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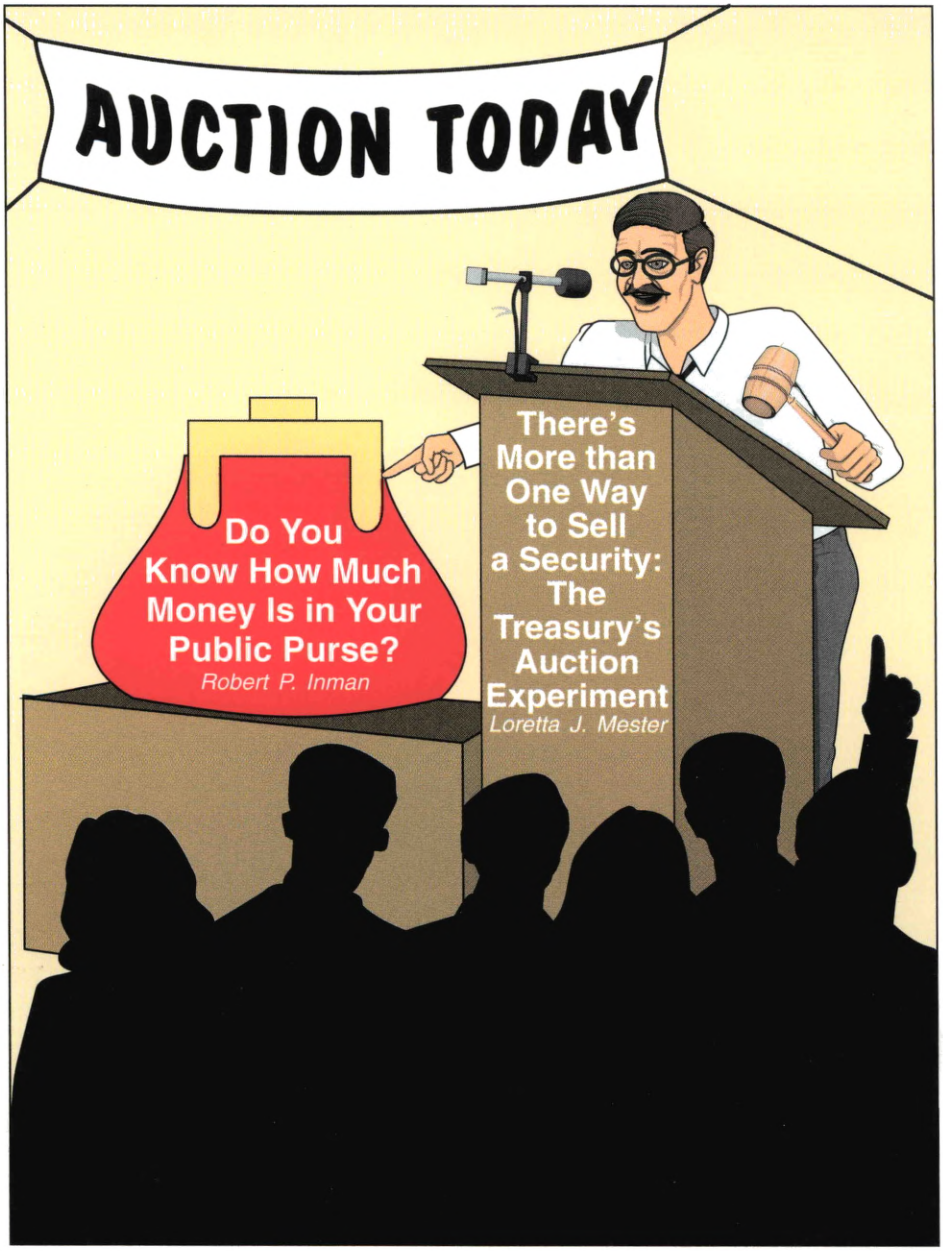

Business Review

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JULY/AUGUST 1995

THERE'S MORE THAN ONE WAY TO SELL A SECURITY: THE TREASURY'S AUCTION EXPERIMENT
Loretta J. Mester
In the wake of Salomon Brothers' acknowledgment of serious violations of the auction rules, the Treasury began experimenting with a new way to auction its securities in 1992. While the Treasury has used auctions to sell securities since 1929, auctions can take many forms, and determining which format produces the most revenue isn't an easy task. Consequently, the Treasury has, from time to time, experimented with different formats. Loretta Mester explains some of the factors involved in auctions and discusses the Treasury's previous and current experiments with auction formats as well as evidence from auctions in other countries.

DO YOU KNOW HOW MUCH MONEY IS IN YOUR PUBLIC PURSE?
Robert P. Inman
Most of us know how our various governments are doing in areas like education, road maintenance, and tax collection, but few of us know how much money is in our public purse—that is, each citizen's share of the national savings and wealth controlled by federal, state, and local governments. Bob Inman describes the various components that make up our national wealth and demonstrates how our governments' net worth affects our economic future. Furthermore, he points out that knowing what's in our public purse is a good starting place if we want more rational and considered public tax and spending policies.

There's More than One Way To Sell a Security: The Treasury's Auction Experiment

*Loretta J. Mester**

To finance a deficit of over $200 billion and to refinance maturing debt, the U.S. government sold more than $2 trillion of Treasury securities in 1994 at regularly scheduled auctions. The ability of the government to continue to borrow in this way depends on there being a well-functioning market for government securities. Such a market benefits the taxpayers by lowering the government's borrowing cost. In addition, it provides a convenient way for the Federal Reserve to implement monetary policy. The health of the Treasury security market depends on participants' perception that it isn't subject to manipulation.

However, the integrity of the Treasury securities auction market was called into question when Salomon Brothers, Inc., admitted in August 1991 to serious violations of the auction rules during 1990 and 1991. This led to Congressional hearings and a review of the market by the Treasury, Federal Reserve System, and the Securities and Exchange Commission.[1] Following one of their recommenda-

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[1]See *The Activities of Salomon Brothers, Inc., in Treasury Bond Auctions, Hearings Before the Subcommittee on Securities of the Committee on Banking, Housing, and Urban Affairs, U.S. Senate,* (September 11-12, 1991), and *Joint Report on the Government Securities Market,* Department of the Treasury, Securities and Exchange Commission, Board of Governors of the Federal Reserve System (January 1992).

tions, in September 1992, the Treasury began selling two-year and five-year Treasury notes using a *uniform-price* auction, in which all winning bidders pay the same price, rather than a *discriminatory-price* auction, in which winning bidders pay what they bid.

The choice of auction format is important, since the format can affect the amount of revenue the government will raise in an auction and, therefore, the government's borrowing costs. In its announcement on September 3, 1992, the Treasury stated that it would consider the uniform-price auction a success if "it reduces the U.S. government's finance costs, whether by encouraging more aggressive bidding by auction participants or by attracting more bidders to the auctions."[2] Auction theory provides a basis for determining which format to use and provides a rationale for the experiment. Yet the theory is based on simple models, and the world is not a simple place. Thus, empirical analysis is needed to ultimately determine which format is better. While analyses of the data from previous experiments both in the United States and abroad are inconclusive, most favor the uniform-price auction. Since the current experiment is quite young, it, too, has not yet produced conclusive evidence, but the results thus far do support continuing the experiment so that more data can be collected.

HOW TREASURY SECURITIES ARE SOLD

Auctions have been used to sell Treasury bills (that is, Treasury securities with maturities of a year or less) since they were introduced in 1929. But auctions are not the only way the Treasury could issue its debt. Until the early 1970s, the Treasury sold notes and bonds (which have maturities of more than a year), using methods that set the price before the sale of the securities.[3] But increased volatility of interest rates made such methods risky for the seller and for buyers. So the Treasury began using a modified auction method for notes and bonds in 1970 and a more standard auction method in 1974.

The Primary Market. The Treasury sells securities at regularly scheduled auctions, which constitute the primary market: 13- and 26-week bills are sold weekly, one-year bills are sold every four weeks, two- and five-year notes are sold monthly, three-year and 10-year bonds are typically sold at the quarterly refinancings, and 30-year bonds are sold semiannually. The gross amount issued has grown through time and was over $2 trillion in 1994 (Figure 1). About one week prior to the auction, the Treasury announces the dollar amount of the particular security it wishes to sell at the auction and invites tenders (sealed bids) for a specified dollar amount of these securities. Bids are due by a specified time on the day of the auction, and the Treasury usually publicizes the results later that afternoon. The securities are then issued to successful bidders within a few days to about a week after the auction.[4]

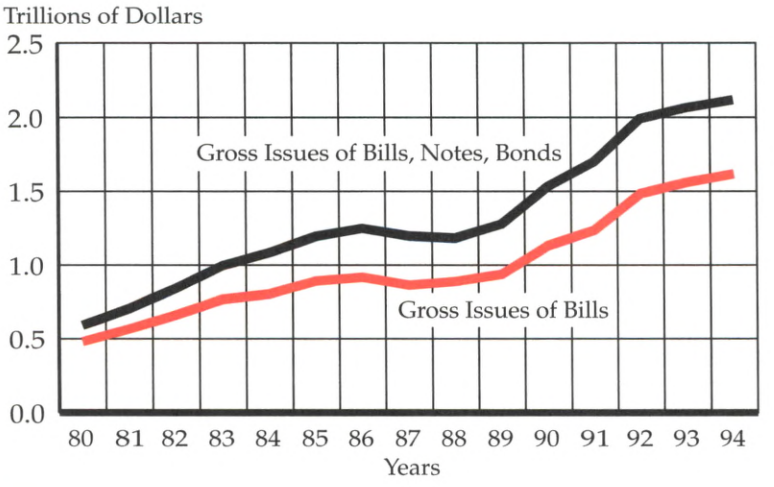
[2]In "Managing the Public Debt," in this *Business Review* (July/August 1994), Keith Sill discusses why the government might want to minimize its interest costs: lower costs mean lower taxes, and if taxes are distortionary to economic activity, then lower taxes provide an economic benefit.

[3]Appendix A of the *Joint Report on the Government Securities Market*, Department of the Treasury, Securities and Exchange Commission, Board of Governors of the Federal Reserve System (January 1992) provides an excellent overview of the history and current operation of the government securities market, and is the source of much of the information in this section. See also James F. Tucker, *Buying Treasury Securities at Federal Reserve Banks* (Federal Reserve Bank of Richmond, October 1993) and Loretta J. Mester, "Going, Going, Gone: Setting Prices with Auctions," this *Business Review* (March/April 1988), pp. 3-13.

