 bonds or roughly 15% of the ARS bond universe. For this sample, the average dollar amount per issue is $54.5 million; the average original term to maturity is 27.0 years; 98% are exempt from federal taxation; 91% are exempt from state

[14]We should note that according to the Official Statements, most bonds allow the issuer to change the auction interval subject to notice to investors, but without investors' approval. Some of the bonds may have had auction intervals different from seven days over other time periods.

taxation; 98% are exempt from AMT taxation, 93% are insured by one of the monoline insurers; and all were issued in 1994 or later. Of these, 54% have only a fixed max rate. The other 46% have both a floating and a fixed max rate.

The VRDO sample includes 905 bonds. We refer to these as "matching" bonds in that they have the same issuer and each has a reset interval of seven days. However, we have included every VRDO with a weekly reset interval as identified by *Bloomberg* that was issued by any ARS issuer in our sample regardless of the VRDO's maturity, face value, tax status, or credit rating. The average face amount of the VRDO issues is $22 million; the average term to maturity is 17.5 years; 91% are exempt from federal taxation; 91% are exempt from state taxation; 70% are exempt from the AMT tax calculation; and 98% were issued in 1994 or later. Thus, the VRDO issues involve smaller dollar issues, have somewhat shorter maturities, and are slightly less likely to be exempt from federal taxation. In various multivariate comparisons, we control for these differences among bonds.

# 5. Auction Failures

In this section, we address the primary question broached at the outset: can auction failures reasonably be attributed to factors other than irrationality on the part of market participants? We express this question in the form of a specific null hypothesis: ARS auction failures were unrelated to bond characteristics. We test this null against the alternative hypothesis that auction failures were systematically negatively related to bonds maximum auction rates.

We test this hypothesis with the sample of the 793 ARS bonds described in Section 4. Because the bonds have weekly reset intervals, we organize the data by calendar week through time.

## 5.1. The Fraction of Auction Failures

Figure 1 plots the fraction of auctions that failed by week over the time period from the first week of September 2007 (the week of the first auction failure in our sample) through the second week of July 2008 (the last week for which we have data as we undertake this study). We classify an auction as having failed if the reset rate that is reported by *Bloomberg* is equal to the maximum auction rate that we calculate for that date based on our reading of the bonds Official Statement. We calculate the max rate for each bond each week based on the bonds reference rate and the bonds rating for that week. (Recall that reference rates float through time and that max rates depend not only on the floating reference rates, but also the bond ratings that can, and do, change through time.)

As described in Section 3 and as illustrated in Figure 1, the failure rate in our sample was minimal until December 2007. During December, 22 of the ARS in our sample experienced failures. In January auctions began to fail in greater numbers. By the third week of January, the failure rate reached 9.7% and by the fourth week of January it had grown to 18.2% Consistent with the headlines stories, it was during the second week of February that the failure rate increased dramatically. In our sample, 40.5% of auctions failed during that week. As shown in Figure 1, the rate of failures remained at about that level throughout the remainder of the period of our analysis. A key point is that even at its peak, the overall failure rate was less than 50%.

## 5.2. Auction Failures and Maximum Auction Rates

Thus, even at the peak of auction failures, not all auctions failed. That raises the question of whether there is a common factor that distinguishes the securities with failed auctions from those with auctions that succeeded and leads directly to the hypothesis set out above. In our first test of this hypothesis, we estimate the coefficients of a model in which the conditional probability of auction failure has a logistic distribution and the key conditioning variable is the bonds maximum auction rate.

To begin, we estimate a base case model that excludes the bonds maximum auction rates. Because, to our knowledge, there is no prior literature that attempts to explain the likelihood of ARS auction failures, we do not have a guide as to variables that may be important in explaining such failures. There is, however, an extensive empirical literature that attempts to explain bond yields. That literature reports that term to maturity, bond rating, size of issue, and insurance status are typically significant explanatory variables. We use these variables to estimate our base case model. For each bond, we include the remaining term to maturity of the bond as of the auction date (Maturity), the dollar amount of the face value of the issue (Face Value), an indicator variable equal to one for issues rated less than AAA (Rating < AAA) as of the week of the auction, and an indicator variable equal to one if the bond is insured (Insured).

For each week, beginning with the third week of January 2008, we estimate a cross-sectional logit model.[15] In the spirit of Fama and MacBeth (1973), we report the average

[15]We are unable to estimate a cross-sectional logit model for the weeks prior to the third week of January 2008. Because there are not enough auction failures during those weeks, the maximization algorithm does not converge. As a robustness check, we pool the data from September 2007 through July 2008 and estimate a panel logit model. The coefficients and pseudo-$R^2$ of this estimation are nearly

of the time series of the weekly coefficients of each variable in column (1) of Table 2. The t-statistics are calculated using standard errors corrected for autocorrelation as in Newey and West (1987). We begin with the third week of January 2008 because that is the first week for which there is a sufficient number of auctions to estimate the logit model. The average pseudo-$\overline{R}^2$ of the base case regressions is 10.3%.

As a first attempt to determine whether investors were rationally selecting among securities in their bidding decisions, we include in our regressions the level of the bonds max rates (Max Rate) as a determinant of the conditional probability of failure. Results are reported in column (2) of Table 2. The average estimated coefficient of Max Rate is negative and highly statistically significant indicating an inverse relation between the probability of an action failure and the maximum auction rate — the lower the max rate, the higher the probability of auction failure. Additionally, the inclusion of bond max rates substantially increases the average pseudo-$\overline{R}^2$ of the regressions relative to the base case model, from 10.3% to 57.2%.

To assess the economic importance of the maximum auction rates on the likelihood of auction failure, we compute the marginal effect. An increase in the level of the max rate by one standard deviation (5.0%) relative to the mean (9.1%) decreases the probability of auction failure from 31.1% to 2.1%.

Clearly, the level of the maximum auction rate was not only statistically, but also economically, significant as a determinant of the likelihood of auction failure. These data are consistent with the hypothesis that auction participants rationally avoiding auctions in which the maximum auction rates were below market clearing yields.

## 5.3. Auction Failures and the Type of Maximum Auction Rates

As a second test of the null hypothesis, we sort the bonds into two categories: those with only fixed max rates and those with both a floating and a fixed max rate. In our sample, 44% of the issues have only a fixed max rate. The fixed max rates tend to be high and the floating max rates tend to be low. As of the dates of the auctions, in our sample, the average max rate for those bonds with only fixed max rates was 14.1%. In comparison, for those bonds with a floating max rate, the average max rate was 4.4%. Thus, the type of maximum auction rate provides a natural dichotomization of the sample.

In the third specification of the logit model, we include an indicator variable that takes

identical to those reported in Table 2.

the value of one if the issue has a floating max rate and zero otherwise (Floating Max Rate). The estimated coefficient of this variable, reported in column (3) of Table 2, is positive and highly statistically significant. The average pseudo-$\overline{R}^2$ is essentially the same as when the level of the max rate is used, suggesting that the dichotomous classification of floating versus fixed max rate captures the same information as the level of the max rate. This result is particularly helpful because it allows us to classify the sample in a straightforward way and, thus, compare the fraction of auction failures of ARS with high (i.e., fixed) max rates with the fraction of auction failures of ARS with low (i.e., floating) max rates.

Figure 2 is a plot of the weekly fraction of failed auctions for the two groups. The rate of failures among the group of ARS with fixed max rates exhibits an uptick in the second week of February but quickly subsides. Even at its peak the fraction of failed auctions with a fixed max rate reaches only 13%. In comparison, the failure rate among ARS with floating max rates auctions reaches 90% in the second week of February and stays near or at that level through the second week of July 2008. Thus, these data, along with regression 3 of Table 2, are consistent with investors, and potential investors, rationally avoiding auctions with max rates less than market clearing yields.

## 5.4. Models of ARS Market Clearing Yields

Of course, the market clearing yields required by market participants for failed auctions are unobservable. When an auction fails, the yield is reset to the maximum auction rate regardless of whether that rate is above or below what the market required yield would have been had the auction succeeded. That is, the market yield is truncated at the maximum auction rate.

To directly test whether the market clearing yields of failed auctions would have been above or below the bonds maximum auction rates had the auctions succeeded, we estimate two models of ARS yields. The first is a cross-sectional model of weekly yields based on bond characteristics. The second is estimated using a panel of cross-sectional and time series data of bond characteristics and market-wide data.

In both models, the dependent variable is the weekly market clearing yield of ARS with successful auctions. In the cross-sectional model, we estimate the coefficients each week, beginning with the first week of September 2007 and ending with the second week of July 2008, and use those to calculate the implied market yields of the bonds with failed auctions in the relevant week. With the panel regression, we estimate one set of coefficients for the entire time period of September 2007 through July 2008 and use those to estimate the implied yields of ARS with failed auctions over that interval.

