Accurate Valuation in the Absence of Markets

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Incomplete markets do not provide accurate information about people's subjective valuations of goods. Knowledge of these subjective valuations is often important, however, for example when compensation payments for damaged or destroyed property are required. We argue that in such cases, an attractive measure of the value of a good is the reservation price of the owner, who is generally the person who values it most highly. If a property is sufficiently unique so that there is no market price that can be used as an approximation, then the only way to learn this subjective reservation price is to have the owner self-assess his property. We describe a mechanism that provides an incentive for the owner to self-assess his property honestly without requiring that the property's value be objectively observable.

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1. Introduction

How does one determine the utility that a good provides to its owner? For goods for which no market exists and for goods that are traded very infrequently, economists have had limited success in developing mechanisms that provide reliable information about the utility that they generate. The demand-revealing process (Tideman and Tullock 1976) can be used to infer valuations for nonexcludable goods, but this process does not solve the problem of valuing private goods and bads that are rarely (or never) traded. We present a simple mechanism that permits us, in the absence of

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any market transaction, to learn how a person values a good that might cease to provide utility to him.

Why would anyone need this information? One application of our mechanism is in property law. When governments take private properties under eminent domain, owners are entitled to just compensation for their losses. But how does one determine an owner's true loss? At best, an independent appraiser can seek to assess the property's market value, but this is difficult if the property in question is located in an area where few comparable properties have been sold recently. For properties that have a high personal value to the owner, even an accurate estimate of the property's market value is likely to be a very imprecise estimate of the owner's true loss. But an estimate of the owner's true loss is needed if he is entitled to compensation. Our mechanism provides incentives for truthful assessments of owners' monetary losses. If it is applied to all properties in a depressed area that is a potential target for urban renewal, then our mechanism can also alleviate the holdout problem of private land assembly. Another application is in general real estate assessment. Communities often levy taxes on property value, which requires a procedure for specifying the value of property that is taxed. It is generally difficult to determine the current value of properties that rarely change hands, and few activities of local governments generate as much ire as real estate assessments. Our mechanism can be used to make real estate assessment for tax purposes more transparent. Finally, our mechanism has applications to the law of torts when owners can demand compensation for damaged or destroyed properties with unique characteristics.

Implementation of our mechanism is straightforward because it only requires that the owner state his own subjective valuation of his property. Such a system of self-assessment must provide an incentive for correct assessment. Offering payment in the event of a loss equal to the self-assessed value discourages underassessment as long as the probability of a loss exceeds zero. A requirement that the owner pays a tax whose amount rises with the reported self-assessed value discourages overassessment. We show that motivating *truthful* self-assessment requires that incentives against over- and underassessment be harmonized through a tax rate that is related in a specific way to the probabilities of loss at different self-assessed values. The only major requirement for motivating truthful assessments in our mechanism is that governments (which levy the tax) and property owners (who announce self-assessed values) have identical beliefs about the probability of a loss. Below, we discuss methods of ensuring that this happens.

Self-assessment of property has a long history both in practice and in the economics literature.[1] Harberger (1965, 119) proposed self-assessment of real estate as "the economist's answer to the assessment problem" that is "simple and essentially foolproof." Strasma (1965), Bird (1984), and Colwell (1990) offered detailed analyses of the benefits and potential obstacles of using self-assessment to determine property values for tax purposes. Most of this literature, however, ignores the fact that self-assessment does not automatically reveal the owner's valuation of his property.

We know of only two previously proposed mechanisms that lead to truthful self-assessment. The simplest is the mechanism proposed by Becker, DeGroot, and Marschak (1964). The owner states a value x, and someone else (possibly the government) draws a random price y; the owner keeps his property if $y < x$, and receives y and loses control of his property if $y > x$. This mechanism provides owners with an incentive to honestly reveal their valuations as long as y is independent of x. It is not applicable to cases in which an owner loses control of his property through a tort, because there would be no corresponding offer y. The mechanism can be used to determine the owner's valuation when a government considers taking the property under eminent domain if the government seeks to implement a social project worth y, but truth telling requires that the owner receive the entire social benefit of the project as compensation. Similarly, if the mechanism is used to determine owners' valuations of real estate, then occasionally the government would have to acquire properties at values far higher than an owner's own valuation, which would be an unpopular use of public funds. The second mechanism, developed by Niou and Tan (1994), does not require that the government pay more than the stated valuation. It leads, however, to truthful self-assessment only if it is possible to establish the true value of property in some way other than asking the (risk-neutral) owner, for example, by an audit.