[4]For 13- and 26-week bills, the Treasury announces the weekly offerings on Tuesday, auctions the bills on the following Monday, and issues the bills on the Thursday following the auction. For 52-week bills, it announces on a Friday, auctions on the following Thursday, and issues

FIGURE 1

Gross Issues of Marketable Treasury Securities



Source: U.S. Department of Treasury, Office of Market Finance

Two different types of bids can be submitted in Treasury auctions: competitive and noncompetitive.[5] The awards to competitive bidders account for the larger percent of total awards: they average about 80 percent of bill auction awards to private investors and over 90 percent of note and bond awards, despite the fact that, on average, only about 75 to 85 bidders submit competitive bids, while there are nearly 20,000 noncompetitive bidders per auction. Money market banks, dealers, and other institutional investors who purchase large quantities of securities typically submit competitive bids. These tenders indicate the amount of the security they want to purchase and the price they are willing to pay. This price is stated in terms of the yield (or the discount rate for bills) that investors are willing to accept for investing in the security: higher yields mean lower prices paid by the investor, and hence, higher borrowing costs to the Treasury. Competitive bidders are permitted to submit more than one bid, but no single bidder is allowed to win more than 35 percent of the total amount of the security being sold.[6] This rule is intended to prevent any bidder from cornering the market in a particular security.

on the Thursday following the auction. For two- and five-year notes, it usually announces on a Wednesday in mid-month, auctions a week later, and issues on the last day of the month. For three- and 10-year notes, it usually announces on the last Wednesday of January, April, July, and October, auctions during the first full week of February, May, August, and November, and issues on the 15th of the auction month. Auctions of 30-year bonds follow the same schedule but are offered just twice a year, in January and July. (See Tucker, p. 25.) The Treasury stopped selling seven-year notes after April 1993; prior to this the Treasury offered them quarterly with the three- and 10-year notes.

The minimum denominations sold are $10,000 for bills; $5000 for two- and three-year notes; and $1000 for other notes and bonds. Securities are sold in $1000 increments above the minimum denominations. (See Tucker, pp. 11 & 17).

[5]Bids can be submitted at Federal Reserve Banks and most of their branches and at the Treasury's Bureau of the Public Debt. Competitive bids are usually due by 1 pm on the day of the auction and noncompetitive bids by noon—these two types of bids are described in the text below. In addition to private bidders, the Federal Reserve also buys securities at the auctions to replace maturing issues in its own account and on behalf of foreign governments. The Fed is treated as a noncompetitive bidder.

[6]While a single bidder can submit bids for more than 35 percent of the offering at one yield, the Treasury does not recognize the excess. See p. A-5 of the *Joint Report*.

A significant group of competitive bidders in Treasury auctions are the so-called primary government securities dealers. Currently there are 39 such dealers, whose role is to ensure that there is wide participation in the Treasury security auctions. They purchase large amounts of Treasury securities in the auctions for their own accounts, and they also purchase securities for their customers. The Federal Reserve buys and sells securities from these dealers in conducting monetary policy. In general, these dealers account for over two-thirds of awards over $1 million. But they typically do not hold the securities they have purchased; often they have made arrangements prior to the auction to sell the securities they will win. (See the discussion of the when-issued market below.)

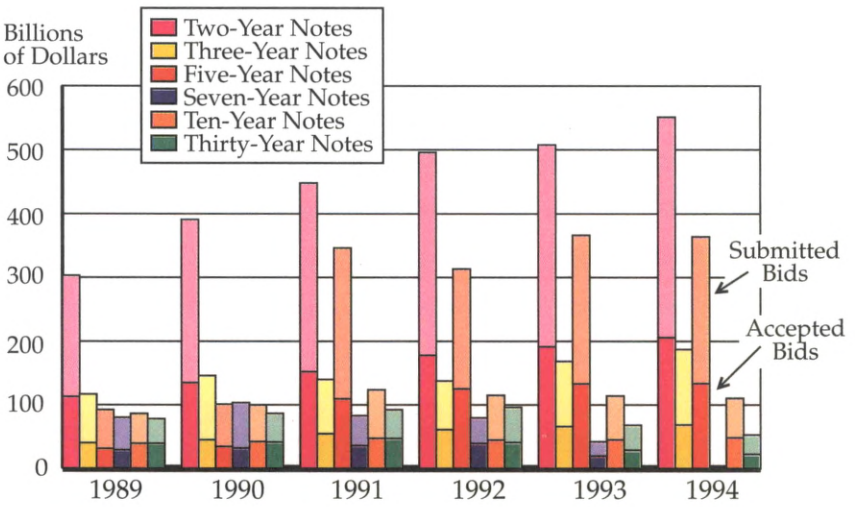
The other type of bids in Treasury auctions, noncompetitive bids, are made by smaller or less experienced investors. By placing a noncompetitive bid, the bidder is assured of winning the amount that he indicated on his tender, up to the $1 million limit placed on such bids for bills and the $5 million limit placed on such bids for notes and bonds. The tender does not indicate the price, since a noncompetitive bidder agrees to pay the quantity-weighted average of the accepted competitive bid prices.

Until the current auction experiment, the Treasury had relied on *discriminatory-price* auctions to determine the winners and the prices they paid in all of its security auctions, and it continues to use this method for securities other than the two-year and five-year notes.[7] Once the bids are in, the Treasury sets aside the amount of securities requested by the noncompetitive bidders. The remainder is allocated to the competitive bidders, beginning with those who bid the highest price (that is, lowest yield) and then working down, until the total amount is issued. A winning competitive bidder pays a price equal to what he bid, which is what makes this a discriminatory-price auction. During the past five years, about 35 to 45 percent of the dollar volume of bids submitted in each auction by private investors were accepted, that is, won securities, with the higher percentage occurring in auctions of longer maturities, since there is a lower volume of bids in these auctions (Figure 2).

[7]The Treasury also experimented with a uniform-price bond auction from 1973-76.

FIGURE 2

Total Volume of Submitted & Accepted Bids (excluding Federal Reserve tenders)



Source: Treasury Bulletin, U.S. Department of Treasury, various issues

This primary auction market does not stand in isolation. Other related markets can affect the strategies bidders use in the primary auction market.

The When-Issued Market. Even though the auction market is called the primary market for Treasury securities, it isn't the first place a particular security is bought or sold. In fact, between the time the auction of a particular security is announced until the time the security is issued, traders can buy or sell that security in a forward market called the when-issued market.[8] In this market, sellers contract to deliver a particular security on its issue date at a certain price. Notice that such trading can (and does) occur before the auction, and so occurs before sellers know whether they have won the security in the auction and before they know the winning prices. Unlike competitive bidders in the auction, the buyers in this market know the amount of the security they will receive on the issue date and the price they will have to pay.[9]

The existence of when-issued trading can affect the strategies bidders use in the auctions because it affects bidders' positions as they go into the auction: bidders who have bought the security in the when-issued market before the auction go into the auction with long positions (that is, they already own some of the securities) and bidders who have sold the security in the when-issued market go into the auction with short positions. Another reason the when-issued market can affect bidders' strategies is that it serves a "price discovery" role. By participating in this market and seeing the prices at which trades are being made, traders gain information on the strength of demand for an issue and on the disparity of participants' views about the issue, which can be useful when they prepare their own bids. On the other hand, participants who feel they have some very valuable private information concerning the value of the issue (for example, they have what they believe is a more accurate forecast of interest rate changes) might refrain from trading in this market so that they can keep the information private and use it in preparing their bids.

The Secondary Market. Once a Treasury security is issued it can be traded in a secondary market. This market is mainly an over-the-counter market in which dealers, brokers, and other investors make trades over the phone; the most active trading is in the most recently issued securities. The existence of the secondary market also affects the strategies bidders use in the auction. In fact, it can affect the choice of participating in the auction in the first place, since it provides another place in which to purchase the security.[10]

THE AUCTION EXPERIMENT AND ITS RATIONALE

One of the Treasury's aims is to maximize the revenue it receives or, what is the same

[8]For example, the weekly auction of 13-week Treasury bills is announced on Tuesday; the auction is held the following Monday, and the bills are issued on Thursday. So the when-issued market for this bill runs from Tuesday to Thursday of the following week.

[9]For further discussion of the when-issued market, see Suresh Sundaresan, "An Empirical Analysis of U.S. Treasury Auctions: Implications for Auction and Term Structure Theories," First Boston Working Paper Series, FB-92-37, Graduate School of Business, Columbia University (November 1992); and Kjell G. Nyborg and Suresh Sundaresan, "Discriminatory Versus Uniform Treasury Auctions: Evidence from When-Issued Transactions," mimeo (October 1994).

[10]Another important market in which Treasury securities are traded is the repo market. Dealers are able to buy or sell Treasury securities for short-term periods (usually overnight) using repurchase agreements ("repos"). A repo seller provides securities in exchange for funds and agrees to repurchase the securities at the price and date specified in the repo contract. The market can be used to finance securities' positions, to obtain securities temporarily to complete other transactions, or to invest idle cash balances. (See *Joint Report*, pp. A11-A12.)

thing, lower its borrowing cost. But it isn't enough to consider which auction format will maximize revenue from a single auction—selling securities isn't a one-shot game; the Treasury has to determine the long-run implications from using a particular format. While one format might lead to more revenue than another when a single auction is considered, if the format is more vulnerable to manipulation by a single bidder or collusion by a group of bidders, it may lead to decreased participation in future auctions, which has negative implications for revenue over the long run. If participants feel the auction is unfair or that more informed bidders can take advantage of less informed bidders (perhaps by colluding), the demand for securities in the auction may decline. Uninformed bidders might decide to wait to purchase the securities they need in the secondary market, which would mean less revenue for the government. Similarly, if one type of format is more vulnerable to collusion, it, too, might not be the best choice, even if in the absence of collusion it might be the type of auction that maximizes the government's revenues.

In September 1992, the Treasury announced that it would conduct a uniform-price auction experiment, including all auctions of two- and five-year notes from September 1992 through August 1993. The experiment has been extended twice, the second time on August 3, 1994, for all two- and five-year notes indefinitely. In the uniform-price auction, the winners are determined in the same way as in the discriminatory-price auction, but instead of paying the price they bid, all winners pay the same price, which is the highest rejected bid (or what is the same thing for Treasury auctions, the lowest accepted bid).[11,12]

On the face of it then, it would seem that the Treasury would make more revenue from selling its securities via a discriminatory-price auction, since those submitting higher bids would pay the amount they bid for a security, while in a uniform-price auction they would pay less. But the auction format can also affect demand for securities; if uniform-price auctions increase demand, this may more than compensate for the loss of revenue due to a single price. And as discussed above, some auction formats are more susceptible to manipulation or collusion than others, which can directly affect revenue and indirectly affect demand and, therefore, revenue.