The virtue of the panel regression is that we can incorporate market-wide variables. The virtue of the cross-sectional model is that the coefficients of the model are allowed to vary each week of the analysis.

As we noted, an extensive set of literature reports that municipal bond yields are related to the variables used in the regressions of Table 2. Thus, we include those as independent variables in both regression models. Both models also include tax indicators to capture the cross-sectional differences in the tax status of the bonds. We include an indicator set to one for bonds that are taxable at the federal level (Federal Taxable), an indicator set to one for bonds that are taxable at the state level for investors who reside in the state of issuance (State Taxable), and an indicator set to one for bonds that are subject to the alternative minimum tax calculation (AMT Taxable).

As we describe in the Section 1, ARS have embedded in them a put option such that, at each failed auction, the bond is "put" to the investor at par value. However, this option is not a simple one-period option. Rather, it is a compound option because the investor is uncertain as to when he will be able to extricate himself from his position over the many weeks of the bonds life.[16] To capture this optionality in ARS yields, we

[16]The possibility of becoming stuck is a compound option because the ARS investor can become stuck with a bond paying a less than market yield for many periods. Thus, in considering his bid for the current auction, the investor must fold in the possibility of being stuck for all future periods. Solution of his bidding problem for one period, therefore, requires that he solves for the market clearing yield for all future periods. Doing so involves solving his bidding strategy recursively starting with the final auction. To consider the problem more formally, let $T$ be the maturity of the bond. At $t = T-1$, the investor knows that he will not be stuck with the bond beyond T. If the required yield is less than the max rate, $i_{(T-1)}$, the investor will bid the one-period rate of $y_{(T-1)} = k_{(T-1)}$ where $k_{(T-1)}$ is the one-period rate at $T-1$ of a one-period bond with the same credit risk as the ARS bond. At $t = T-2$ the investor faces the possibility that the auction will fail at $t = T-1$. In that instance, the investor will be forced to hold the bond for two periods. In essence, the investor has written a put option to the issuer according to which, if the auction fails at $t = T-1$, i.e. the market clearing rate is above the maximum auction rate, the issuer can put the bond to the investor at par for one period. Over that period the investor will receive the maximum auction rate which is lower than the market required yield. Therefore, at $t = T-2$, the investor will submit a bid equal to $k_{(T-2)}$ plus the value of the put option

$$y_{(T-2)} = k_{(T-2)} + E\left[\max(y_{(T-1)} - i_{(T-1)}, 0)\right].$$

Similarly, at $t = T-3$, the investor will submit a bid of

$$y_{(T-3)} = k_{(T-3)} + E\left[\max(y_{(T-2)} - i_{(T-2)}, 0)\right].$$

Thus, the market clearing yield at time $t = T-3$ depends upon the market clearing yield at time $T-2$, which also depends on the market clearing yield at time $T-1$. Solving recursively, the market clearing yield at $t = 0$ depends on a series of compound options. For a 20-year bond with weekly auctions, the calculate the degree to which the option is in the money each week as the ratio of the market clearing yield to the bond maximum auction rate (Moneyness) for each bond with a successful auction. To capture volatility, for each week we include a forecast of the conditional volatility (Sigma) of the yield of each bond based on a GARCH(1,1) model.[17]

The panel regression includes each of the variables used in the cross-sectional regressions along with the level of one-month LIBOR as of the week of the auction and the average spread of five-year credit default swaps for investment grade corporations as of the week of the auction (CDX Spread). We include LIBOR as a proxy for the market-wide level of interest rates. We include the CDX spread as a proxy for the sensitivity of investors to the market-wide level of credit risk.

The first column of Table 3 reports the averages of the time series of the weekly coefficients of the cross-sectional regressions. The t-statistics are calculated as in Table 2. The coefficients of the variables have sensible signs and all but the coefficients of Face Value and Insured are statistically significant. The coefficient of Maturity is positive (longer maturity bonds have higher required yields) as are the coefficients of the tax indicators (greater tax exposure increases required bond yields) and the coefficient of Rating (lower rated bonds have higher required yields). The coefficient of Insured is negative, albeit not statistically significant. The coefficient of the floating max rate indicator is negative and significant.

Further, the coefficients of bond implied optionality are also sensible. Both the coefficient of Moneyness and the coefficient of Sigma are positive and significant indicating that the closer the option is to being in the money and the greater the volatility of the underlying bond yields, the higher is the bonds market clearing yield.

Given that we are most concerned with the explanatory power of the models, the important statistic is the average adjusted $\overline{R}^2$ of the regressions — which is a highly reassuring 67.7%.

The second column of Table 3 gives the coefficients of the panel regression. The t-statistics are adjusted for heteroskedacity and autocorrelation in residuals and are clustered at the issuer level. For the variables included in both regressions, the signs of the coefficients are the same as those reported in column (1). The new variables in column

market clearing yield at $t = 0$ depends on the value of $20 \times 52 - 1$ compound options.

[17]For each week for each bond, we estimate a GARCH(1,1) model using yields from the prior 52 weeks. We then estimate the one-week ahead forecast of the bonds conditional volatility using the estimated parameters.

(2) are LIBOR and CDX Spread. The coefficients are both positive and significant. Thus, the higher the level of interest rates (as proxied by LIBOR), the higher the level of the ARS market clearing yields and the greater the level of market-wide concern with credit risk (as proxied by CDX Spread), the higher the ARS market clearing yields.

As with the regressions of column (1), the important statistic is the adjusted $\overline{R}^2$. In this model, at 80.6%, the adjusted $\overline{R}^2$ is also reassuringly high.

We use the coefficients of the two models to calculate implied market clearing yields for ARS with failed auctions. We then compare the implied market clearing yields with the bonds maximum auction rates for the week of the failed auction. Finally, we calculate the fraction of the bonds with failed auctions for which the implied market clearing yield is above the bonds maximum auction rate. With the cross-sectional model, this fraction is 92%; with the panel regression, this fraction is 86%.

In Figure 3, we plot the fraction of failed auctions for each week for which the market clearing yield implied by each model is above the bonds maximum auction rate. The asterisks represent the results using the panel regression; the crosses represent the results using the cross-sectional regressions. As the figure shows, with the exception of four weeks, the fraction of failures implied by the panel regression is at or above 80% each week. Likewise, with the exception of four weeks, the fraction of failures implied by the cross-sectional model is at or above 80% for each week. With both models, the fraction is often above 90%.

The results in Figure 3, coupled with those in Tables 2 and 3 and shown in Figures 1 and 2, strongly reject the null hypothesis of no relation between maximum auction rates and auction failures and strongly support the alternative hypothesis that auction failures were directly linked to ARS maximum auction rates. Apparently market participants rationally discriminated among ARS and chose not to bid on those for which market required yields lay above the bonds maximum auction rates.

# 6. Related Issues

In this section, we take up two issues related to ARS auction failures that made headlines in their own right during 2008. The first is the official inquiries and lawsuits that followed in the wake of the auction failures. The second is the speculation that the increase in ARS yields that occurred during the first half of 2008 was attributable to a spillover or contagion from difficulties that were being experienced in the subprime asset backed securities market during the summer and fall of 2007. We first address the issues raised in the official inquiries and lawsuits. We then take up the question of contagion.

## 6.1. ARS Yields vs. Cash Equivalent Yields

As we describe in Section 3, a by-product of the ARS auction failures were official inquiries undertaken by State Attorneys General and the accompanying civil lawsuits filed the by states and by individual investors. Major investment banks and brokerage firms were named as defendants in the lawsuits. One of the primary complaints was that the bankers and brokers misled investors into believing that ARS were "cash equivalent" investment alternatives.[18] For example, from the lawsuit filed by the Attorney General of the State of New York:

> UBS financial advisers marketed auction rate securities to UBS retail clients and others as liquid, short term investments that were similar to money market instruments. Customers then received account statements that reinforced the misrepresentations, as statements identified auction rate securities as cash equivalent securities. (The People of the State of New York, by Andrew Cuomo, Attorney General of the state of New York, Plaintiff, against UBS Securities LLC and UBS Financial Services, Inc., Defendants July 24, 2008.)

Similarly, from the lawsuit filed by the Attorney General of the Commonwealth of Massachusetts:

> ... Merrill Lynch marketed ARS as safe, cash like, and liquid investments. It categorized ARS as "Other Cash" on customers statements, even after the market imploded. (Commonwealth of Massachusetts: In the matter of: Merrill Lynch, Pierce, Fenner & Smith, Incorporated, Respondent, Administrative Complaint, Docket No. 2008-0058.)

Of course, we do not have any evidence as to whether any individual investor was duped into believing that ARS were cash equivalent investments and/or that auction failures could never occur. We can, however, provide certain inferential evidence by comparing ARS yields with contemporaneous yields of various cash equivalent investment alternatives. [19]

[18]Morgenson (March 9, 2008) and Kim (April 1, 2008)

[19]On the other side of the coin, certain ARS issuers have sued bankers and bond insurers alleging that the banks and/or the insurers misled the issuers, Wright (September 26, 2008). We have no evidence regarding this question.