In contrast, our mechanism is applicable to all cases in which owners can lose control of their properties, as long as they do not value their properties at infinite amounts and as long as the probability of a loss can be determined objectively. It works even if owners are the only persons who know the values of their properties, and it applies to risk-averse as well as risk-neutral owners.

Discussions of self-assessment of property in the context of real-estate assessment are often accompanied by a comment that, although self-assessment might be interesting in theory, it is not practical because requiring owners to sell their properties against their wishes would be an unacceptable intrusion on property rights.[2] We believe that this reaction is

due mainly to a misconception about the meaning of *value*. We therefore begin our analysis in section 2 by reviewing some of the difficulties with concepts of value and argue that an attractive measure of a good's value is the reservation price of its owner. We do not claim that our discussion is original, but we consider it necessary to forestall some objections that might be raised against our mechanism. In section 3, we analyze the economics of self-assessment, examine some common objections, and review Niou and Tan's proposal. We describe our mechanism in section 4, discuss several of its characteristics in section 5, and suggest a range of possible applications in section 6. Section 7 concludes.

2. What Is the Value of a Good?

2.1. The Concept of Value

Neoclassical economists generally agree that there is no such thing as "objective value," and they relate a good's value solely to the subjective utility that people receive either directly from consuming it or indirectly from consuming other goods for which it can be exchanged.[3] If markets were complete, then every tradable good would have a contingent market price for each possible state of the world. This price would reveal the marginal utilities that owners and potential owners thought they would receive from owning the good in that state of the world.

Observable prices do not always fulfill this function when markets are incomplete because consumers do not know the prices of goods in missing markets and therefore determine their marginal valuations conditional only on the information about prices that is available to them. This implies that, even if preferences are assumed to be stable, there is no such thing as "absolute subjective value" and that subjective values are always measured, at best, relative to consumers' information about prices.

Although this implies that there is no unique measure of value for any good, it is nevertheless sometimes necessary to assign such a measure, for example to provide adequate compensation for losses. We suggest that an attractive definition of *value* is the reservation price of the person who values the good most highly. This definition of value is attractive because this reservation price is the only price that nobody considers too low and at least one person considers not too high. When free exchange is possible and transaction costs are ignored, the assumption of rationality implies that the owner of any good values it at least as highly as the person who makes the highest offer for it.[4] It follows that the owner's reservation price

(which is infinite if the owner plans to refuse all offers) represents the highest subjective value that anyone attaches to this particular good.[5] The owner's reservation price can then be defined as the price at which he is indifferent between selling and not selling his property.

There is a long tradition in economics of identifying a good's value with its opportunity cost. From the perspective of that tradition, the value of any good is determined by the highest offer from someone other than the owner (that is, the second highest bid, with the highest bid being that of the owner) because this is the opportunity cost of having the good owned by its owner. Defining the value of a good as its opportunity cost, however, creates the puzzle that whenever a buyer is willing to split the gains from trade, he is intentionally paying a price that exceeds the good's value. Defining the good's value as the reservation price of the buyer (the person who values the good most highly) rather than as the reservation price of the seller (the person who values the good second highest) prevents the buyer's bid from exceeding the good's value.

Although it is straightforward to define a good's value as the reservation price of its owner, it is not obvious whether and how this reservation price can be measured objectively. If a good's value is the subjective utility that it provides to its owner, then value is measured in *utils*. The owner's reservation price is any bundle of other goods that provides him with the same utility as the good and for which he would voluntarily exchange the good. Any attempt to measure the owner's reservation price in monetary terms leads to three problems.

First, an expression of the owner's reservation price in units other than utils cannot be an objective measure of the subjective utility that he receives from the good because there is no interpersonally meaningful yardstick that can be used to express subjective measures of value. Subjective values can be expressed in terms of money because money provides utility, but monetary reservation prices do not provide interpersonally meaningful information about the owner's experience of utils. Rather, they represent the amount of money that the owner believes is required to purchase other goods that will give him the same number of utils.

Second, if a person's marginal utility of money changes, then his monetary valuations of all goods change as well, even though his valuations in utils may remain unchanged. Monetary reservation prices do not represent invariant measures of value.

Third, virtually all decisions are to some extent restricted by a person's intertemporal budget constraint. The lower a person's income and wealth, the higher are his opportunity costs of not selling his property. If the process

of measuring a good's monetary value lowers the owner's wealth, then the very act of measuring value may change the owner's valuation of the good because it increases the owner's opportunity costs of not selling his property.