Some Simple Auction Theory. Arguments in favor of the uniform-price auction for Treasury securities are based on what has been learned from economic models of auctions.[13] Economists model an auction as a game with bidders playing against each other. The object of the game is to win the object being auctioned at the lowest possible price, and each bidder devises a strategy with this in mind. A bidder's strategy will depend on what information the bidder has. Some information will be available to all bidders (for example, the Treasury an-

[11]In Treasury auctions these two prices are the same, since there is always excess demand for Treasury securities at the lowest accepted bid.

[12]This was not the first time a uniform-price auction had been recommended or used in U.S. financial markets. In 1960, Milton Friedman, who later won the Nobel Prize in economics, recommended that the Treasury switch to a uniform-price auction to sell Treasury bills; others disputed his recommendation. In six auctions between January 1973 and May 1974, the Treasury sold long-term bonds this way. In the wake of the Salomon Brothers scandal, Friedman reiterated his recommendation for the uniform-price auction (see *Wall Street Journal*, August 28, 1991, p. A8).

[13]Most of the models have focused on the auctioning of a single object. For nontechnical discussions of auction theory see Mester (1988); Paul Milgrom, "Auctions and Bidding: A Primer," *Journal of Economic Perspectives*, 3 (Summer 1989), pp. 3-22; Sushil Bikhchandani and Chi-fu Huang, "The Economics of Treasury Securities Markets," *Journal of Economic Perspectives*, 7 (Summer 1993), pp. 117-34; John McMillan, "Selling Spectrum Rights," *Journal of Economic Perspectives*, 8 (Summer 1994), pp. 145-62.

nounces the auction date and size of the issue before each auction, and the auction rules are known to all), but other information is privately held by each bidder. The assumptions made in theoretical models about the nature of bidders' private information range along a broad spectrum. At one end of the spectrum, models assume each bidder knows for certain how she values the object and that this information is totally private, reflecting her individual taste for the object—this is called a *private values auction.* At the other end, models assume that the object is worth the same to all bidders but that they are unsure of this value—this is called a *common values auction.* A bidder's private information might tell her something about the true market value of the object, although not enough to be certain. At the time of bidding, no bidder knows the market value for sure and each makes an estimate of this value based on her private information.

Treasury auctions are more like common values auctions than private values auctions, since the value of the security is largely determined by its value in the secondary market. A bidder in a common values model would like to discover the private information of other bidders not only because it would tell her something about how those other bidders are likely to bid, but also because it would reveal something more about the likely market value of the object, which is what each bidder is trying to estimate. Also, the bidder's profit is determined by her private information—if all information is public, then the winner will not earn any profit in the auction; the rewards to bidding in a common values auction depend on the value of the bidder's private information.

Common values auctions are subject to the "winner's curse," which affects bidders' strategies and therefore the revenue that a seller, like the Treasury, can expect to receive in the auction. Each bidder is unsure of, but forms some estimate about what the object being sold is worth; in Treasury security auctions it would be the price of the security in the secondary market. If she bids her estimate and wins, this tells her that everyone else thinks the object is worth less than she did. On average, the winner who bids her estimate will pay more than the object is worth on the open market. Hence, winning is a curse! To avoid the curse, each bidder should shade her bid down from what she thinks the object is worth. But shading the bid below her estimate can affect the bidder's probability of winning. Hence, the amount a bidder shades from her estimate depends on how many other bidders there are and also how the bidder feels about the risk of losing. When there are fewer bidders, a bidder can shade down her bid more without affecting her probability of winning, because there is less chance that someone else's bid lies just below hers. If a bidder is risk-averse, she will care very much about the risk of losing the object and will shade down her bid less than if she were risk-neutral, as a kind of insurance against losing: a risk-averse bidder is willing to pay more to avoid the loss from losing. The amount of bid shading is also affected by the degree of information differences across bidders.

The winner's curse also gives bidders the incentive to gather more information about the value of the object being sold. As explained above, in Treasury auctions this information can be garnered in the when-issued market. Hence, when the winner's curse is severe, it is likely that there will be more trading in the when-issued market. It also means that bidders have more incentive to pool their bids, since this helps them get a better estimate of the common value, and the use of dealers who pool bids and place large orders will be higher.[14]

Rationale for the Experiment. One ration-

[14]See Vincent Reinhart, "An Analysis of Potential Treasury Auction Techniques," *Federal Reserve Bulletin*, 78 (June 1992), pp. 403-13.

ale for switching to a uniform-price auction from a discriminatory-price auction is that, when bidders are risk-neutral, the uniform-price auction is less susceptible to the winner's curse. In a discriminatory-price auction, a risk-neutral bidder will tend to shade down her bid more than in a uniform-price auction because her bid is also what she pays when she wins; if other bidders estimate the value to be much lower than she does, the winning bidder will be paying much too high a price. In a uniform-price auction, on the other hand, the winning bidder need not be too worried about paying way too much; she can bid high to improve her chance of winning, but she doesn't have to pay this high price. (Recall, she only has to pay the lowest accepted bid.) In other words, bidders bid more aggressively in the uniform-price auction than in the discriminatory-price auction. In fact, when bidders are risk-neutral and only one object is being sold, the price paid by the winner in a uniform-price auction is higher on average than the price paid by the winner in a discriminatory-price auction. This theoretical result for auctions of single objects plays a large role in arguments made for switching to uniform-price Treasury auctions, despite the fact that in Treasury auctions more than one object is being sold.

The other line of argument for changing auction formats is based on the potential for manipulation or collusion afforded by different auction techniques, which can affect auction revenues. Collusion is bad from the seller's viewpoint if it involves bidders' conspiring to keep prices down. Several economists have argued that collusion might be more difficult in the uniform-price auction than in the discriminatory-price auction. They argue that because the winner's curse is less severe in the uniform-price auction, less informed bidders will be less disadvantaged, which should encourage participation. Collusion would be more difficult, as the number of bidders would be larger.[15] Either shading down bids to avoid the winner's curse or colluding with others to keep bids down will lead to less revenue for the Treasury. So if the uniform-price format alleviates the winner's curse and makes collusion less likely, it should be the preferred format.

Theory and Practice. But the real world of Treasury-security auctions isn't as simple as the theory discussed above may suggest. First, even in the simple models, if bidders are risk-averse, one can't predict which auction format—uniform-price or discriminatory-price—will yield the higher expected revenue. Although it is likely that most bidders in Treasury auctions are risk-neutral, since any one auction represents a small percentage of their assets, the fact that many come to the auction with a significant short position (from selling in the when-issued market before the auction) can make them act in a risk-averse manner, since losing would be costly if they are unable to obtain the securities they want at a reasonable price in the secondary market.

Second, Treasury auctions are multiple-object auctions in which bidders desire more than one unit of the item being auctioned, but there has been little analysis of these kinds of auctions. As in single-unit auctions, a uniform-price auction of multiple units will yield greater revenue on average than a discriminatory-price auction when each bidder just demands a single unit. But this is not generally true when bidders want to win more than one unit. In auctions where bidders demand multiple units, Kerry Back and Jaime Zender (1993) show that bidders will tend to play strategies in uniform-price auctions that will curtail price competition, and thereby hold down revenue. In some cases this effect will be strong enough so that the discriminatory-price auction will

[15]See Kerry Back and Jaime F. Zender, "Auctions of Divisible Goods: On the Rationale for the Treasury Experiment," *Review of Financial Studies* (Winter 1993), pp. 733-64 and Friedman (1991).

generate more revenue than the uniform-price auction when bidders demand multiple units, even though the opposite occurs in single-unit auctions. (See *Steeper Bids Can Curtail Price Competition in Uniform-Price Multiple-Unit Auctions.*)

A third complication is the impact of the when-issued and secondary markets on bidders' strategies, which has not been well studied. In their theoretical model, Sushil Bikhchandani and Chi-fu Huang (1989) show that accounting for the secondary market can be important in that it can lead bidders to bid more aggressively in uniform-price auctions to indicate to secondary-market participants that the securities are valuable. This suggests that for Treasury auctions, the uniform-price auction might generate more revenue for the Treasury.[16]

Finally, the argument that uniform-price auctions are less susceptible to collusion or manipulation than discriminatory-price auctions doesn't seem that strong. It's hard to believe that the *competitive* bidders in a Treasury auction are uninformed—under either auction format, the uninformed bidders are better off placing noncompetitive bids (see Bikhchandani and Huang, 1993). And in either format, collusion among a group of bidders would be hard to sustain, since one of the group could deviate from the agreed upon price, bid a slightly higher amount, and win a large share of the amount auctioned (subject to the quantity limits set by the Treasury). In fact, Bikhchandani and Huang (1993) have argued that it might even be easier to sustain collusion in uniform-price auctions than in discriminatory-price auctions.[17]

Manipulation by a single bidder is more likely to be a potential problem than collusion by a group of bidders. So long as there are those who need securities but do not bid in the auction and so must purchase in the secondary market, there is the potential for manipulation. A well-capitalized bidder might try to corner the market in a Treasury issue, and profit by selling to anyone who sold short in the when-issued market and decided to purchase the issue in the secondary market instead of at the auction. While the Treasury might gain in the short term (since to corner the market, the bidder would have to bid high in the auction), if such manipulation is widespread and occurs often, it would tend to drive participants from the market and this would lead to losses for the Treasury in the long term.[18,19] While it is illegal to corner the market, the auction format might have an influence on the ability to (illegally) do so. Bikhchandani and Huang (1993) argue that a uniform-price auction is more vulnerable to

[16]See Sushil Bikhchandani and Chi-fu Huang, "Auctions with Resale Markets: An Exploratory Model of Treasury Bill Markets," *Review of Financial Studies*, 2 (1989), pp. 311-39.