We, thus, compare ARS yields with the seven-day average yields of a sample of tax-exempt MMF, the yields of one-month constant maturity T-bills, and the yields of seven-day CD.[20]

The comparison of ARS yields with the cash equivalent alternatives is complicated by the fact that, as we described above, some of the ARS bonds are taxable at the federal level and some are tax exempt, while some are taxable for citizens of the state in which the bonds are issued and some are tax exempt. Additionally, some are subject to the alternative minimum tax, while others are not. In comparison, T-bill and CD are taxable at both the federal level and state level, while the tax-exempt MMF are tax exempt from taxes at the federal, but not the state level. Further, T-bill and CD are subject to the alternative minimum tax calculation, while tax-exempt MMF are not.

Thus, in our first test, we compare the yields of federally tax-exempt ARS with the yields of federally tax-exempt MMF. This comparison obviates the need to adjust yields for differences in the federal tax status of the bonds and the benchmark.

To conduct this comparison, we estimate weekly cross-sectional regressions in which the dependent variable is the yields for that week of the federally tax-exempt ARS bonds minus the contemporaneous average yield of the federally tax-exempt MMF for that week. Note that we have only one observation each week for the MMF yield. We estimate the weekly regressions for each week for the interval beginning with the first week of January 2003 and ending with the second week of January 2008. We end with the second week of January 2008 because that is the last week prior to the onset of the wave of auction failures in our sample. We drop failed auctions from this analysis.

As independent variables, the regressions include indicators to identify ARS that are taxable at the state level (State Taxable) and ARS that are subject to the alternative minimum tax calculation (AMT Taxable). In addition to the tax indicators, other independent variables are indicators that summarize the ARS bond characteristics. They are: Long v. Short (where the indicator is equal to one if the remaining term to maturity of the bond is greater than the average term to maturity of the bonds in our sample), Large v. Small (where the indicator is equal to one if the dollar amount of the issue is greater than the average dollar amount of the bonds in our sample), Rating $<$ AAA (where the indicator is equal to one if the bond rating is lower than AAA), and Not Insured (where the indicator is equal to one if the bond is not insured by one of the monoline insurers).

[20] To identify the sample of money market funds, we search *Bloomberg* for funds that invest in tax-exempt securities. We find 261 such funds. From that list, we exclude funds that invest only in securities issued within a single U.S. state. These screens leave us with a sample of 107 money market funds.

By using indicator variables in lieu of the original continuous independent variables, the intercept of the regression can be interpreted as the conditional mean of the spread between the ARS yields and the benchmark yields after controlling for bond characteristics. Because the yields are annualized, the coefficient of the intercept represents the average annual difference in yields between tax-exempt ARS and tax-exempt MMF.

Column (1) of Table 4 gives the averages of the weekly coefficients. As shown in the table, after controlling for differences in bond characteristics, the average difference between ARS yields and MMF yields over the period from the first week of January 2003 through the second week of January 2008 was 26 basis points per year. This difference is highly statistically significant.

To compare ARS yields with the other cash equivalent securities (i.e., T-bill and CD), we adjust yields for federal taxes. To do so, if an ARS is taxable at the federal level, we multiply the yield by (1 – 0.35) where 0.35 is the statutory federal corporate tax rate. Similarly we multiply the T-bill and CD yields by (1 – 0.35).[21] This adjustment assumes that the marginal investor is a taxable corporation, that the effective federal marginal tax rate is the statutory corporate tax rate, and that the effective marginal tax rate is stable over time. To capture any federal tax effect not picked up by this tax adjustment, we also include an indicator to identify ARS that are taxable at the federal level.

We further include the state and AMT tax indicators along with the indicators for the ARS bond characteristics used in the regressions of column (1) of Table 4. We exclude failed auctions from the analysis.

As shown in columns (2) and (3), after adjusting for tax status and controlling for bond characteristics, ARS provided significantly higher returns than both T-bill and CD. The excess returns are also economically significant. ARS provided a return of 25 basis points per year greater than T-bill and a return of 8 basis points per year greater than CD.

We now consider only the period between the first auction failure in our sample, the first week of September 2007, through the second week of January 2008. We present the averages of the coefficients of the weekly cross-sectional regressions in columns (4) - (6) of Table 4.

[21]Because there is uncertainty about the magnitude of the marginal tax rate, see for example Ang, Bhansali, and Xing (2008) and Longstaff (2008a), we conduct sensitivity analysis by varying the tax rate from 30% to 60%. The coefficients of the intercepts are similar to those reported in Table 4.

As shown in the table, after controlling for bond characteristics and adjusting for taxes, the average spread between ARS yields and the yields of the cash equivalent alternatives widened considerably in the last four months of 2007 and into 2008. Of particular note, in the regression of column (4), in which we include only tax-exempt ARS and tax-exempt MMF, the average spread is 48 basis points. This compares with a spread of 26 basis points in the parallel regression in column (1). Apparently investors became increasingly concerned about possible auction failures during the fall of 2007 and into January of 2008 and, as a consequence, increased their required yields relative to those of various cash equivalent alternatives.

## 6.2. ARS Yields vs. VRDO Yields

According to the analysis above, ARS provided yields significantly above certain cash equivalent alternatives. Whether those are the appropriate benchmark for this analysis is unclear. As an alternative benchmark, we compare ARS yields with yields of VRDO.

As we describe in Sections 1 and 2, when an auction fails, investors who are holding the securities immediately prior to the failure are stuck with the securities until the next successful auction. Investors are stuck because they have, in essence, sold a put option to the bond issuer that allows the issuer to put the bond to the investor at par at any auction date. Should the auction fail, the investor is stuck holding a security that is providing a less than market required yield.

VRDO are like ARS in that VRDO yields reset at periodic intervals and most VRDO are issued by government-related entities. With VRDO, the yields are reset by re-marketing agents who canvass the market for buyers and sellers. VRDO differ from ARS in that, with a VRDO, the investor can "put" the bond to the re-marketing agent at par on any reset date. It is the re-marketing agent's responsibility to locate a new investor for the bond. If the re-marketing agent cannot place the bond with a new investor, a "liquidity provider" guarantees liquidity. That is, the liquidity provider stands ready to buy the bonds at par at every auction. Liquidity is assured either by means of a letter of credit (LOC) or a stand-by purchase agreement (SPA) in combination with bond insurance. The LOC and SPA are customarily issued by large commercial banks. The insurance is customarily provided by one of the monoline bond insurers.

The important point is that VRDO eliminate the possibility that the investor will be stuck with a bond providing a below market yield. Thus, after controlling for differences in bond characteristics, the difference in yields between ARS and VRDO, if any, can be attributed to the price of the put option embedded in the ARS bond structure. To state it slightly differently, after controlling for differences in bond characteristics, the difference in yields, if any, between ARS and VRDO, can be thought of as the reward for the risk of being stuck with an illiquid bond.

As in Table 4, to conduct the tests, we run weekly cross-sectional regressions and report the averages of the weekly coefficients for the two time periods of January 2003 through the second week of January 2008 and from the first week of September 2007 though the second week of January 2008. The estimated coefficients are reported in Table 5 along with the relevant t-statistics.

To increase comparability between ARS and VRDO, and as described in Section 4, we use VRDO issued by the same issuers as the issuers of the ARS in our sample. Because ARS and VRDO can have different maturities, different face values, different credit ratings, different insurance status, and different tax status, we include Maturity, Face Value, Rating $<$ AAA, Insured, and Federal, State, and AMT Taxable as independent variables.

The dependent variable in the regression is the yields of both the ARS and the VRDO. To test whether ARS yields differ from VRDO yields, we include, as an independent variable, an indicator (ARS) that is set to one if the issue is an ARS. The coefficient of the indicator measures the difference between the yields of ARS and VRDO after controlling for differences in bond characteristics. We interpret the coefficient of this variable as indicating whether and to what extent investors priced the put option embedded in ARS bonds.

Each regression is estimated with issuer fixed effects because some issuers have issued more than one ARS or VRDO in the sample.

Results of the analyses are reported in Table 5. As shown in column (1) ARS yields were not greater than VRDO yields over the full period. Indeed, over this time period, the coefficient of the ARS indicator variable is negative and significant. On average, annualized ARS bond yields were 10 basis points less than yields of VRDO. Given the structures of the bonds, this result is puzzling. One reasonable possibility is that an auction is a more competitive pricing mechanism than is the periodic resetting of VRDO yields by a re-marketing agent.

Column (2) gives the coefficients of the regressions estimated over the period that begins with the first week of September 2007 and ends with the second week of January 2008. Over this time period, the coefficient of the ARS indicator variable is positive and statistically significant. Further, the spread is economically significant at 25 basis points per year. Thus, over the period following the first auction failure of 2007, ARS yields did incorporate a price for the bonds embedded put option. To better illustrate this phenomenon, we plot the time-series of weekly estimates of the coefficient of the ARS indicator variable in Figure 4. This coefficient measures the average difference between ARS yields and VRDO yields each week after controlling for bond characteristics.