This implies that there are at least three different notions of value. First, there is the utility that a good provides to its owner. Second, there is the monetary measure of the utility that the good provides to its owner. Third, there is the owner's monetary reservation price, which is the price at which he is prepared to sell his property if society's attempt to measure this reservation price is costly for him. The first is the value that we would like to learn; the third is the value that we are able to learn if markets are not complete.

Fortunately, these difficulties are of only secondary importance for our purposes. First, we do not seek to determine the value of things in general but only in cases in which it is important that a good's value can be determined. Even if we are unable to measure the utility that a good provides to its owner, measuring the owner's monetary reservation price is likely to be a better approximation of this value than any alternative measure. Second, when our mechanism is used to determine the basis for monetary compensatory payments, subjective value must be expressed in monetary terms as well.

2.2. The Relationship between a Good's Value and Its Market Price

When a good's value is defined as the reservation price of the highest bidder, it is not possible to learn the value of a good by observing its market price, because the market price reflects the reservation price of the seller (Samuelson 1948) but not necessarily the reservation price of the buyer.[6] The market price understates the buyer's reservation price whenever the buyer's consumer surplus for the last unit purchased is positive. This may happen either because the buyer's marginal utility function is discontinuous or because a traded good is not infinitely divisible. In such cases, the only person who knows the value of a good is the owner himself, and the only way for others to learn the value of this good is to persuade the owner to report his reservation price.

Because it is cheaper to observe a good's market price than to have the owner report his reservation price, it is useful to examine the conditions under which market prices—if they exist—provide adequate approximations of owners' reservation prices. A good's market price is likely to be close to the buyer's reservation price if the good is divisible and the buyer

is not a monopsonist. The first characteristic makes it possible for the buyer to purchase additional units of the good until his reservation price no longer exceeds the market price. The second characteristic gives the buyer an incentive to do so. Similarly, a seller who is able to price-discriminate among buyers can charge prices that come closer to individual buyers' reservation prices than if he had to charge identical prices to all buyers. The less frequently a good is traded, the harder it will be for sellers to identify buyers' reservation prices. This suggests that market prices do not approximate buyers' reservation prices very well for indivisible goods that are rarely traded and for goods for which buyers are monopsonists.

One example of such a good is real estate. Most consumers do not buy more than one or two pieces of real estate in their lives, and preferences for locations are fairly heterogeneous. Both characteristics make it difficult for sellers to identify and charge the buyers' reservation prices. Real estate that is bought for personal use and not for speculation is not traded very frequently, which means that any initial relationship between the price of the most recent sale and the buyer's reservation price will loosen once the owner updates his valuation of his property through use. Additional examples are collectibles like rare books and old paintings, and family heirlooms that are valued only by small groups of persons.

When market prices do not approximate owners' reservation prices very well, the only way to learn the value of the good in question is to persuade the owner to report his reservation price. In the next section, we describe the characteristics of self-assessment procedures and examine a mechanism for truthful self-assessment that has been proposed in the public choice literature.

3. The Economics of Self-Assessment

3.1. The Idea of Self-Assessment and Common Objections

A person who is subject to self-assessment can be expected to provide a truthful report of the (monetary equivalent of the) value that he attaches to a good that he owns if and only if truthful reporting maximizes his utility. One way of making overassessment costly is to levy a tax that increases with the self-assessed value. Underassessment can be made costly by specifying that the owner will receive not more than the self-assessed value if he loses ownership of the good.

A common assumption in the literature on self-assessment of real estate is that the self-assessed value represents an offer to sell the property at the

self-assessed price. Self-assessment can then be administered in two ways: the owner can be required to sell his property when someone offers to buy it at the self-assessed price, and an owner who receives an offer for his property can be given the alternatives of either selling at the self-assessed price or paying a fine. Other forms of self-assessment are variations of these two approaches. For example, a system in which a bidder must offer a specified percentage above the self-assessed value is equivalent to the first method discussed above with a lower tax rate. A system without a penalty for turning down offers to buy at the self-assessed price is a limiting case of the second method with a fine of zero. The first method is the limit of the second as the fine approaches infinity.