[17]Bikhchandani and Huang (1993) point out that in discriminatory-price auctions, any profitable collusive arrangement involves every bidder agreeing to bid only at low prices. But then deviating and bidding a slightly higher (but still low) price yields a short-term gain. Profitable collusion in the uniform-price auction need not involve all bidders bidding at low prices (since they pay the highest accepted or lowest rejected bid and not what they themselves bid). Therefore, a deviation from the collusive arrangement in a uniform-price auction might involve bidding at a high price; such a deviation would not necessarily be profitable. Hence, the collusive arrangement might be easier to sustain in the uniform-price auction than in a discriminatory-price auction. In other words, discriminatory-price auctions might be less susceptible to collusion.

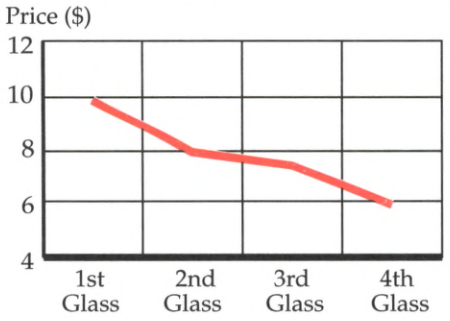
[18]Bikhchandani and Huang (1993) and Reinhart (1992) discuss the potential for manipulation in different auction formats.

[19]In August 1991, Salomon Brothers, Inc., admitted to placing unauthorized bids in some auctions in 1990-91 in an attempt to gain a larger share of the securities being sold. See *Press Release of Salomon Brothers, Inc.*, August 9, 1991; the Joint Report, Appendix C; and "Statement of Salomon, Inc. Submitted in Conjunction with the Testimony of Warren E. Buffett," *Hearings* (1991), pp. 256-312.

Steeper Bids Can Curtail Price Competition in Uniform-Price Multiple-Unit Auctions

How might a discriminatory-price auction of multiple units generate more revenue for the seller than a uniform-price auction, even though in auctions of single items (with risk-neutral bidders) the opposite revenue ranking occurs? Back and Zender (1993) point out that when bidders demand more than one unit, they can play strategies in uniform-price auctions that essentially curtail price competition. The reduced price competition can lead to diminished revenue for the seller, making the discriminatory-price auction a better choice in multiple-unit auctions.

Nick's Initial Bid Schedule



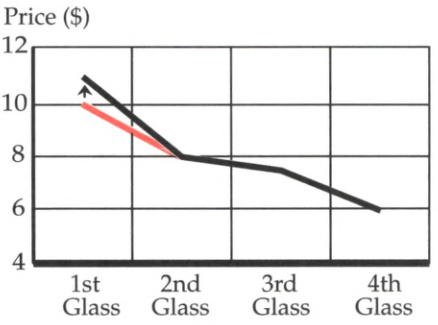
A simple example illustrates this. Suppose there are four martini glasses being sold via a uniform-price auction to two bidders, Nick and Nora, and they both believe that after the auction each glass will be worth $13. Nick and Nora submit bids describing the quantities and prices of the glasses they want to purchase. Suppose Nick submits the following four bids: $10 for one glass, $8 for one glass, $7.50 for one glass, and $6 for one glass, and suppose Nora also submits these bids. The auctioneer will award the glasses starting with the highest bid-price and working down until all four glasses are awarded. So the bids Nick and Nora have submitted essentially describe what each is willing to pay for each additional glass they might win. For example, each knows that the $8 bid won't be accepted unless the $10 bid is accepted, and so on. Given their bids, in a uniform-price auction, Nick and Nora would each receive two glasses, and they would pay $8 per glass (the lowest accepted price).[a] Since they expect the glasses to be worth $13 apiece, each would earn an expected profit of $10 [= 2×($13-$8)] on their winnings.

Now suppose Nora wanted to win all four glasses. To win four, she would have to increase the prices in all four of her bids to $10.01, since she would need to beat Nick's bid of $10 and drive him out of the market. With this new set of bids, Nora's total profit would increase to $11.96 [= 4×($13-$10.01)], so it pays her to change her bids.[b] And the seller would receive $40.04 [= 4×$10.01] in revenues.

But suppose Nick had submitted a steeper schedule of bids. That is, suppose he had bid $11, instead of $10, for one glass and left the rest of his bids the same. Nothing would change in the uniform-price auction; again, Nick and Nora would each receive two glasses and pay $8 per glass. But for Nora to increase her winnings from two to four, she would now have to beat Nick's $11 bid. So she would have to increase the prices in all four of her bids to $11.01. Nora's total profit with her new set of bids would be only $7.96 [= 4×($13-$11.01)], and it would not be profitable for Nora to change her bids.[c] Hence, the seller's revenues would remain $32.

Thus, by submitting steeper bid schedules, bidders can in effect "collude" to keep down the prices they pay. And in a uniform-price auction, such a strategy is costless—Nick did not have to pay the $11 he bid to win the first glass, whereas in the discriminatory-price auction he would have had to.

Nick's New, Steeper Bid Schedule



[a]We use the lowest accepted price as the uniform price instead of the highest rejected price, since that is what is specified in the Treasury experiment. The analysis is similar using the highest rejected price as the uniform price.

[b]This occurs because the value of the two additional glasses is greater than the marginal cost of purchasing the extra glasses. The additional glasses are worth $26 [= 2×$13], and to win four glasses instead of two, Nora would have to pay only an additional $24.04 (= the cost of the two new glasses [= 2×$10.01], plus the extra cost for the first two glasses [= 2×$2.01]).

[c]This occurs because the value of the two additional glasses is now less than the marginal cost of purchasing the extra glasses. The additional glasses are worth $26 [= 2×$13], but to win four glasses instead of two, Nora would have to pay an additional $28.04 (= the cost of the two new glasses [= 2×$11.01], plus the extra cost for the first two glasses [= 2×$3.01]).

manipulation than a discriminatory-price auction, since in the discriminatory-price auction if a bidder bids high to corner the market, he has to pay what he bid. This also means it is more costly in discriminatory-price auctions to build a reputation for aggressive bidding, which can be manipulative.[20]

The divergence between simple auction theory and auction practice means that it is really an empirical question as to which auction format is best; hence, the need for the Treasury's auction experiment. The results will very likely be interesting for theoretical economists as well as the Treasury because the results will suggest which differences between reality and theoretical models are the economically important ones and, therefore, worth further study.

WHAT WE HAVE LEARNED FROM AUCTION EXPERIMENTS

We can look to some previous empirical studies as well as the data gathered so far from the current Treasury experiment to assess the likely impact of switching to the uniform-price auction.[21] Figure 3 helps keep track of the results.

The Treasury's Previous Experiment. Studies that examine the Treasury's previous experiment in the 1970s might give us an idea of what to expect this time (although there have been many innovations and regulatory changes in financial markets since that experiment was run). In an unpublished Treasury Department study, Che Tsao and Anthony Vignola found that in the six single-price auctions out of 16 auctions from January 1973 through August 1976, demand from nondealers increased somewhat, and the authors concluded that the Treasury would have saved about $60 million by using a uniform-price auction for the 10 issues sold via discriminatory-price auctions. This study is often cited by those advocating the uniform-price format, but David Simon (1994a) reports that the authors told him that their results should be viewed as preliminary because of important data problems they subsequently discovered.[22]

Simon's own study re-examined the early experiment and found that the Treasury did better with the discriminatory-price auctions than with the uniform-price auctions. He found the markup of the average accepted rates in the auctions over rates in the when-issued market shortly after the auctions were a statistically significant 7 to 8 basis points higher at uniform-price auctions than at discriminatory-price auctions, holding constant the effects of other factors. This markup measures the premium the Treasury has to pay to issue new debt. The when-issued rate is the rate market participants require to purchase the security; a lower rate means they are willing to pay a higher price. Therefore, the higher the markup, the higher the Treasury's borrowing costs and the higher the profits that go instead to dealers who sell to these market participants after the auction. Simon estimated that the early single-price auctions cost the Treasury about 0.75 percent of the face value of the auctioned securities in lost revenue.

Evidence from Other Countries. Evidence from other countries that switched auction

[20]If one bidder is known to bid aggressively, it can deter others from doing so by making the winner's curse worse—if a bidder beats the aggressive bidder it means he's really paid too much. See Bikhchandani and Huang (1993) for further discussion.

[21]Back and Zender (1993) have a helpful review of some of the empirical studies.

[22]See Che S. Tsao and Anthony J. Vignola, "Price Discrimination and the Demand for Treasury's Long Term Securities," unpublished manuscript, U.S. Department of Treasury (1977); and David P. Simon, "The Treasury's Experiment with Single-Price Auctions in the Mid-1970s: Winner's or Taxpayer's Curse?" *Review of Economics and Statistics*, 76 (November 1994a), pp. 754-60.

FIGURE 3

Empirical-Study Score Card

Study		Results Favor	
		Discriminatory-Price Auction	Uniform-Price Auction
Tsao and Vignola (1977)	16 U.S. Treasury bond auctions, January 1993-August 1976 (data problems subsequently discovered)		×
Simon (1994a)	16 U.S. Treasury bond auctions, January 1993-August 1976	×	
Umlauf (1993)	Mexican Treasury bill auctions, 1986-91		×
Tenorio (1993)	Zambian foreign exchange market auctions, October 1975-January 1987		×
Nyborg and Sundaresan (1994)	U.S. Treasury when-issued market, July 1992-August 1993		×
U.S. Department of Treasury	U.S. Treasury securities, June 1991-May 1994	inconclusive	

formats suggests a different story. Steven Umlauf (1993) studied bidding in Mexican Treasury bill auctions over the period 1986-91.[23] In 1986, the Mexican government began auctioning its Treasury bills using rules similar to the ones used in the United States. In 1990 its Treasury substituted uniform-price auctions for discriminatory-price auctions to try to combat collusion and to increase auction revenues. Umlauf found that before the switch, the six largest bidders, who accounted for very large shares of the auction purchases, were colluding and making profits. But these profits were eliminated after the switch.[24] These results suggest (but don't prove) that there was

[23]He focused on one-month peso-denominated zero-coupon securities called CETES. See Steven R. Umlauf, "An Empirical Study of the Mexican Treasury Bill Auction," *Journal of Financial Economics*, 33 (1993), pp. 313-40.

[24]In the 181 discriminatory-price auctions analyzed, aggregate competitive bidder profits averaged $36,000 per auction, with the six largest bidders earning over 80 percent of total competitive auction profits. But in the 26 uniform-price auctions analyzed, aggregate competitive

collusion in the discriminatory-price auctions but not in the uniform-price auctions, and they favor the uniform-price auction from a revenue standpoint. (Although since only 26 uniform-price auctions are included in the sample and they span only 10 months, it is debatable whether the bidders had enough experience with the new auction to make the results a certainty.)