The spread between ARS and VRDO yields was close to zero during September and October, but started increasing in November, reached 99 basis points during the last week of December of 2007, and increased further during the first week of January 2008. One interpretation of this finding is that, prior to November 2007, investors viewed the possibility of being stuck with an ARS as remote. As the likelihood of being stuck increased, the price of the put embedded in the ARS increased during the fall of 2007 and into the winter of 2008. The increase in the value of the put showed up as an increase in ARS bond yields relative to VRDO yields.

Thus, we cannot determine whether any individual investor was misled about the liquidity of ARS. However, according to the results in Tables 3 and 4 and in Figure 4, regardless of whether we use MMF, T-bill, CD, or VRDO as the benchmark, market participants were not pricing ARS as if they were cash equivalent securities.

### 6.3. Contagion from the Subprime Market

Beginning in the late fall of 2006 and continuing through 2007 and into 2008, a series of difficulties engulfed the U.S. and world financial markets. The origins of the difficulties appear to have begun with a general decline in U.S. residential real estate prices that was followed by a wave of defaults of so-called subprime mortgages in tandem with the failure of a number of major subprime mortgage originators. These, in turn, lead to a decline in the prices of securities backed by subprime mortgages. Much of the dollar value of the asset backed securities was held by certain large commercial banks, certain investment banks, and some marquee-name hedge funds. As the banks and funds wrote down the values of their portfolios, the levels of their equity capital shrank. The decline in the value of their assets and capital led to the failure or near failure of several major banks and funds.

Perhaps the most high-profile funds were two Bear Stearns & Co. funds — the High-Grade Structured Credit Strategies Enhanced Leverage Fund and the High-Grade Structured Credit Fund — both of which had heavy concentrations of asset backed securities in their portfolios and both of which announced suspensions of redemptions during the summer of 2007. Further evidence of the difficulties were the asset backed writedowns of $8.5 billion announced by Merril Lynch Pierce Fenner & Smith, Inc. in October of 2007 and the writedown of $14.0 billion announced by UBS AG in early January of 2008.

It was against this climate of difficulties in the subprime asset backed securities market that the ARS auction failures of 2008 occurred. The close proximity in time of difficulties in the subprime mortgage market and the auction failures led some commentators to speculate that the auction failures occurred as a result of a financial contagion spreading from subprime asset backed securities to ARS:

> Today we're witnessing another kind of contagion, not so much across countries as across markets. Troubles that began a little over a year ago in an obscure corner of the financial system, BBB-minus-subprime-mortgage-backed securities, have spread ... to the market for auction-rate securities. (Krugman (February 15, 2008), A crisis of faith, The New York Times, 23.)

As the analyses of Sections 6.1 and 6.2 illustrate, the spreads between the yields of ARS and the cash equivalent alternatives widened in late 2007 and early 2008. The spreads widened further into January and February of 2008 in concert with the ARS auction failures. The question is whether the increase in ARS yields that occurred in tandem with the auction failures can reasonably be attributed to a contagion from the subprime asset backed securities market.

One of the difficulties of testing this conjecture is identifying a precise definition of contagion and then constructing a reasonable test. To this end, Longstaff (2008b) has put forth a framework for conducting such a test. Longstaff proposes that a contagion has occurred when there is an increase in the predictive power of returns from one type of security to those of another type (or types) of securities. In his case, he tests whether there was an increase in the predictive power of returns from subprime asset backed securities for the returns of t-bonds and common stocks during the "subprime crisis of 2007." He finds that there was an increase in predictive power during 2007 relative to the prior year and concludes that these results provide strong support for a contagion spreading from subprime securities to t-bonds and equities (Longstaff, 2008b, p. 15).

We adopt and expand upon Longstaff's framework. We adopt his framework to test whether the increase in ARS auction failures that occurred during the first six months of 2008 can reasonably be attributed to a contagion spreading from subprime asset backed securities to ARS. We expand upon his framework to test whether the auction failures can instead be attributed to an increase in credit concerns more broadly.

In both analyses, we use a vector autoregressive model. In the first analysis, we test whether asset backed security (ABX) returns had predictive power for changes in ARS yields during 2006, 2007, and the first half of 2008. In the second analysis, we test whether changes in credit default swap (CDX) spreads had predictive power for changes in ARS yields over the same time periods. We acknowledge that our decision to conduct the tests over the three discrete time periods is influenced by Longstaff who demarcates 2007 as the beginning of the subprime asset backed securities crisis.

In the analyses, we run time-series regressions where the dependent variable is the log change of the weekly average yield of all successful ARS auctions and the independent variables are lags, up to four weeks, of the log change in the weekly average ARS yield and lags, again up to four weeks, of the log change of weekly ABX index prices or lags of the log change of CDX spreads. With ABX, we run separate regressions for 2006, 2007, and the first six months of 2008 for indexes with ratings of AAA, AA, A, BBB, and BBB-. With CDX, we run separate regressions for 2006, 2007, and the first six months of 2008.

The results of the analysis are presented in Table 6. Panels A, B, and C give the results for 2006, 2007, and 2008, respectively. Columns (1) through (5) give the results for AAA, AA, A, BBB, and BBB- ABX indexes, respectively, and column (6) gives the results for CDX spreads. The columns give the t-statistics of the estimated coefficients of the lagged ABX (or CDX) price (spread) changes, the $R^2$ of the regression, and the p-value of a joint significance test in which the null hypothesis is that the coefficients of the lags of the log ABX (or CDX) price (spread) changes are jointly equal to zero.

For our purposes, the key statistic is the p-value of the joint significance test. As shown in the table, if 2007 is defined as the year of the subprime asset backed securities crisis, then an argument can be made that the increase in ARS yields that occurred during 2007 was caused by a contagion spreading from asset backed securities to ARS. Such an argument can be sustained because the p-values of the joint test during 2007 are less than 0.001 for each series of ABX prices. In contrast, during 2006, only the p-value of the A index at 0.104 approaches statistical significance. The fly in the ointment are the p-values for 2008. It was during 2008 that the ARS auction failures occurred. During 2008, the p-values of the joint test do not approach statistical significance. On that basis, it is difficult to support an argument that the auction failures were due to a contagion spreading from asset backed securities to ARS.

The results with CDX spreads in column (6) paint a different picture. The p-values here suggest no or only mild predictive power of CDX index prices for ARS yields during 2006 and 2007 — the p-values are 0.18 and 0.11, respectively. However, during the first six months of 2008, the p-value drops to 0.002. Thus, during the first six months of 2008, credit default swaps have significant predictive power for ARS yields.

One interpretation of significant predictive power of CDX for ARS yields is that the increase in ARS yields, and the related auction failures, that occurred during 2008 were the result of a broad-based or market-wide concern with credit risk generally. Of course, it might be argued that this concern was a direct outgrowth of difficulties that were being experienced with subprime asset backed securities during 2007 and, therefore, ARS auction failures were the result of a contagion that began with subprime asset backed securities and that eventually spread to encompass all financial assets. If that is the case, then, almost by definition, ARS auction failures were merely another manifestation of a contagion that spread from asset backed securities to encompass all financial markets and it is difficult to envision a test that would reject that hypothesis.

# 7. Conclusions

In this study we investigate the market for auction rate securities (ARS) prior to and during the wave of auction failures that occurred during the winter through the spring and into the summer of 2008. Headline stories have attribute these failures to "irrationality" on the part of investors and hint that market participants were unwilling to bid for the bonds at any price. We conjecture that market participants recognized that ARS bond yields are capped by maximum auction rates that limit the yield that the bonds can pay. Further, we hypothesize that if the market clearing yields of bonds that experienced auction failures had been observable, they would have been above the bonds maximum auction rates. Thus, investors quite reasonably did not bid at these auctions.

Consistent with our hypothesis, we find that, after controlling for other bond characteristics in a multivariate analysis, the likelihood of auction failure was negatively and significantly related to the level the bonds maximum auction rates — the lower the maximum auction rate, the higher the likelihood of auction failure. We then estimate cross-sectional and panel regression models of market clearing yields based on ARS bonds with successful auctions and use these to calculate implied market clearing yields of ARS with failed auctions. We find that in over 80% of the cases in which an auction failed, the implied market clearing ARS yield was above the bonds maximum auction rate. This result is also consistent with our hypothesis.