Both approaches can be divided into cases in which everybody is permitted to submit bids for the self-assessed property and cases in which a specified set of possible buyers (for example, only the government or only neighbors) can bid for the property. The argument for permitting anyone to submit a bid is that collusion, corruption, and/or limited competence reduce the accuracy of self-assessment when there are only a few permitted buyers. Governments are unlikely to be as able as private bidders to determine which properties are underassessed and might have to sell many properties at a loss if they overestimate values. Permitting only the immediate neighbors or some other small set of individuals to buy at the self-assessed prices is an invitation to collusion or, if not that, an invitation for the owner to seek a price that is just high enough to avoid tempting the permitted buyers to buy.

Three common objections against the requirement that a self-assessed valuation be an offer to sell are worth reviewing. The first objection is that such a requirement is an unacceptable intrusion on property rights, because nobody should be required to sell his property against his will. This objection is meaningful only if self-assessment is compulsory and its use is adopted by less than unanimous consensus. If the citizenry adopts a compulsory self-assessment mechanism by unanimous consensus, then enforcing an obligation to sell is no different from enforcing an option contract in which one party has agreed to sell property to another party. If self-assessment is voluntary, then owners who object to selling their properties can simply let society assess their properties with traditional methods. For example, current assessment of real estate is based on the sales of nearby properties whose observed market values are interpolated to those properties that have not been sold. This practice yields imprecise assessments in areas with few sales. A community could offer each property owner the opportunity to self-assess his

property and use the additional information obtained from the self-assessed properties to improve the assessments of the remaining properties whose owners do not self-assess. Because owners who self-assess provide a positive externality in the form of more precise overall assessment, the community could offer a (Pigouvian) lump-sum reward as incentive to self-assess. When self-assessment is voluntary, it is also appropriate to speak of a valuation fee instead of a valuation tax because the payment that depends on the self-assessed value does not have the compulsory character of a tax.

If a compulsory self-assessment mechanism is adopted by less than unanimous consent, then it does indeed have a confiscatory character. In this regard, our mechanism is subject to caveats that apply to taxation generally and to any other limitations on property rights. For example, a government that is permitted to levy a tax on wealth can require an owner to sell his property to pay the tax—the main purpose of inheritance taxes is to reduce wealth inequality by requiring an heir to relinquish part of his inheritance. Similarly, a government may require that a person sell his property to pay his income tax liability, which ensures that people cannot escape their income tax liabilities by reducing their liquidity to zero. Whether it is appropriate for governments to enforce property sales to provide owners with an incentive to reveal their reservation prices truthfully depends on whether the social benefit of such self-assessment exceeds the cost of the consequent intrusion on property rights. For example, few activities of local governments are as hotly contested as the assessment of real estate for tax purposes. If self-assessment reduces these disputes sufficiently, then it could justify the consequent intrusion on property rights.

The objection that the obligation to sell is an unacceptable intrusion on property rights weighs most heavily if a compulsory self-assessment procedure provides owners with an incentive to understate their reservation prices. There should be less concern about requiring owners to sell their properties at prices at which they would voluntarily sell their properties. A mechanism that provides owners with the incentive to reveal their true reservation prices should therefore not be considered an unacceptable intrusion on established property rights. The only exception to this rule is the case when owners are not willing to sell their properties at any price, but the requirement to pay a tax on the self-assessed value prevents owners (with finite wealth) from stating infinite values. It is likely, however, that very few owners would refuse to sell their transferable properties for any finite price, even if they are not taxed, because the opportunity cost of refusing all finite offers is infinite.

The second common objection is that the obligation to accept all offers at the self-assessed price may require the owner to sell at an inconvenient time and cause intolerable transaction costs. This objection is based on the misconception that a property's value is constant. Rather, the owner's reservation price at any time depends on the inconvenience of selling at that particular time. An owner who is willing to sell his home for $200,000 at a time when he wants to relocate to another city may be unwilling to sell his home for anything less than $350,000 at any other time. The additional $150,000 is the satisfaction that the owner obtains from living in *his* home, and $350,000 is the true subjective value of his home because it represents the amount that he considers adequate compensation for the inconvenience of having to move at a time when he had not planned to do so.

The third objection is that owners may simply not have enough information to determine the (potentially substantial) transaction costs that they need to know to derive their reservation prices. The seriousness of this objection depends on the purpose for which the self-assessment mechanism is used. If it is used to determine owners' losses in takings under eminent domain or in cases in which owners incur losses as a result of accidents that are some other party's fault, then an owner's guess of his subjective loss, however inaccurate, is likely to be more accurate than someone else's estimate of this loss. Consider the owner who deems the convenience of living in his current home worth $350,000, although the market value of his property (the price that someone else may be willing to pay for the home) is only $200,000. If his property is taken and the owner is entitled to compensation for his loss, a third party's estimate of the owner's loss is likely to be much closer to the market value than to the owner's true loss. To resolve any ambiguity about whether the owner prefers self-assessment to conventional methods, one can allow each owner to choose whether he wants to self-assess his property or rely on third-party estimates of his loss.