Rafael Tenorio (1993) analyzed data from foreign exchange market auctions held weekly in Zambia from October 1985 to January 1987.[25] Funds that were auctioned came mainly from export proceeds and from foreign aid. At the start, Zambia used uniform-price auctions, but after authorities became alarmed about what they considered an excessive depreciation of the Zambian currency (Kwacha), the authorities switched to a discriminatory-price format with the 43rd auction. The difference between the supply and demand of currency grew so much that the auctions had to be suspended after the 68th. Tenorio found that uniform-price auctions yielded higher revenues than discriminatory-price auctions because there was greater participation (as measured by the number of bids and the total quantity demanded); had participation been the same in both auctions, his results suggest there would have been no significant difference in revenues. Tenorio also found that it takes a while for bidders to adapt to a new auction format.

The Current U.S. Treasury Experiment. Kjell Nyborg and Suresh Sundaresan (1994) studied the period July 1992 to August 1993 using data on all the transactions in the when-issued market executed by Garban, one of the four most active interdealer brokers in the U.S. Treasury market. They found that for discriminatory-price auctions, the average accepted yield in the auction was higher then the average rate in the when-issued market during the half-hour before the auction, but for uniform-price auctions, there was no difference. This suggests that dealers were shading down their bid prices (and so bidding at higher yields) in discriminatory-price auctions but not in uniform-price auctions, which is consistent with the theoretical result for single-unit auctions that the winner's curse is more severe in discriminatory-price auctions. Hence, the uniform-price auction should produce more revenues for the Treasury.[26]

Nyborg and Sundaresan also show that with uniform-price auctions, when-issued rates were highly volatile before bidding but fluctuated less after the auction, while with discriminatory-price auctions, volatility increased after the auction. This suggests that more information is released in the when-issued market before the auction when the uniform-price format is used than when the discriminatory-price format is used. And it suggests that in discriminatory-price auctions, dealers are bet-

bidder profits averaged -$3000 per auction (essentially zero). And the average profits of the six largest bidders were essentially zero, too. The weighted-average profit margin (that is, the quantity-weighted average spread between the resale price and auction price) was 1.84 basis points for discriminatory-price auctions and -0.3 basis points for uniform auctions. This difference across auction format is statistically significant at the 1 percent level.

[25]See Rafael Tenorio, "Revenue Equivalence and Bidding Behavior in a Multi-Unit Auction Market: An Empirical Analysis," *Review of Economics and Statistics*, 75 (May 1993), pp. 302-14.

[26]For the discriminatory-price auctions of two- and five-year notes, the markup ranged from 0 to 1/2 of a basis point, and was statistically different from zero. For the uniform-price auctions, the markup ranged from -1/2 to 3-1/2 basis points and was not statistically different from zero, since it fluctuated a great deal. The markup's higher volatility in the uniform-price auctions occurs because there are more trades in the when-issued market prior to the auction when the auction format is uniform price than when it is discriminatory price, indicating greater liquidity of the when-issued market when the auction is uniform price. See Nyborg and Sundaresan (1994) for further details.

ter able to trade strategically, masking their private information (that is, knowledge of their customers' orders) prior to the auction and trading on it after the auction, thereby inducing higher volatility in the when-issued rates.[27] The greater level of information released in uniform-price auctions means there is less disparity in information held by bidders, which can lessen the severity of the winner's curse; this might encourage participation and so lead to a higher selling price and, therefore, revenues for the Treasury.

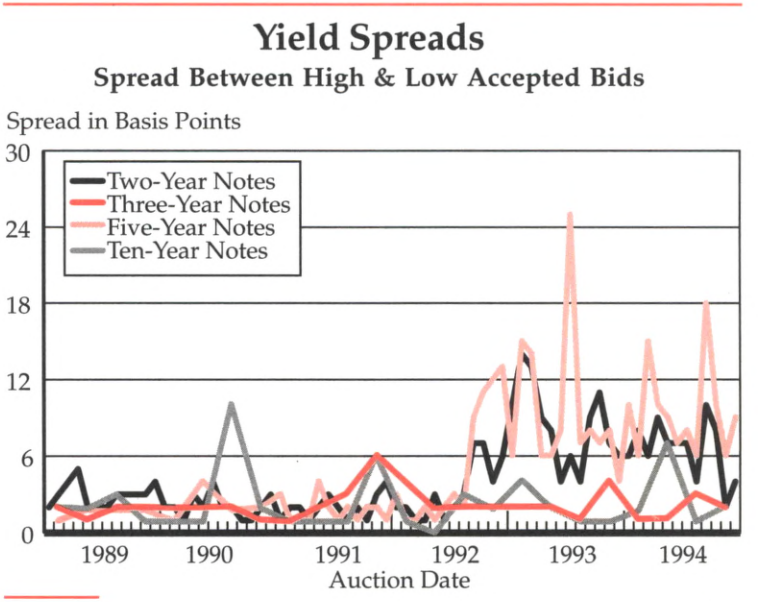
Based on the data collected on the experiment through May 1994, the Treasury Borrowing Advisory Committee, which advises the Treasury on the amount to auction, feels that the uniform-price auction is neutral with respect to Treasury borrowing costs.[28] The data do show that the two- and five-year notes may be more widely distributed under the uniform-price format than under the discriminatory-price format. Broader participation and less concentration suggest less chance of collusion and manipulation. The average share of large competitive awards (based on bids of at least $1 million) to primary dealers in the September 1992 to May 1994 experiment period fell to about 66 to 67 percent of total private awards from about 69 percent in the June 1991 to August 1992 period when discriminatory-price auctions were used; the share to their customers rose to 25 to 26 percent from about 21 percent.[29] (Note, however, that these changes aren't statistically significant.) By contrast, the awards to dealers of three- and 10-year securities rose between the two periods, and awards to their customers of three-year notes were unchanged and of 10-year notes were down about 13 percentage points.[30]

[27]Simon also found evidence of trading on private information in discriminatory-price auctions. See David P. Simon, "Markups, Quantity Risk, and Bidding Strategies at Treasury Coupon Auctions," *Journal of Financial Economics*, 35 (February 1994b), pp. 43-62. But Bikhchandani and Huang (1992) found no evidence of collusion in discriminatory-price auctions of 13- and 26-week Treasury bills from February 1986 through February 1988. See Sushil Bikhchandani and Chi-fu Huang, "The Treasury Bill Auction and the When-Issued Market: Some Evidence," WP #3467-92 Sloan School of Management, MIT (September 1992).

[28]See "Report to the Secretary of the Treasury from the Treasury Borrowing Advisory Committee of the Public Securities Association" (August 3, 1994).

[29]These data are reported in "Charts on the Uniform-Price Experiment," attached to the "Committee Charge," U.S. Department of Treasury (August 2, 1994).

FIGURE 4



Source: *Treasury Bulletin*, U.S. Department of Treasury, various issues

The data also show that transaction volumes in the when-issued market on days of uniform-price auctions have increased notably, suggesting improved liquidity, which can lower borrowing costs. And as auction theory would predict, the spread between the highest and lowest yield of accepted bids has increased in the two- and five-year note auctions since the uniform-price auction has been adopted, while in the three- and 10-year auctions there has been little change (Figure 4).

WHICH FORMAT IS BETTER?

Auction theory cannot yet provide a definitive answer as to whether a discriminatory-price auction or a uniform-price auction would result in lower borrowing costs for the U.S. Treasury. Thus, we must rely on empirical work to make a choice of auction format. Studies of an earlier Treasury auction experiment, auctions in other countries, and the current U.S. experiment are inconclusive as to which auction format is better, but most favor the uniform-price format. While data from the current experiment have not shown that the uniform-price auction format has produced higher revenues for the Treasury, they also have not shown that it has resulted in lower revenues than the discriminatory-price auction. And there is some evidence that participation is higher under the uniform-price format, which might ultimately lead to higher revenues for the Treasury. As the experiment continues and further data are collected, perhaps a more definitive answer can be obtained.

[30]Similarly, the concentration of competitive awards to the top 10 dealers and their customers was reduced by 4 to 9 percentage points for the two-year and five-year uniform-price auctions, but their share increased by 11 percentage points for the three-year notes and remained unchanged for the 10-year notes.

Working Papers

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95-11 Richard Voith, "Parking, Transit, and Employment in a CBD"

95-12 Gary Gorton and Richard Rosen, "Banks and Derivatives"

95-13 Sherrill Shaffer, "Translog Bias Under Declining Average Costs"

95-14 Alberto Trejos and Randall Wright, "Toward a Theory of International Currency: A Step Further"

Do You Know How Much Money Is in Your Public Purse?

*Robert P. Inman**

In the fall of 1990, the City of Philadelphia almost fell into bankruptcy. In the summer of 1994, Orange County, California, lost approximately $2.5 billion because aggressive investments in financial derivatives turned sour. In January 1995, a Superior Court judge in California ruled that the state owed its public employee pension plan $900 million in past payments due, a burden that now sits atop the state's already estimated $5 billion deficit for fiscal year 1995-96. And after decades of declining, the ratio of the federal debt to national income has now risen to its highest level since 1955.

While we all know how our governments are doing when it comes to teaching our children, protecting our lives and property, removing our trash, maintaining our roads, and collecting our taxes, few of us know that local and state governments and the federal government also control an important share of our national savings and wealth. Do you know how much money is in your public purse? For a typical family of four in Philadelphia in 1990 my estimate is $41,696.

HOW DO GOVERNMENTS SAVE YOUR MONEY?

When calculating your family's financial net worth, your accountant will total all your family's assets and then subtract all liabilities.

*Bob Inman is a professor of finance and economics, Wharton School, University of Pennsylvania. When he wrote this article, he was a visiting scholar in the Research Department of the Philadelphia Fed. Bob thanks Ted Crone, Len Nakamura, and Dick Voith for very helpful comments on an earlier draft. This article should be read as a companion piece to Dean Croushore's 1990 article in the *Business Review*.

Assets will include all the money in your checking and savings accounts plus all the money in your retirement account plus the market value of your tangible assets such as your car, your home and property, and other possessions. Liabilities will include all the money your family owes for short-term loans on credit cards and cars and long-term loans for a home mortgage or college tuition. Your assets minus your liabilities defines your net worth. This will be the amount of money in your private purse. The more you save and the less you borrow, the more you have in the family's private purse. Your family's net worth—along with your future income—will be an important determinant of your family's future consumption; the higher your net worth today, the more you can consume tomorrow.