We then address the question of whether ARS yields compensated investors for bearing the risk of being "stuck" with an ARS bond because of an auction failure. Here we find that, after controlling for bond characteristics, ARS did provide higher returns than money market funds, treasury bills, and certificates of deposit. Further, at least in the months immediately prior to the rash of auctions failures that occurred during the second week of February 2008, ARS yields exceeded yields of Variable Rate Demand Obligations (VRDO). The importance of this finding is that the only difference between the ARS and VRDO is that in the one case (i.e. ARS), the investor can be "stuck" with a bond providing a below market yield, whereas, in the other case (i.e. VRDO), investors have an unlimited option to put the bond to the bond "re-marketing agent" should the agent be unable to locate a buyer of the bond at each interest reset date. The implication is that market participants were pricing ARS bonds so as to be compensated for the risk of auction failure.

Finally, using a vector autoregressive model, we conduct tests to determine whether the ARS auction failures of 2008 can be reasonably attributed to a contagion spreading from subprime asset backed securities to ARS. The tests do not lend support to that hypothesis.

Overall, the results of our analysis are reassuring for economists who are likely to be mystified with the idea that auctions can fail. After all, there must be some price at which investors are willing to buy any asset. In the case of failed ARS auctions, those prices were apparently unobservable in that they lay above the bonds maximum auction rates. Our analysis suggests that in the absence of the bonds embedded maximum auction rates, most, if not all, auctions would have been successful.

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## Figure 1: Fraction of Failed ARS Auctions

This figure plots the weekly time-series of the fraction of failed auctions for a sample of 793 ARS bonds over the time period from the first week of September 2007 through the second week of July 2008. An auction is classified as a failed auction if the reset rate reported by *Bloomberg* is equal to the maximum auction rate that is computed as of the day of the auction based on our reading of the bond's Official Statement. Data is from *Bloomberg*.

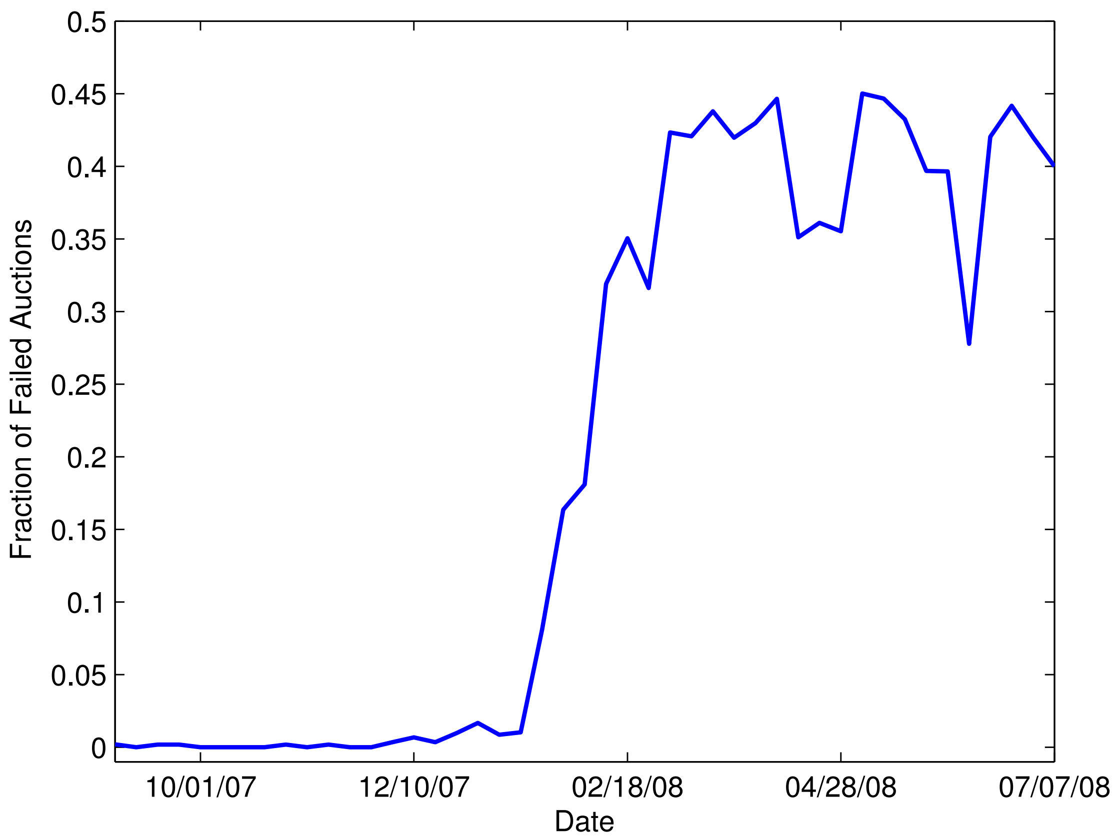
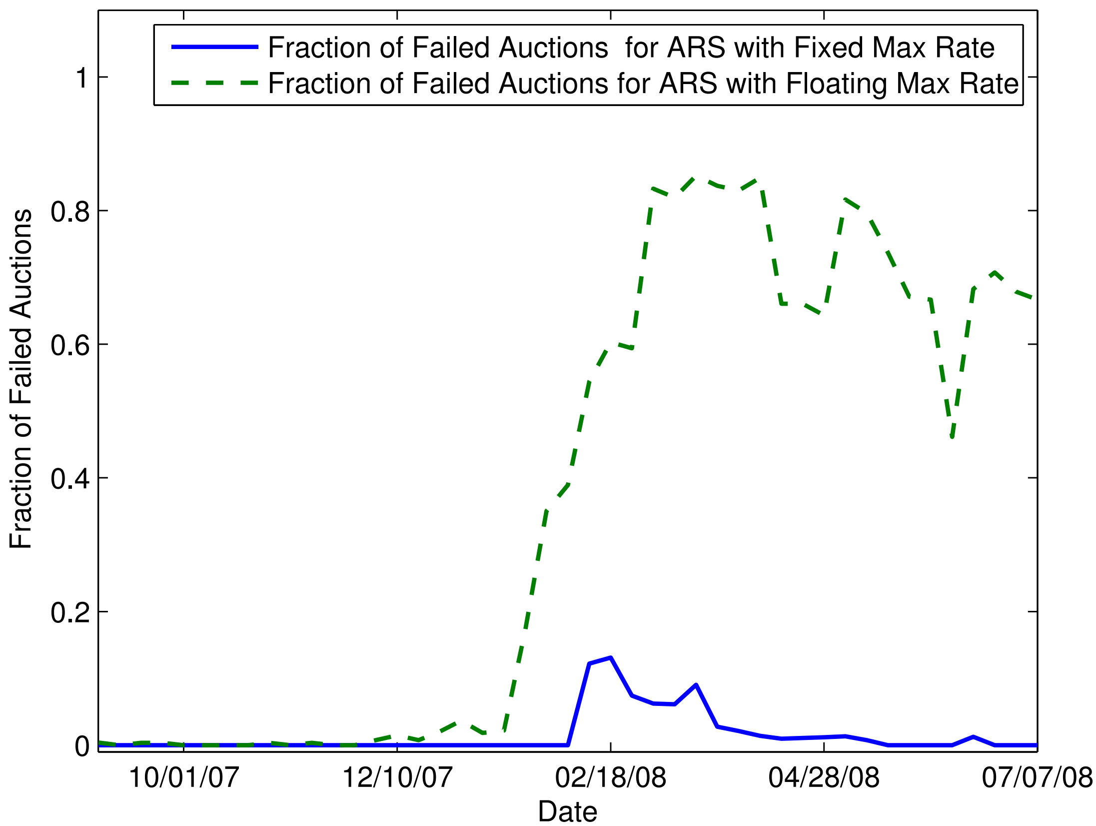


**Figure 2: Fraction of Failed ARS Auctions by Type of Maximum Auction Rate**

This figure plots the weekly time-series of the fraction of failed auctions for a sample of 793 ARS bonds over the time period from the first week of September 2007 through the second week of July 2008. ARS bonds are divided into two groups according to the type of maximum auction rate. An auction is classified as a failed auction if the reset rate reported by *Bloomberg* is equal to the maximum auction rate that is computed as of the day of the auction based on our reading of the bond's Official Statement. The solid (dashed) line plots the fraction of failed auctions for bonds with fixed (floating) maximum auction rates. Data is from *Bloomberg*.



## Figure 3: Fraction of Failed ARS Auctions Explained by the Models

This figure plots the fraction of failed auctions for each week for which the market clearing yield implied by the models is above the bonds maximum auction rate over the time period from the first week of September 2007 through the second week of July 2008. An auction is classified as a failed auction if the reset rate reported by *Bloomberg* is equal to the maximum auction rate that is computed as of the day of the auction based on our reading of the bond's Official Statement. The model implied yields are computed using the models described in Section 5.4. The asterisks represent the fraction of failed auctions correctly predicted as failed using the panel regression model; the crosses represent the fraction of failed auctions correctly predicted as failed using the cross-sectional regression model. Data is from *Bloomberg*.