The objection weighs more heavily if self-assessment is compulsory and owners can lose control over their properties because someone buys them. One way of ameliorating the anxiety that owners may feel is to restrict the occasions at which someone may buy properties at their self-assessed prices to a few days during a year and to provide each owner with the opportunity to update his reservation price on which he will be taxed by asking, "How much compensation would you consider appropriate if the government were to take your property under eminent domain during the next few days?"

3.2. Truthful Self-Assessment When
Property Value Is Objectively Observable

For cases in which governments are able to determine property values without the help of owners but want to reduce the cost of assessment by requiring owners to report self-assessed valuations, Niou and Tan (1994) developed a mechanism that induces risk-neutral owners to truthfully report the values of their properties. Their mechanism requires that the government make its own (assumedly costless) estimates of the true value of property and that it audit the property owner to learn the true value if the owner's reported value is below the government's estimate.[7] In addition to estimating the property value, the government sets a "cutoff value." If it audits the owner and learns the true value of the property, the government's subsequent actions depend on the owner's reported value and on this cutoff value. If the reported value is below the cutoff value and below the true value, then the government levies a tax on the true value and buys the property at the reported price. If the reported value is between the cutoff value and the true property value, then the government levies a tax on the true value, buys the property at the reported value, and imposes a fine on the owner that depends on the amount of underassessment, the tax rate, and the probability of an audit. If the reported value is at or above the true value, then the government does not buy the property and the property owner pays taxes on the true value.

Niou and Tan's mechanism induces property owners to report their property values truthfully, but it relies on the assumption that the government can learn the true value through an audit. This requires that the government have access to information other than the owner's reported value to estimate the property value with appropriate precision, albeit at a cost that the government prefers not to pay. It also requires that an owner be able to estimate the market value of his property more accurately and more efficiently than the government. Niou and Tan suggested that their mechanism can be used for the assessment of land. But, as argued in section 2, the market price of real estate, including land, does not approximate the reservation price of its owner very well. Even if one were to accept the market price as a reasonable approximation of the value of real estate in general, the infrequency of real estate sales in some areas limits the accuracy with which the location-specific market value of real estate can be estimated using observable sale prices. In most cases, it is therefore not possible to learn the value of real estate in any way other than asking the owner to report his reservation price. This

reduces the usefulness of Niou and Tan's mechanism for the assessment of real estate.

Although the property owner has an incentive to report the true value in cases in which auditing reveals this true value to the government, the government still needs to audit randomly to make its threat of auditing credible. Because auditing is costly, Niou and Tan's mechanism imposes a steady cost of assessment on the government. They said (Niou and Tan 1994, 113) that an "interesting problem is to design a scheme that induces truth-reporting at no costs. Unfortunately, such a scheme does not exist."

In the following section, we show that there is a scheme that comes close to the no-cost ideal. Because the government does not need to audit, no auditing costs arise. If anyone is permitted to acquire properties at their self-assessed prices, then no costs arise for the government besides the administrative costs of ensuring that the owners receive the self-assessed prices. If only the government is permitted to purchase properties, then transactions costs of acquiring and selling properties arise. To the extent that the government is able to ensure that such transactions do not occur too frequently, the mechanism is likely to be cheaper than a mechanism that relies on continual audits, in addition to being applicable to cases in which audits are not capable of determining value.

4. A Mechanism That Provides an Incentive for Honest Self-Assessment

Let v be the subjective value of a rival good to its owner. We assume that society considers it desirable that this subjective value be known (for example, for any of the applications discussed in section 6), so the government requires the owner to report a self-assessed value x. The owner has to pay valuation taxes $t(x)$ per unit of time that vary with x, and the owner faces a probability of $p(x)$, $0 < p(x) < 1$ per unit of time that the good will cease to provide utility to him. This may happen either through a natural disaster or as the result of human action—for example, the good might get stolen, damaged beyond repair, or destroyed. In such cases, the probability is unlikely to depend on the self-assessed value.[8] Alternatively, the government might consider taking the good under eminent domain or the owner might be required to sell the good if someone is willing to purchase it at the self-assessed price. In these cases, it is likely that the probability depends on the self-assessed value. An increase in the self-assessed value lowers the probability that either the subjective valuation of others or the

value of public use of the property exceeds the self-assessed value, so the probability that someone will purchase the property falls. It is therefore reasonable to assume that $dp(x)/dx \leq 0$. We assume that the owner and the government have the same beliefs about the value of $p(x)$ at every x, and we discuss this assumption in section 5.