In calculating your net worth your accountant does not consider what's in your public purse. But a government's assets and liabilities—the contents of your public purse—are no less important to the average American family's economic future than its private net worth. Because Philadelphia allowed the city's short-term debt to become excessive, the average city resident has suffered sharp reductions in public services and a 1-percentage-point increase in the local sales tax. Residents of Orange County, California, are likely to face similar declines in their service levels over the next few years as they recover from an investment loss of $2.5 billion. The average Californian faces additional budget cuts as the state seeks to solve its current deficit problem, exacerbated by past underfundings of its public employee pension plan. Finally, paying interest on the federal debt and controlling its growing burden on private incomes will require reduced federal spending, higher federal taxes, or both.

Your share of your governments' net worth is your money, and it holds important consequences for your economic future.[1] When a government's net worth declines—possibly even becoming negative—you will see either higher taxes or lower services in the future. When a government's net worth increases, your future services can be increased or your taxes can be reduced. Either way, your family is better off.

Governments create net worth by adding savings and tangible assets to the public purse and by limiting those activities that take money from the purse, such as new debt or contractual liabilities. By definition, government *Net Worth* equals *Savings* in financial assets plus the value of *Tangible Assets* minus the present value of future *Government Debt* and future government contractual *Liabilities:*

Net Worth = Savings+Tangible Assets
-Government Debt-Liabilities.

Financial Savings and Tangible Assets. *State and local governments* save in five accounts: an unrestricted savings account, often called a "rainy day" fund; a bond fund, which holds the proceeds of government borrowings until they are spent on government investment projects; a sinking fund, which holds savings for future repayments of government debt; a state insurance trust fund, which holds private employers' tax contributions to cover state payments for unemployment benefits and workers' compensation; and a pension fund, which holds government and employee contributions to cover future pension payments to state and local employees. The *federal government* saves in three ways: a general cash savings account; various pension fund accounts, which hold government and employee contributions to cover future pension payments to federal employees and military personnel; and the Social Security trust fund, which holds

[1]Not every one gets an equal, per person share of a government's net worth. I will present estimates for the average resident. Your share will be determined by your use of public services and by your share of your governments' tax burdens. You may receive more or less than the average resident in your community.

payroll taxes to cover future payments to retirees. State and local governments typically invest their savings funds in stocks, corporate bonds, and U.S. Treasury bonds. Federal government pension funds and the Social Security Trust Fund invest their savings in U.S. Treasury bonds. When included in the public purse, such public savings should be valued at their current market prices.

Governments' investments in public schools, public hospitals, roads, bridges, public lands, and military equipment add to the tangible assets in the public purse. These tangible public assets create economic wealth in much the same way that private tangible assets create wealth: by contributing to the production of valuable goods and services. Schools provide education, and hospitals provide health care. Roads and bridges facilitate transportation. Public lands provide mineral resources and scenic beauty. Tanks, planes, and ships protect our economic wealth from foreign expropriation. Each of these public assets should be valued in the public purse for the stream of economic benefits it creates.

Government Debt and Contractual Liabilities. Offsetting the value of government financial and tangible assets are the future obligations on the government from previous borrowing and other contractual promises. Debt liabilities equal the future stream of interest and principal repayments required to service the government debt. This stream of payments needs to be expressed in today's dollars, however. In effect, the present value of the debt measures what the government would have to pay current bondholders in the open market to buy back—or "defease"—the government's debt obligation. Alternatively, this lump sum payment equals what current holders of the government's debt would have to put out today for an identically risky alternative investment that provided the same stream of future payments.

In addition to the promise of debt repayment, local and state governments and the federal government promise other future payments as well. Those promises can take either of two forms: contractual or political. Contractual promises are enforceable in court; political promises are not. For this analysis, only contractual promises are included as a government liability.

At the state and local levels, the important contractual obligation of government is the promise of a pension for public employees. The discounted present value of these promised pension payments measures the government's pension liability. Again, this is equal to what the government would have to pay the beneficiaries of these promises—current and future retirees—so they could invest and earn an identical stream of future payments.

At the federal level, the important contractual liabilities include promised pension payments to government employees, including military personnel, and the promised payments to depositors of failed banks and savings and loan institutions whose accounts are insured by the federal government.

MEASURING GOVERNMENT NET WORTH

Government savings is the market value of the cash and security holdings of the government. Annual surveys of city and state government finances provide estimates of their cash and security holdings.[2] The financial assets held in state and local governments' rainy day funds, bond funds, sinking funds, and insur-

[2]The surveys are part of the *U.S. Census of Government*. There is an important question as to whether the reporting state and local governments provide "market value" or "book value" estimates of their cash and security holdings. Even if the governments report only book value, however, city and state governments turn over assets in their accounts every year or two. Thus, book values will closely approximate true market values, and the difference from market value in the survey reports is likely to be small.

ance trust funds are combined into a single savings account for these governments.[3] Table 1 reports estimates of the average real (1990 dollars) per capita savings for all 50 states and a sample of local governments in each of the fiscal years, 1972-90. Savings were estimated for all states but for only 41 of the largest U.S. cities.[4] The estimated state and local savings reported in Table 1 represent the per capita state savings plus the per capita city savings of the sample of 41 large cities.[5]

The value of tangible assets held by state and local governments is estimated by the replacement value of all publicly owned capital in all U.S. states and in 36 of our largest cities.[6] The replacement value of the public asset—a bridge, a road, or a public building—is an estimate of what it would cost in real (1990) dollars to replace the asset at its current quality if it were destroyed. The replacement value of a public asset adjusts for the depreciation over time in the stock of that asset.[7] Thus, an old bridge or roadway has a lower replacement value than a new bridge or road. The replacement value of state and local government assets is not the same as the assets' market value—that is, the value that a purchaser of an asset would offer for its use. Market values are the preferred measure of the true worth of any asset, but unfortunately, public capital is not bought and sold in an open market. Thus, published measures of the market value of state and local public assets do not now exist.[8] Like all previous estimates of the value of government assets, the estimates in Table 1 rely on the replacement cost measure.[9]

[3]Financial assets held by state and local governments for their public employee pensions are deducted from pension liabilities and reported separately as the state or local government's unfunded pension liability; see footnote 11.

[4]While savings, assets, debt, and pension liabilities could be estimated for all state governments, only a sample of local governments could be included in the analysis. Large U.S. cities for which full financial data could be obtained from the *U.S. Census of Government* surveys constitute the local government sample. Table 1 lists the 41 included cities. These cities represent approximately 15 percent of the U.S. population in 1990. Of the $12,539 per resident in total state and city net worth in 1990, the average city contributed $8626 per resident (69 percent) and the average state contributed $3913 (31 percent). At the time this study was done, the *U.S. Census of Government* surveys were complete only to 1990.

[5]We do not know how representative the large city estimates of savings, assets, debts, and pension liabilities will be for all U.S. cities and towns. Furthermore, county government assets and liabilities have been excluded from the analysis. It is likely that each of the components of net worth is larger in our sample cities than for an average U.S. community, but the difference between assets and liabilities—the net worth estimate—may reasonably approximate net worth in the average community. Until a full analysis is done, however, the conclusions from Table 1 must be limited to the states and the large cities in our sample.

[6]A complete series of investment data for the years 1902-90 needed to estimate assets could not be obtained for five of the sample's 41 cities: Birmingham, Louisville, Norfolk, Rochester, and St. Paul.

[7]Replacement values of the public infrastructure in our sample cities and states were estimated using the perpetual inventory method, which defines the capital stock at time t as: $K_t = K_{t-1} - \delta K_{t-1} + I_t$, where K_t is the replacement value estimate of the capital stock in period t, K_{t-1} is the replacement value of the capital stock in the previous period, δK_{t-1} is the depreciation in that capital stock over the previous period, and I_t is the level of gross investment made by the city or state in period t. K_t, K_{t-1}, and I_t are all measured in constant (1990) capital goods prices. The capital stock series reported in Table 1 is the aggregate of state and city investments in construction, equipment, and land. See Boskin et al. (1989) for a discussion of this approach to public capital stock measurement.

[8]In a creative study of the effects of public capital stocks on local land prices using the database summarized in Table 1, Haughwout (1994) has estimated the marginal benefit of an additional dollar of public capital spending. He finds that new public capital investment has a positive rate of return in growing cities and a negative rate of return in declining cities.

The reported estimates of assets in Table 1 are therefore the average replacement values of state and city public assets per resident for the residents of the largest U.S. cities.

Debt liabilities of state and local governments are measured as the discounted present value of all future interest and principal repayments owed to the holders of the governments' debt. The present value measures the current worth of the future stream of promised interest and principal repayments. If the government were to buy back—or defease—its debt, it would have to pay bondholders this current value. This current market value, therefore, measures the financial liability of the governments' debt. As current interest rates rise, the market value of existing debt falls because bond buyers could purchase newly issued bonds with the same total interest payments for a lower price. Conversely, as cur-

[9]Important previous studies using the replacement cost methodology include Musgrave's (1986) ongoing work estimating the national stock of public capital and Boskin et al.'s (1989) study of government assets and liabilities.

TABLE 1

Average State and City Government Assets and Liabilities*

Year	Savings	+ Tangible Assets	- Government Debt	- Unfunded Pension Liabilities	≅ Net Worth
1972	$2576	$13,720	$3302	$3341	$9651
1973	2714	13,915	3401	4021	9166
1974	2826	14,113	3502	4477	8902
1975	2815	14,320	3221	4381	9479
1976	2755	14,478	3280	4250	9649
1977	2561	14,573	3179	4568	9391
1978	2765	14,552	3138	4627	9558
1979	2785	14,612	2680	4979	9727
1980	2897	14,750	2456	5119	10,079
1981	2708	14,851	2038	4785	10,740
1982	2717	14,880	1837	4567	11,214
1983	2979	14,902	2345	4093	11,469
1984	3148	14,926	2474	4537	11,096
1985	3296	14,975	2532	4113	11,664
1986	3749	15,050	3148	3862	11,840
1987	4114	15,169	3638	4261	11,458
1988	4395	15,319	3448	4121	12,235
1989	4451	15,463	3571	3727	12,701
1990	4537	15,621	3710	3989	12,539

* The Savings, Government Debt, and Unfunded Pension Liabilities columns are based on all 50 states and a sample of 41 cities: Atlanta, Baltimore, Birmingham, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Columbus (Ohio), Dallas, Denver, Detroit, Ft. Worth, Houston, Indianapolis, Kansas City (Missouri), Long Beach, Los Angeles, Louisville, Memphis, Milwaukee, Minneapolis, Newark, New Orleans, New York City, Norfolk, Oakland, Oklahoma City, Omaha, Philadelphia, Phoenix, Pittsburgh, Portland, Rochester, San Antonio, San Diego, San Francisco, Seattle, St. Louis, St. Paul, and Toledo. Unfortunately, the Tangible Assets and final Net Worth columns could only be estimated for a restricted sample of 36 cities; see footnote 6 in text. Because of the differences in column samples, the Net Worth column will not exactly equal the sum of Savings and Tangible Assets minus Government Debt and Unfunded Pension Liabilities.