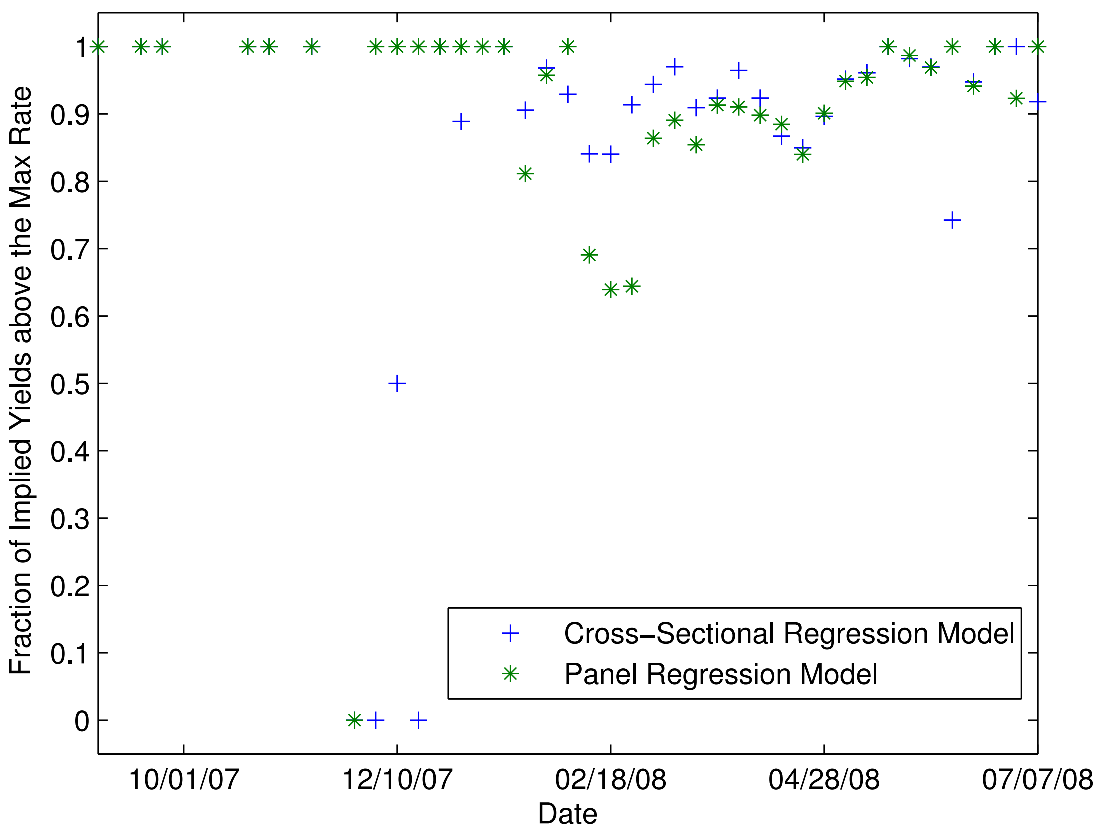
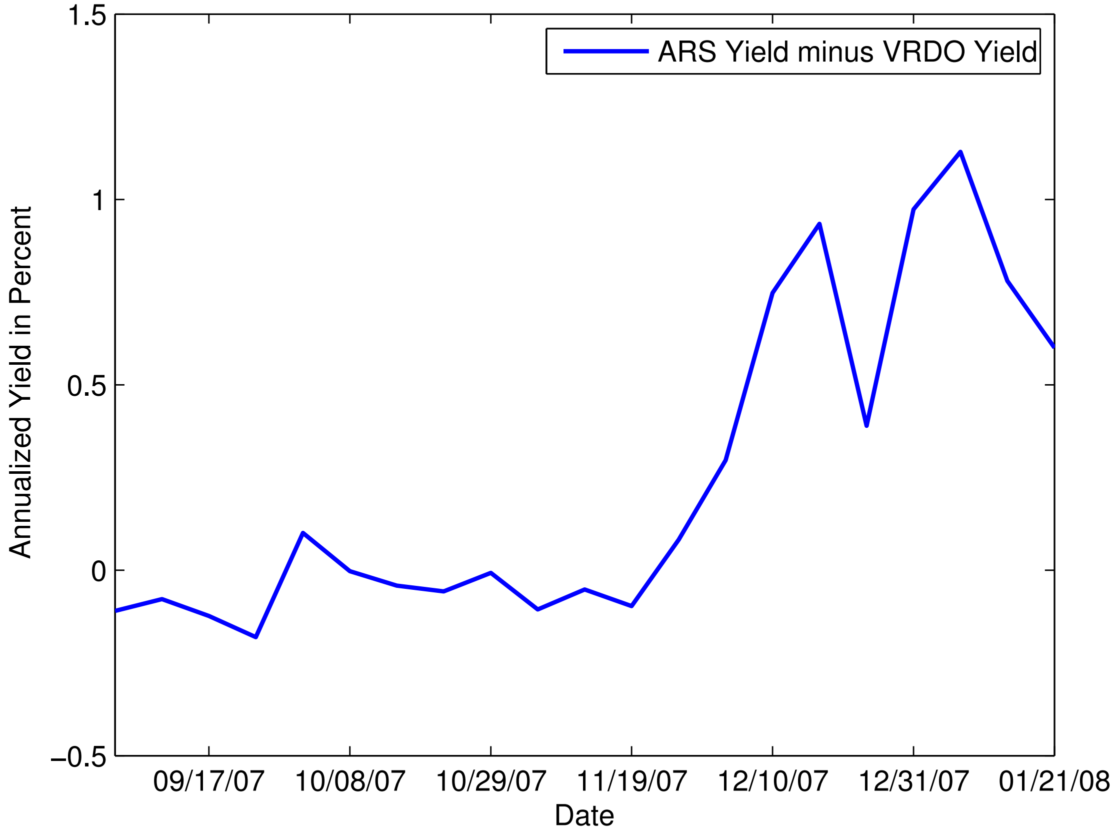


**Figure 4: Estimated Difference Between ARS and VRDO Yields**

This figure plots the time series of the weekly estimated coefficients of the ARS indicator variable obtained from specification (2) of the regression model reported in Table 5. The coefficient is an estimate of the weekly average difference between ARS and VRDO yields after controlling for maturity, tax status, credit rating, face value and insurance status of the bonds. The sample is composed of 793 ARS bonds and 905 "matching" VRDO bonds. The sample encompasses the time period from the first week of September 2007 through the second week of January 2008. Data is from *Bloomberg*.



## Table 1: Descriptive Statistics for ARS Bonds

This table presents selected descriptive data by year of issuance for ARS bonds outstanding as of March 15, 2008. Column 1 gives the year of issuance. Column 2 gives the number of bond issues. Columns 3-6 give the number of bonds issued in each respective year with the respective auction interval. Column 7 gives the aggregate dollar amount of bonds issued in each respective year. Column 8 gives the average maturity of the bonds issued in each respective year. Column 9 gives the fraction of issues that are tax-exempt at the federal level in each respective year. Column 10 gives the fraction of issues that are insured by a monoline insurer in each respective year. Data is from *Bloomberg*.

| Year | Number of Issues | Number of Issues by Auction Interval | | | | Total Face Value (in Mil $) | Average Maturity (in Years) | Fraction of Tax-Exempt Issues | Fraction of Insured Issues |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 day | 7 days | 28 days | 35 days | | | | |
| 1985 | 7 | 1 | 4 | 0 | 2 | 397.3 | 35.0 | 1.000 | 0.857 |
| 1986 | 1 | 0 | 0 | 0 | 1 | 50.0 | 40.0 | 1.000 | 1.000 |
| 1987 | 3 | 0 | 0 | 0 | 3 | 119.0 | 40.0 | 1.000 | 1.000 |
| 1988 | 17 | 0 | 3 | 3 | 11 | 761.5 | 26.1 | 1.000 | 0.941 |
| 1989 | 5 | 0 | 0 | 0 | 5 | 176.5 | 30.2 | 1.000 | 0.600 |
| 1990 | 8 | 0 | 2 | 0 | 6 | 310.3 | 33.3 | 1.000 | 0.375 |
| 1991 | 81 | 2 | 1 | 3 | 75 | 1,769.8 | 28.9 | 1.000 | 0.642 |
| 1992 | 129 | 1 | 12 | 6 | 110 | 2,938.3 | 25.9 | 0.992 | 0.752 |
| 1993 | 277 | 5 | 10 | 4 | 258 | 3,798.7 | 20.8 | 1.000 | 0.643 |
| 1994 | 134 | 4 | 21 | 10 | 98 | 3,764.4 | 23.4 | 0.881 | 0.597 |
| 1995 | 116 | 0 | 20 | 17 | 79 | 4,087.8 | 26.1 | 0.698 | 0.414 |
| 1996 | 88 | 0 | 8 | 15 | 65 | 2,758.0 | 26.9 | 0.682 | 0.398 |
| 1997 | 107 | 0 | 20 | 21 | 66 | 4,317.7 | 28.7 | 0.776 | 0.467 |
| 1998 | 161 | 6 | 25 | 42 | 88 | 6,352.0 | 26.8 | 0.689 | 0.410 |
| 1999 | 206 | 9 | 57 | 49 | 91 | 8,529.3 | 25.7 | 0.704 | 0.534 |
| 2000 | 287 | 3 | 104 | 90 | 90 | 12,645.3 | 27.3 | 0.655 | 0.477 |
| 2001 | 316 | 5 | 99 | 101 | 111 | 14,772.8 | 28.0 | 0.722 | 0.576 |
| 2002 | 497 | 6 | 156 | 146 | 189 | 26,143.7 | 28.8 | 0.714 | 0.588 |
| 2003 | 732 | 8 | 256 | 168 | 300 | 38,064.2 | 26.3 | 0.820 | 0.686 |
| 2004 | 755 | 5 | 351 | 167 | 232 | 39,631.4 | 27.1 | 0.797 | 0.732 |
| 2005 | 563 | 5 | 338 | 88 | 132 | 29,090.3 | 28.0 | 0.842 | 0.748 |
| 2006 | 531 | 2 | 317 | 116 | 96 | 30,191.3 | 29.1 | 0.729 | 0.678 |
| 2007 | 603 | 8 | 418 | 93 | 84 | 35,671.2 | 28.2 | 0.826 | 0.731 |
| 2008 | 12 | 0 | 12 | 0 | 0 | 162.0 | 14.9 | 0.917 | 0.417 |
| Total/Average | 5,636 | 70 | 2,234 | 1,139 | 2,192 | 266,502.8 | 27.2 | 0.793 | 0.646 |