If the owner keeps the good, then his net property value π is $\pi = v - t(x)$.[9] If he loses the good, then he receives net proceeds $\pi = x - t(x)$. The owner receives utility $U(\pi)$ from his property. We assume that his utility function is twice differentiable with $U'(\pi) > 0$ and $U''(\pi) < 0$, which correspond to the assumption that the owner is risk averse. In applications in which $dp(x)/dx < 0$, we can also admit risk-neutral owners for whom $U''(\pi) = 0$.[10] The owner maximizes his expected utility, or

$$V = [1 - p(x)]U(v - t(x)) + p(x)U(x - t(x)) \tag{1}$$

by choosing the x that solves the first-order condition

$$
\begin{aligned}
\frac{dV}{dx} = & \frac{dp(x)}{dx}(U(x - t(x)) - U(v - t(x))) \\
& - U'(v - t(x))\frac{dt(x)}{dx}[1 - p(x)] \\
& + U'(x - t(x))\left(1 - \frac{dt(x)}{dx}\right)p(x) = 0.
\end{aligned}
\tag{2}
$$

Theorem 1: The owner has an incentive to truthfully announce $x = v$ if the valuation tax rate equals the probability of a loss.

Proof: The government chooses $t(x)$ so that the owner's first-order condition holds if and only if $x = v$. This is equivalent to setting

$$\frac{dt(x)}{dx}[1 - p(x)] = \left(1 - \frac{dt(x)}{dx}\right)p(x) \Leftrightarrow \frac{dt(x)}{dx} = p(x), \tag{3}$$

where $dt(x)/dx$ is the tax rate. The solution to differential equation (3) is $t^*(x) = C + \int_0^x p(z)dz$, where C is a constant. If owners who report $x = 0$ do not pay any tax, then $C = 0$. The optimal tax $t^*(x)$ simplifies the owner's first-order condition (2) to

$$
\begin{aligned}
\frac{dV}{dx} = & \frac{dp(x)}{dx}(U(x - t^*(x)) - U(v - t^*(x))) \\
& + \left[p(x) - p(x)^2\right](U'(x - t^*(x)) - U'(v - t^*(x))) = 0
\end{aligned}
\tag{4}
$$

so that dV/dx is negative if the owner reports $x > v$, and dV/dx is positive if the owner reports $x < v$.[11] It follows that the owner maximizes

his expected utility if and only if he announces his reservation price, so that $x = v$.

5. Discussion of the Mechanism

First, our mechanism provides owners with the incentive to truthfully reveal their reservation prices only for goods with the following two characteristics: first, the good's value can be expressed in terms of a finite amount of money, and second, it can cease to provide utility to the person whose evaluation is of interest with a probability that can be determined objectively. The mechanism fails with respect to goods that do not possess both properties. A good whose reservation price is infinite (e.g., human life) would require an infinite tax payment, which makes it impossible to assess the good truthfully.[12] For goods for which the flow of utility cannot be turned off at will, there is no credible threat that would make underassessment costly. The mechanism therefore cannot be used to determine the value at which an individual assesses, say, the cost of global pollution or the existence of biodiversity, even if it were possible to express these values in monetary terms. Similarly, the mechanism will not result in honest assessment with respect to public goods that are likely to be provided even if some individuals state that they do not value the public goods at all.

Second, property is not worth as much when it is subject to a tax as it would be if it were not taxed, and measuring the value of property through a valuation tax necessarily changes the value of property. No matter how low the tax, property that is subject to a valuation tax cannot have an infinite value as long as there is a positive lower bound on $dt(x)/dx$, because this would require an infinite tax, whereas property that is not subject to such a tax can have an infinite value (the owner can refuse all offers). Thus, what is measured is not the value that property would have if it were not taxed but rather its value when it is taxed.