Source: Author's calculations.

rent interest rates fall, the market value of existing debt rises. The Debt column of Table 1 reports estimates of the real (1990) market value per resident of outstanding short- and long-term state and local government debt for residents of the largest U.S. cities for the period 1972-90.[10]

The other important contractual liability of state and local governments is their promise to pay *pension annuities* to their current and retired workers.[11] The discounted present value of all promised annuities to current and retired government employees is the total pension liability of the governments, where future annuities are discounted at the rate of return available to government investment. Offsetting this total pension liability are all the assets currently held by the government in its pension account and the required contributions of the employers and employees eligible for the promised benefits. The difference between total pension liabilities and total pension assets is called the unfunded liability of the government's pension plan.[12] The column entitled Unfunded Pension Liability in Table 1 provides estimates of the real (1990) dollar value of unfunded state and local pension liabilities per resident in the sample 41 largest cities, again for the period 1972-90.

Together, the Savings, Assets, Debt, and Unfunded Pension Liability columns of Table 1 provide an estimate of the per capita net worth held by state and local governments for residents in the average large city in the United States for the years 1972-90 (see Net Worth in Table 1). Real government net worth for our sample states and large U.S. cities has been rising modestly since 1972, at a rate of about 1.9 percent per year. Importantly, state and city governments make a significant positive contribution to family net worth. For an average family of four, the public purse was richer by about $50,156 in 1990 (= $12,539 x 4) because of past and current fiscal policies of state and city governments. (For how Philadelphia and the Third District states compare with other cities and states, see *How Much Money Is in A Philadelphian's Public Purse?* and *How Much Is in the Public Purse of Delaware, New Jersey, and Pennsylvania?* in the Appendix.)

What has the federal government contributed to the public purse? Table 2 summarizes Bohn's (1992) estimates of federal government assets and liabilities for the sample period 1972-89. While our nation's states and cities were putting money into our public purse over the sample period, the federal government was taking money out. Federal government net worth has been consistently negative because federal government liabilities exceeded federal government assets over the sample period.[13]

Included in federal government savings (Table 2, Column 1) is the market value of all government cash and deposits, gold and official foreign exchange, and credit market instruments held by the government. Included in federal government tangible assets (Table 2, Column 2) are estimates of the replacement value of all physical assets, including military equipment, the market value of government

[10]The estimates of the market value of state and local government debt use the methodology described in Butkiewicz (1983).

[11]Not included as a contractual obligation of state governments are possible liabilities within the state unemployment insurance trust fund and the state's workers' compensation trust fund. These funds are best seen as political rather than contractual liabilities. For a careful analysis of state unemployment systems from the perspective of the public purse, however, see Vroman (1986).

[12]The methodology used to estimate state and city unfunded pension liabilities is described in Inman (1986).

[13]Croushore's article was based on estimates by Robert Eisner and Paul Pieper, who did not consider unfunded federal pensions. Hence, that analysis showed a positive federal net worth in some periods.

TABLE 2

Federal Government Assets and Liabilities[a]

Year	Savings	+ Tangible Assets	- Gov't Debt	- Pension Liabilities	- Other Liabilities	= Net Worth
1972	$1516	$6073	$5027	$4657	$289	-$2384
1973	1631	6233	4756	4964	329	-2185
1974	1803	6830	4408	5074	402	-1251
1975	1651	6733	4994	5151	364	-2125
1976	1761	6861	5527	5290	426	- 2621
1977	1776	7062	5583	5391	399	-2535
1978	1955	7285	5487	5420	504	-2171
1979	2461	7598	5117	5354	659	-1071
1980	2520	8194	4914	5292	799	-291
1981	2152	8881	4964	5119	1011	-61
1982	2177	8787	5946	5209	873	-1064
1983	2138	8637	6599	5464	729	-2017
1984	2135	8401	7448	5429	687	-3028
1985	2310	8218	8672	5253	774	-4171
1986	2424	7488	9784	5204	922	-5998
1987	2352	7464	9666	5070	905	-5825
1988	2078	7177	9752	5072	1081	-6650
1989	1937	7244	10,179	5168	1003	-7169
1990	-	-	-	-	-	-7307[b]

[a]Source: Bohn (1992) adjusted to real (1990) dollars per capita. Bohn's data do not contain estimates for 1990.

[b]Author's calculation. See footnote 16.

land, and the market value of government-owned mineral rights. The replacement value of the federal government's physical assets is calculated by the same methods used to estimate replacement values for state and city governments. Federal government debt (Table 2, Column 3) is an estimate of the market value of government debt, using the same methodology employed for the state and city estimates. Federal government liabilities are divided into its two components: aggregate pension liabilities (Table 2, Column 4[14]) and "other" contractual liabilities (Table 2, Column 5), the largest of which, over our sample period, is deposit insurance guarantees.[15] All assets and liabilities are reported in real (1990) dollars per U.S. resident.

Federal government net worth (Table 2, Column 6) is the sum of Savings and Tangible Assets minus Government Debt minus Pension Liabilities minus Other Liabilities.

[14]The pension liability estimates in Table 1 are state and city aggregate liabilities less state and city pension fund assets. These net liabilities are reported in Table 1 as the unfunded pension liability. Bohn's accounts of federal assets and liabilities, however, report only the aggregate pension liability; pension fund assets are included as part of aggregate Savings in Table 2. Importantly, since the net worth calculation does subtract all liabilities from all savings, the final estimates of Net Worth in the federal sector are unaffected.

[15]Excluded from other liabilities are future federal Social Security payments to current and future retirees. Boskin et al. (1989) argue that because the promise is politically uncertain and benefits can be adjusted at any time, Social Security liabilities should not be counted within the same ledger as other government assets or government debt. On the other hand, Feldstein (1974) and Bohn (1992) have argued that Social Security should now be a promise as binding as any legal contract. Unfortunately, compelling estimates of the true value of this liability are not available. Bohn (1992) provides one estimate that effectively doubles the 1990 liabilities of the federal government!

Over the sample period, federal net worth has been consistently negative. The net worth of the federal government did improve over the 1970s, largely because of increases in government savings and nonmilitary tangible assets. The 1980s, however, saw a major decline in net worth, and the central cause was the large increase in federal government debt. Averaged over the entire two decades, federal net worth has been declining at the rate of 6.7 percent a year.[16]

Together, state and city government net worth plus federal government net worth defines all the money in an average family's public purse. For residents of our largest cities, total public net worth (= Net Worth from Table 1 plus Net Worth from Table 2) is always positive, equaling $7267 per resident in 1972 (= $9651 - $2384), rising to a peak of $10,679 per resident in 1981 (= $10,740 - $61), and then falling to a low of $5232 by 1990 (= $12,539 - $7307).[17] Table 2 reveals clearly that the last decade's large increase in the federal government's debt liabilities is the cause of this large decline in our public wealth.

SHOULD WE BE WORRIED?

Should we as a society be concerned about the decline in our public wealth over the past decade? If these large federal government borrowings of recent years had been allocated to increase public-sector capital stocks at the local, state, and federal levels or if they had been placed in a government savings account, there would be little reason for concern. As Tables 1 and 2 make clear, however, this was not the case. Since 1980, federal tangible assets have declined with the shrinking of the defense budget while the stock of public capital at the state and city level has grown only slightly. Federal cash and security holdings have also fallen. The only recent good news in Tables 1 and 2 is the growth of state and city savings, both generally (Table 1, Savings) and in the pension fund (Table 1, Unfunded Pension Liabilities).[18] On balance, however, these state and local savings gains do not offset federal borrowings. There are three practical reasons to be worried about these trends: government bankruptcy, future fiscal inefficiencies, and intergenerational inequities.[19]

Government bankruptcy occurs when the

[16]There is no reason to think federal net worth has improved since Bohn finished his study. On the contrary, government debt has only gotten larger since 1989, and federal tangible assets have only gotten smaller because of the reductions in military spending. (Even though military assets have declined, we are surely better off now that the old Soviet nuclear threat has been reduced.) Aggregate pension liabilities and other liabilities are probably unchanged. If we assume all other columns except Government Debt have remained constant in real terms from 1989 to 1990 and then subtract 1990's actual real (1990) level of government debt per capita of $10,317, we obtain a preliminary estimate of federal government net worth in 1990 of -$7307.

[17]See footnote 15.

[18]Metcalf (1990) and Gramlich (1991) provide two alternative studies of state and local government savings behavior.