### Table 2: Coefficients of a Logit Model of ARS Auction Failures

This table presents estimated coefficients of an ARS auction failure model. An auction is classified as a failed auction if the reset rate reported by *Bloomberg* is equal to the maximum auction rate that is computed as of the day of the auction based on our reading of the bond's Official Statement. The conditional failure probability is modeled as a logistic distribution. For each week in the sample beginning with the third week of January 2008, we run a cross-sectional logit model. Maturity is the log of the remaining term to maturity of the bond as of the auction date; Face Value is the log of the original dollar amount of the issue; Rating < AAA is an indicator variable equal to one for issues rated less than AAA; Insured is an indicator variable equal to one if the bond is insured; Max Rate is the level of the maximum auction rate; Floating Max Rate is an indicator variable equal to one if the bond has a floating max rate. Reported parameters are obtained by averaging the time-series of the weekly estimated coefficients for each variable *a la* Fama and MacBeth (1973). The $t$-statistics, reported in parenthesis, are corrected for autocorrelation as in Newey and West (1987). The reported pseudo-$\overline{R}^2$ is the time-series average of the weekly regression pseudo-$R^2$. The sample is composed of 793 ARS bonds for which we have time-series of credit ratings and have identified at least one VRDO. The data used to obtain the estimates reported in this table encompasses the time period from the third week of January 2008 (W3 Jan-08) through the second week of July 2008 (W2 Jul-08). Data is from *Bloomberg*.

| | W3 Jan-08 – W2 Jul-08 | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Intercept | 4.513 | 2.506 | -5.811 |
| | (6.21) | (6.81) | (-1.28) |
| Maturity | -1.237 | 0.804 | -0.614 |
| | (-5.87) | (6.09) | (-3.66) |
| Face Value | -0.593 | -0.215 | -0.669 |
| | (-6.00) | (-1.73) | (-5.16) |
| Insured | 0.867 | 0.419 | 2.932 |
| | (1.79) | (1.27) | (1.02) |
| Rating < AAA | -0.071 | -0.267 | -0.469 |
| | (-0.60) | (-1.56) | (-2.99) |
| Max Rate | | -0.776 | |
| | | (-10.55) | |
| Floating Max Rate | | | 8.690 |
| | | | (5.09) |
| pseudo-$\overline{R}^2$ | 0.103 | 0.572 | 0.552 |

## Table 3: Regression Model of ARS Market Clearing Yields

This table presents estimated coefficients of linear regression models of ARS yields based on ARS bond characteristics. We estimate two models: the first is a cross-sectional model that we re-estimate every week; the second is a panel regression model that we estimate using all available data. The dependent variable is the annualized yield of the ARS bonds. Maturity is the log of the remaining term to maturity of the bond as of the auction date; Face Value is the log of the dollar amount of the issue; Federal (State) Taxable is an indicator variable equal to one if the issue is taxable at the federal (state) level; AMT Taxable is an indicator variable equal to one if the bond is subject to the alternative minimum tax calculation; Insured is an indicator variable equal to one if the bond is insured; Rating < AAA is an indicator variable equal to one for issues rated less than AAA; Floating Max Rate is an indicator variable equal to one if the bond has a floating maximum auction rate; Moneyness is the ratio of the bond yield as of the week of the auction to the bonds max rate; Sigma is the conditional volatility of the bonds yields as predicted by a GARCH(1,1) model; LIBOR is the London Interbank Offer Rate as of the week of the auction, and CDX Spread is the average spread of five-year credit default swaps for investment grade corporations as of the week of the auction. Each specification also includes issuer fixed effects. Reported coefficients in Column (1) are obtained by averaging the time-series of the weekly cross-sectional regression coefficients as in Fama and MacBeth (1973). The relative $t$-statistics, reported in parenthesis, are corrected for autocorrelation as in Newey and West (1987). The reported $\overline{R}^2$ is the time-series average of the weekly adjusted $R^2$. Reported coefficients in Column (2) are from the panel regression. The relative $t$-statistics, reported in parenthesis, are corrected for autocorrelation as in Newey and West (1987) and are clustered at the issuer level. The sample is composed of 793 issues for which we have time-series of credit ratings and have identified at least one VRDO. The data used to obtain the estimates reported in this table encompasses the time period from the first week of September 2007 (W1 Sept-07) through the second week of July 2008 (W2 Jul-08). Data is from *Bloomberg*.

| | W1 Sep-07 – W2 Jul-08 | |
|---|---|---|
| | Cross-Sectional Regression | Panel regression |
| | (1) | (2) |
| Intercept | 1.565 | -1.347 |
| | (8.07) | (-4.70) |
| Maturity | 0.228 | 0.210 |
| | (9.72) | (4.07) |
| Face Value | 0.001 | 0.017 |
| | (0.11) | (0.52) |
| Federal Taxable | 0.793 | 0.786 |
| | (5.64) | (5.05) |
| State Taxable | 0.322 | 0.262 |
| | (6.31) | (2.70) |
| AMT Taxable | 0.365 | 0.340 |
| | (5.76) | (2.19) |
| Insured | -0.015 | -0.197 |
| | (-0.28) | (-1.40) |
| Rating $<$ AAA | 0.258 | 0.066 |
| | (8.16) | (0.88) |
| Floating Max Rate | -2.231 | -1.434 |
| | (-8.53) | (-14.34) |
| Moneyness | 4.659 | 4.271 |
| | (9.96) | (13.53) |
| Sigma | 0.037 | 0.051 |
| | (4.10) | (29.67) |
| LIBOR | | 0.550 |
| | | (15.45) |
| CDX Spread | | 0.960 |
| | | (11.10) |
| $\overline{R}^2$ | 0.677 | 0.806 |

## Table 4: Regression Model of ARS Yields versus Yields of Cash Equivalent Investment Alternatives

This table presents estimated coefficients of weekly cross-sectional regressions of the difference between ARS yields and the yields of cash equivalent investment alternatives against ARS bond characteristics. The dependent variable is the difference between the yield of an ARS bond and the yield of the one of the short-term investment alternatives. MMF is the average yield of a portfolio of 107 money market funds that invest in tax-exempt securities; T-BILL is the 30-day constant maturity Treasury bill yield; CD is the 7-day average certificate of deposit rate. The regressions corresponding to Columns (1) and (4) use only ARS yields of bonds that are not taxable at the federal level and are not subject to the alternative minimum tax. The regressions corresponding to Columns (2), (3), (5) and (6) use ARS yields of all bonds, irrespective of their tax status, however, if an ARS bond is taxable, we multiply the yield by $(1 - 0.35)$; we multiply the yield of T-Bill and CD by $(1 - 0.35)$. The independent variables are a set of indicators: Long vs Short is equal to one if the remaining term to maturity of the bond is greater than the average term to maturity of the bonds in the sample; Large vs Small is equal to one if the dollar amount of the issue is greater than the average dollar amount of the bonds in the sample; Federal (State) Taxable is equal to one if the issue is taxable at federal (state) level; AMT is equal to one if the bond is subject to the alternative minimum tax; Not Insured is equal to one if the bond is not insured by one of the monoline bond insurers; Rating < AAA is equal to one if the bond rating is less than AAA. Reported coefficients are obtained by averaging the time-series of the weekly cross-sectional regression coefficients as in Fama and MacBeth (1973). The $t$-statistics, reported in parenthesis, are corrected for autocorrelation as in Newey and West (1987). The reported $\overline{R}^2$ is the time-series average of the weekly cross-sectional adjusted $R^2$. The sample is composed of 793 ARS bonds for which we have time-series of credit ratings and have identified at least one VRDO. The data used to obtain the estimates reported in this table encompass the time period from the first week of January 2002 (W1 Jan-02) through the second week of January 2008 (W2 Jan-08). Data is from *Bloomberg*.