A simple way of ameliorating the owners' tax burdens is for the government to randomly divide owners into groups and divide the tax revenue from each group among the members of a different group. (Recall that the purpose of the valuation tax is to provide an incentive for truthful self-assessment, not to generate government revenue.) The expected tax burden of the average owner across all groups is then zero, and returning the tax revenue does not destroy the incentive for truthful assessment because an owner's payment has no effect on the share of tax revenue that he receives.[13]

Third, the owner knows that he will receive the self-assessed value in certain cases in which the property ceases to provide utility to him. Because

the truth-inducing tax is a function of the probability with which such cases occur, the mechanism can be interpreted as an insurance mechanism under which the owner pays a premium equal to the expected loss. The mechanism does *not*, however, amount to government-supplied insurance against losses, because the government does not reimburse owners for their losses. The sole purpose of the mechanism is to determine the owner's true loss in cases in which the owner is already entitled to compensation (which must be paid, for example, by the person who wishes to acquire the owner's property or by the government agency that takes private property under eminent domain) and when it is important to determine the owner's loss but the property's market value is either a bad approximation of the true value or impossible to determine. The mechanism therefore provides the owner not with insurance but rather assurance that he will receive compensation for his *true* loss, rather than an amount that someone else considers "reasonable."

Fourth, the mechanism requires that governments and owners have identical beliefs about the probability that a loss will occur. This assumption seems unrealistic as long as the owner has primary control over this probability. The applicability of our mechanism therefore requires that the probability of a loss not be under the owner's immediate control. In applications in which the government considers taking a property under eminent domain, it is important to provide the government with an incentive to honestly announce the probability that it might take the property. In Tideman and Plassmann (2005), we described a mechanism that provides the government with such an incentive.

In applications in which the owner's self-assessed price is interpreted as an offer to sell, a simple way of ensuring that governments and owners have identical beliefs about the probability that the property will be purchased at this price is to permit only the government to buy at the self-assessed price. The government then specifies the function that describes how the probability with which it buys properties varies with the self-assessed value. If the government uses a stochastic mechanism to determine which property to buy and honestly announces to the owners the probability used by the random process, then the government and owners have perfect knowledge of the probability of a "loss." Because the probability function is arbitrary, the government can set the schedule low enough to prevent the tax from becoming unacceptably high.

An alternative, sometimes mentioned in the literature, to requiring the owner to sell his property at his reported value is to give the owner the choice of either selling his property at the self-assessed price or keeping it and paying a fine $f(x) > 0$ to the government.

Theorem 2: There is no combination of a fine and a tax that will always induce an owner to report his reservation price truthfully.

Proof: With probability $(1 - p(x))$, the owner does not receive a bid for his property, in which case his net property value is $\pi_N = v - t(x)$. Assume that the fine is low enough that the owner prefers paying the fine to selling his property at x (otherwise, this alternative would not differ from the first method in practice). He receives a bid for his property with probability $p(x)$, which reduces his net property value to $\pi_B = v - t(x) - f(x)$, and his expected utility is

$$V = [1 - p(x)]U\big((1-p(x))\big) + p(x)U(\pi_B)$$
$$= [1 - p(x)]U(v - t(x)) + p(x)U(v - t(x) - f(x)). \quad (5)$$

1. *Risk-neutral owners*: Risk neutrality is equivalent to assuming $d^2U/d\pi^2 = 0$ so that the owner's expected utility is

$$V = [1 - p(x)]\alpha(v - t(x)) + p(x)\alpha(v - t(x) - f(x))$$
$$= \alpha(v - t(x) - p(x)f(x)), \quad (6)$$

where α is a factor of proportionality. Because the government does not know the owner's subjective value v, it can make neither the tax nor the fine dependent on it, so that the owner's first-order condition,

$$\frac{dV}{dx} = -\frac{dt(x)}{dx} - \frac{dp(x)}{dx}f(x) - \frac{df(x)}{dx}p(x) = 0, \quad (7)$$

is independent of v. A risk-neutral owner therefore minimizes the total cost of the tax and the fine by selecting a self-assessed value that is independent of his subjective valuation. His utility-maximizing x equals v only by chance.

2. *Risk-averse owners*: A risk-averse owner faces the first-order condition

$$\frac{dV}{dx} = \frac{dp(x)}{dx}(U(\pi_B) - U(\pi_N))$$
$$+ U'(\pi_N)\frac{d\pi_N}{dx}[1 - p(x)]$$
$$+ U'(\pi_B)\frac{d\pi_B}{dx}p(x) = 0, \quad (8)$$

and v affects his decision through the wealth effect. Unless, however, the government has knowledge of how exactly wealth affects

the owner's decision process so that it can set the tax and fine schedules accordingly, the owner's utility-maximizing x will equal v only by chance.