[19]And there's one theoretical argument why not to worry. Under the economic theory of "Ricardian equivalence," it does not matter whether government net worth is large or small. The Ricardian view of public finance, developed in Barro (1974), assumes:(1) taxpayers anticipate fully the economic implications of a richer or poorer public purse; (2) there are no fiscal inefficiencies in moving dollars between the public and private sectors (i.e., governments use "lump-sum" taxes); and (3) parents care as much about their children's economic fortunes as they care about their own. In the Ricardian economy, taxpayers fully understand that increased government net wealth means more public services and/or lower taxes in the future and rationally adjust their savings and private wealth downward to share in some of those benefits today. Taxpayers also understand that reduced public wealth means less public or private consumption in the future and thus rationally adjust their savings and private wealth holdings upward. Thus, private wealth adjusts dollar for dollar to changes in public wealth. The current empirical evidence goes against the strict Ricardian view of public finance; see Bernheim (1989).

contractual obligations of the government to bondholders and pensioners exceed the ability of the government to raise taxes to pay for these obligations. A useful first indicator of how close a government is to falling into bankruptcy is the ratio of the government's debt to its tax base. When that ratio is too high, the government can no longer service its debt and must default. While the estimates summarized in Tables 1 and 2 allow us to conclude that government bankruptcy is not now a threat to the U.S. public sector, this does not mean that individual local or state governments cannot fall into trouble. Philadelphia's recent fiscal crisis is a case in point.[20,21]

Of greater concern are the fiscal inefficiencies forced upon us today by yesterday's decisions to reduce our public net worth. When government net worth declines—either because of large increases in debt or large reductions in savings and tangible assets—meeting current service needs and contractual debt and pension obligations will require potentially significant tax increases. To maintain public services at their 1980 levels yet meet governments' new contractual obligations in 1990, the combined average local, state, and federal tax rate would have to rise from an average rate of 19.1 percent to an average rate of 20.6 percent.[22] Such tax increases, if continued over many years, can have significant adverse effects on private-sector investment, new business formation, and work effort. Again, Philadelphia offers a telling example. In the 1980s, 19 tax increases pushed the city to the point where any additional increase in property or wage tax rates would generate virtually no new revenues.[23]

Perhaps the largest worry, however, is what our declining public net worth means for future generations of taxpayers. Increased public debt and reduced public savings and investment today means more consumption for today's taxpayers but less consumption for tomorrow's taxpayers. If the recent declines in government net worth continue for one or two more decades, our children will face not only higher taxes because of larger public debts and lower public savings but also lower incomes because productive public capital per worker has been reduced.[24] Taking dollars from the public purse to increase the consumption of today's adults lowers government net worth without increasing private net worth and, if continued, will mean fewer dollars in the purse and lower consumption for our children when they are adults tomorrow. Thus, a declining public net worth signals a potential intergenerational redistribution.[25] What goes into the pockets of today's taxpayers comes directly from the public purse we might pass on to our children. Unless replaced, the decline in the public net worth during the 1980s has cost our heirs approximately $5400 per person in future consumption.[26]

[20]See Abel (1992).

[21]See Inman (1995).

[22]The tax rate of .191 was calculated as that tax rate on 1990 income needed to buy the 1980 bundle of local, state, and federal governments' services and transfers and to service the *1980* level of local, state, and federal Net Debt (= Debt + Contractual Liabilities - Savings) at the 1990 10-year Treasury interest rate of .071. The tax rate of .206 was calculated as that tax rate on 1990 income needed to buy the 1980 bundle of local, state, and federal services and transfers and to service the *1990* level of local, state, and federal Net Debt (= Debt + Contractual Liabilities - Savings) at the 1990 10-year Treasury interest rate of .071.

[23]See Inman (1992).

[24]What is relevant for the production of private income is the ratio of public capital to labor, and this ratio has been declining steadily over the past two decades.

[25]See Auerbach, Gokhale, and Kotlikoff (1991).

[26]This approximation is based on the decline in public net worth from $10,679 in 1981 to $5232 in 1990, a loss to the public purse of $5447 per citizen. If public capital earns

CONCLUSION: WHAT SHOULD WE DO?

The public purse holds a significant share of every family's total savings. The estimates in Table 1 show that in the average U.S. city for the average family of four, state and city governments in 1990 held $50,156 per family (= $12,539/resident x 4) in net wealth. The estimates in Table 2, updated to 1990, show that the federal government imposed a net liability on this same family of $29,228 (= - $7307 x 4). Together, all governments in the United States have accumulated a public-sector net worth of $20,928 per family. Hence, public net worth is significant.[27]

What should we do if we want to increase the size of our public purse? Clearly, the state and local sectors have been the main public savers in our economy, and the federal government the main public borrower. Why? There are two possible explanations. First, we may want the federal government to run deficits and the state and local sector to save. The economic theory of federalism assigns the federal government the responsibility to use deficit policy for the management of cycles in our macro economy. Furthermore, to the extent that there are significant economic spillovers across state lines from the provision of public capital, the federal government should borrow and use the proceeds to subsidize the formation of state and local capital. However, sound fiscal policy requires the federal budget to be balanced over the business cycle, and this clearly has not happened. Nor is there any compelling economic evidence that state government investments create significant economic spillovers across state lines.[28] Alternatively, state and local governments simply may be more fiscally responsible, perhaps because they are constitutionally required to run balanced budgets. Yet Vermont, one of the states with the highest level of per capita net worth, is also the only state without a balanced-budget requirement.

There is no easy answer to why some governments save and others borrow, and thus no easy solution for how we might act to increase funds in our public purse. Ultimately, whether a government saves or borrows turns on what its citizens want. If we want a more rational and considered public policy toward our economic futures, a good place to start is for each of us to know what's in his or her public purse.

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the competitive rate of return and there is no population growth, this lost public net worth would have generated a future consumption stream whose present value just equals $5447 per future resident.

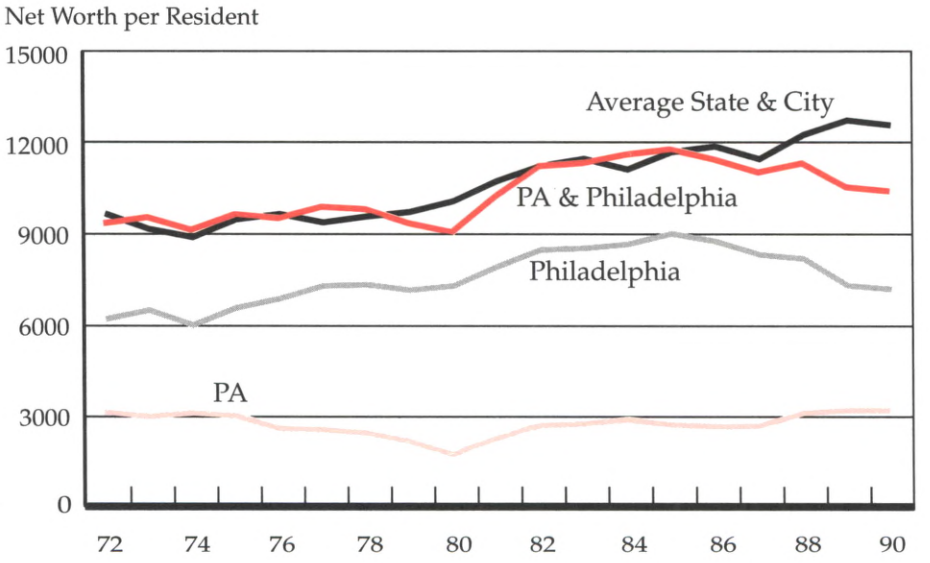
[27]For comparison, by 1989 a typical (median) U.S. family had accumulated a private net worth of $47,800 (in 1990 dollars); see Kennickell and Starr-McCluer (1994; Table 3). The average U.S. family, which includes the very wealthy, had a private net worth of $183,800 in 1989. These estimates do not include expected Social Security receipts.

One must be careful not to simply add together estimates of public and private net worth, however. There is the possibility of significant double counting. State and local government net worth—$50,156 per average family—constitute assets that households potentially buy and sell when they relocate from one community or state to another. *If markets work perfectly*—possibly a big "if"—market competition will force households and businesses moving into a new location to pay the current owners of homes and businesses for the value of the city's and the state's public net worth. In this case, private land prices will fully reflect the value of state and local government net worth, and adding together private and public net worth would be double-counting.

[28]See Holtz-Eakin (1994).

APPENDIX

How Much Money Is in a Philadelphian's Public Purse?

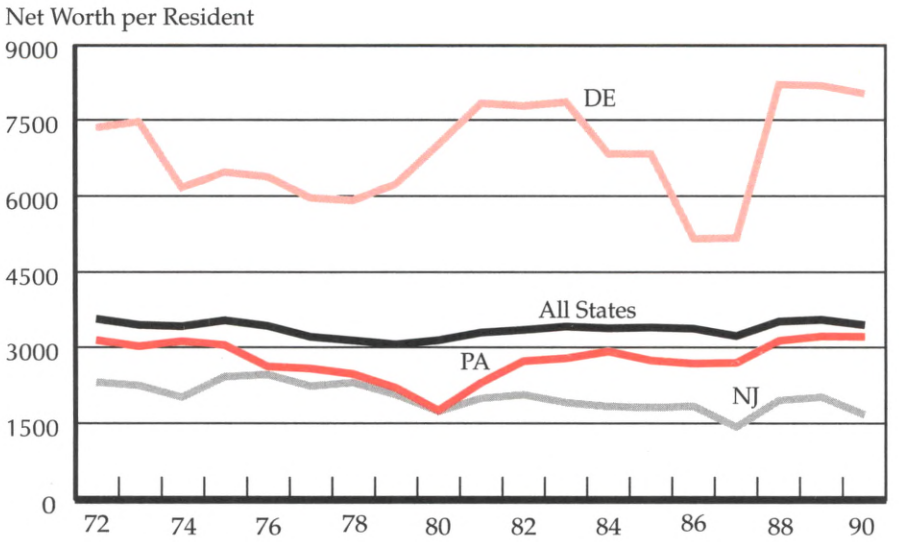


This figure illustrates the levels and time paths of the estimated net worth of Philadelphia and Pennsylvania compared with the level and time path of the net worth of all state and large city governments over our sample period, 1972-90. Philadelphians followed the national average rate of accumulation over most of this period until 1985. By 1990, residents in other states and cities had accumulated $12,539 per resident in public wealth (see Table 1, page 23), while Philadelphians had collected $10,424 per resident, about 20 percent less than the national average. *For a typical family of four living in Philadelphia, the family's public purse contained an estimated $41,696.*

But what caused the sharp decline in the value of the public purse since 1985? The answer is the fall in the net worth of Philadelphia. From a peak of $9013 per resident in 1985, cash and security savings were systematically reduced and government borrowing and unfunded pension liabilities were systematically increased so that, by 1990, net worth had been reduced to $7201 per resident, a 20 percent decline over the intervening five budget years. In hindsight, this run on city savings and buildup of public debt were clear indicators of the city's 1990 fiscal crisis.

APPENDIX

How Much Money Is in the Public Purse of Delaware, New Jersey, and Pennsylvania?



This figure illustrates the levels and time paths of the estimated net worth of the three state governments of the Third District compared with the per capita net worth of all state governments. Pennsylvania follows closely the average net worth of all other state governments while Delaware is significantly above the average for all states and New Jersey is significantly below. New Jersey falls below the average for all states because of its larger-than-average levels of government debt and pension underfundings. Delaware exceeds that average because of its significantly larger-than-average level of tangible public assets per resident. Pennsylvania resembles averages for all states in all its accounts—savings, tangible assets, debt, and pension underfunding.

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