| | W1 Jan-03 — W2 Jan-08 | | | W1 Sep-07 — W2 Jan-08 | | |
|---|---|---|---|---|---|---|
| Cash Equivalent | MMF | T-BILL | CD | MMF | T-BILL | CD |
| Investment Alternative: | (1) | (2) | (3) | (4) | (5) | (6) |
| Intercept | 0.259 | 0.253 | 0.082 | 0.482 | 1.284 | 0.392 |
| | (17.67) | (6.49) | (3.79) | (4.71) | (9.20) | (4.03) |
| Long vs Short Maturity | 0.016 | 0.011 | 0.012 | 0.087 | 0.086 | 0.089 |
| | (3.98) | (2.33) | (2.40) | (7.96) | (7.17) | (8.29) |
| Small vs Large Size | 0.037 | 0.041 | 0.040 | 0.047 | 0.040 | 0.040 |
| | (11.86) | (10.65) | (10.42) | (2.77) | (2.52) | (2.51) |
| Federal Taxable | | -0.178 | -0.178 | | -0.237 | -0.247 |
| | | (-11.92) | (-11.98) | | (-4.55) | (-4.67) |
| State Taxable | 0.225 | 0.251 | 0.249 | 0.162 | 0.161 | 0.164 |
| | (7.02) | (6.92) | (6.85) | (12.33) | (9.05) | (9.71) |
| AMT Taxable | | 0.258 | 0.258 | | 0.561 | 0.561 |
| | | (12.12) | (12.07) | | (4.37) | (4.30) |
| Not Insured | 0.014 | 0.006 | 0.008 | -0.226 | -0.218 | -0.214 |
| | (1.56) | (0.63) | (0.91) | (-9.54) | (-9.84) | (-9.40) |
| Rating < AAA | 0.105 | 0.104 | 0.106 | 0.601 | 0.602 | 0.598 |
| | (6.53) | (6.52) | (6.69) | (16.64) | (16.60) | (16.06) |
| $\overline{R}^2$ | 0.134 | 0.246 | 0.245 | 0.161 | 0.195 | 0.200 |

## Table 5: Regression Model of ARS Yields versus VRDO Yields

This table presents estimated coefficients of weekly pooled cross-sectional regressions of ARS yields and VRDO yields on bond characteristics. The dependent variable is the annualized yield of ARS and VRDO as of the week of the auction. ARS is an indicator set to one when the issue is an ARS; Maturity is the log of the remaining term to maturity of the bond as of the auction date; Face Value is the log of the original dollar amount of the issue; Federal (State) Taxable is an indicator variable equal to one if the issue is taxable at the federal (state) level; AMT is an indicator variable equal to one if the bond is subject to the alternative minimum tax calculation; Insured is an indicator variable equal to one if the bond is insured; Rating < AAA is an indicator variable equal to one for issues rated less than AAA; Sigma is the conditional volatility of yields as predicted by a GARCH(1,1) model as of the week of the auction. Each regression specification includes issuer fixed effects. Reported coefficients are obtained by averaging the time-series of the weekly cross-sectional regression coefficients as in Fama and MacBeth (1973). The $t$-statistics, reported in parenthesis, are corrected for autocorrelation as in Newey and West (1987). The reported $\overline{R}^2$ is the time-series average of the weekly adjusted $R^2$. The sample is composed of 793 ARS bonds and 905 VRDO bonds for which we have time-series of credit ratings. The data used to obtain the estimates reported in this table encompasses the time period from the first week of January 2003 (W1 Jan-03) through the second week of January 2008 (W2 Jan-08). Data is from *Bloomberg*.

| | W1 Jan-03 – W2 Jan-08 | W1 Sep-07 – W2 Jan-08 |
|---|---|---|
| | (1) | (2) |
| Intercept | 2.273 | 3.077 |
| | (23.61) | (20.19) |
| ARS | -0.101 | 0.247 |
| | (-6.35) | (2.01) |
| Maturity | 0.002 | 0.005 |
| | (11.32) | (13.36) |
| Face Value | -0.009 | -0.004 |
| | (-30.57) | (-1.87) |
| Federal Taxable | 0.930 | 1.491 |
| | (16.78) | (19.00) |
| State Taxable | 0.093 | 0.109 |
| | (15.72) | (6.40) |
| AMT Taxable | 0.110 | 0.129 |
| | (51.20) | (13.36) |
| Insured | -0.008 | 0.055 |
| | (-2.62) | (2.50) |
| Rating < AAA | 0.017 | 0.062 |
| | (13.01) | (14.14) |
| Sigma | 1.698 | 5.710 |
| | (4.06) | (3.35) |
| $\overline{R}^2$ | 0.819 | 0.747 |

## Table 6: Contagion

This table reports $t$-statistics of the parameters of the following regression:

$$\Delta \log ARS_t = \gamma_0 + \sum_{k=1}^{4} \gamma_{1k} \Delta \log ARS_{t-k} + \sum_{k=1}^{4} \gamma_{2k} X_{t-k} + \epsilon_t$$

where $\Delta \log ARS$ is the weekly log change of the average yield of all successful ARS auctions, and X is either the weekly log change of ABX index prices or the weekly log change of the CDX index spreads. ABX is an index of asset backed security prices. AAA, AA, A, BBB, and BBB- refer, respectively, to indexes composed of asset backed securities rated AAA, AA, A, BBB, and BBB-. CDX is an index of credit default swap spreads for investment grade U.S. corporations. The tables also gives the $R^2$ and the p-value, $P(\gamma_2 = 0)$, of a joint significance test in which the null hypothesis is that the coefficients of the lags of log ABX price changes or the log CDX index spread changes are jointly equal to zero. The data used encompass the period from the first week of January 2006 (W1 Jan-06) through the second week of July 2008 (W2 Jul-08). Data is from *Bloomberg*.

| | $\Delta \log ABX$ | | | | | $\Delta \log CDX$ |
|---|---|---|---|---|---|---|
| | AAA | AA | A | BBB | BBB- | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | Panel A: W1 Jan-06 – W4 Dec-06 | | | | | |
| $\gamma_{21}$ | -0.519 | -0.309 | -2.364 | -1.693 | -0.913 | 0.542 |
| $\gamma_{22}$ | 1.187 | 1.502 | 2.194 | 1.865 | 1.956 | 1.000 |
| $\gamma_{23}$ | -0.852 | -0.711 | -1.131 | 0.326 | 0.151 | -1.979 |
| $\gamma_{24}$ | -0.686 | 0.258 | -0.994 | -1.673 | -2.139 | 1.304 |
| $P(\gamma_2 = 0)$ | 0.612 | 0.714 | 0.104 | 0.169 | 0.132 | 0.182 |
| $R^2$ | 0.491 | 0.485 | 0.540 | 0.529 | 0.535 | 0.525 |
| | Panel B: W1 Jan-07 – W4 Dec-07 | | | | | |
| $\gamma_{21}$ | 0.019 | 0.977 | 2.218 | 3.592 | 2.963 | 0.339 |
| $\gamma_{22}$ | -1.083 | -0.883 | -0.336 | -0.540 | -0.503 | 0.174 |
| $\gamma_{23}$ | 1.329 | -0.236 | -0.428 | -0.456 | -0.205 | 2.939 |
| $\gamma_{24}$ | -7.894 | -5.864 | -4.965 | -3.606 | -3.725 | 2.912 |
| $P(\gamma_2 = 0)$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.114 |
| $R^2$ | 0.661 | 0.675 | 0.666 | 0.577 | 0.566 | 0.324 |
| | Panel C: W1 Jan-08 – W2 Jul-08 | | | | | |
| $\gamma_{21}$ | -1.774 | -1.180 | -0.879 | -0.835 | -1.223 | 1.508 |
| $\gamma_{22}$ | 0.619 | 0.591 | 0.581 | 0.933 | 0.880 | -1.210 |
| $\gamma_{23}$ | 0.946 | 0.764 | 0.740 | 0.266 | -0.189 | 1.614 |
| $\gamma_{24}$ | -0.364 | -0.410 | -0.716 | -1.049 | -1.099 | 5.503 |
| $P(\gamma_2 = 0)$ | 0.664 | 0.782 | 0.762 | 0.261 | 0.186 | 0.002 |
| $R^2$ | 0.153 | 0.134 | 0.137 | 0.228 | 0.250 | 0.601 |