It follows that there is no combination of taxes and fines that will always provide an incentive for all owners to announce their true reservation prices to the government.

Fifth, if the probability of loss depends on the value that the property owner reports, then different persons who assess equivalent property at different values face different valuation tax rates.[14] One might consider this a violation of the principle of horizontal equity, which requires that persons in equal positions be treated equally. In cases in which the government causes the loss by purchasing properties at the self-assessed price and owners are risk averse, horizontal equity can be restored by setting the probability of purchasing property equal to a positive constant. If p is independent of x, then the solution to the differential equation $t^*(x) = \int_0^x p(z)dz$ is $t^*(x) = px$, which implies that the optimal tax rate is p. As a result, all owners face the same tax rate, regardless of the amounts at which they assess their properties.

One might object that, even if all owners face the same tax rate, those who assess their properties at high values will face higher tax bills than those who assess their properties at low values, even if all properties are equivalent. This is not necessarily objectionable. A person who assesses his property at a high value because he values it highly has more to lose if his property ceases to provide utility to him than a person who assesses an equivalent property at a low value because it has little value for him. To the extent that the first person expects to receive higher compensation in case of a loss, it is not unreasonable to require that he pay a higher valuation tax.

Sixth, it is worthwhile to point out the difference between our mechanism and the "shotgun clause" that is often used to dissolve partnership agreements.[15] The shotgun clause permits any partner who wants to dissolve the partnership to make an offer to buy the other partners' shares, and the other partners have the options of either selling their shares or acquiring the shares of the partner who made the initial offer at the price offered. Exercising the shotgun clause necessarily leads to a market transaction, however, whereas our mechanism provides information about an owner's reservation price in the absence of any market transaction. In addition, the shotgun clause does not provide an incentive for truthful self-assessment.

Theorem 3: Requiring an owner to sell his property at the price at which he offers to buy additional property does not generally induce an owner to report his reservation price truthfully.

Proof: Assume that the partner who makes the initial offer owns q_1 shares that he values at v each. He values the additional q_2 shares at z and offers to buy them at x. With probability $[1 - p(x)]$, the other partners accept his offer to buy their shares, and his net property value is $\pi_N = q_1 v + q_2 z$. If the other partners reject his offer and buy his shares at x instead, then his net property value is $\pi_B = q_1 x + q_2 x$ (he receives $q_1 x$ for the q_1 shares that he sells and keeps the amount $q_2 x$ that he would otherwise have spent on the additional q_2 shares). The initiating partner's expected utility is therefore

$$V = [1 - p(x)]U(\pi_N) + p(x)U(\pi_B)$$
$$= [1 - p(x)]U(q_1 v + q_2 z) + p(x)U(q_1 x + q_2 x), \qquad (9)$$

and his first-order condition is

$$\frac{dV}{dx} = \frac{dp(x)}{dx}(U(q_1 x + q_2 x) - U(q_1 v + q_2 z)) + p_x U'(\pi_B)(q_1 + q_2) = 0 \quad (10)$$

Because equation (10) depends on the initiating partner's valuation of the other partners' shares (z), $x = v$ is not a general solution to the initiating partner's utility maximization problem, regardless of the properties of his utility function U.

6. Applications

6.1. Eminent Domain

When governments take private property under eminent domain, owners often do not relinquish their properties voluntarily, because owners and government officials disagree about the value of the properties in questions. As we argued in section 3, the owner's true loss may exceed the market price of his property by a wide margin, and if the property in question is a piece of real estate, then it may be impossible to determine even this market price with the necessary accuracy. In most taking cases, there is a span of time between the moment when a government agency identifies properties that it may wish to take for public use and the time when this agency decides that it will take a particular property. To apply the mechanism, the

government announces to a property owner the probability (as a function of property value) that it will take a property, has the owner state his reservation price, collects the corresponding valuation tax, and pays self-assessment compensation corresponding to the government's estimate (prior to the owner's self-assessment) of the owner's loss from the obligation to pay a self-assessed valuation tax. If it takes the property, then the owner receives the value he stated as compensation.

6.2. Land Assembly

If all persons are allowed to buy property at the self-assessed value, then our mechanism can help to lower the cost of land assembly. A person who wants to redevelop land can assemble a site for redevelopment by simply announcing that he is buying the properties that he wishes to redevelop. Our mechanism would therefore eliminate the need for resorting to eminent domain in cases in which governments take properties for the purpose of private redevelopment (see the recent U.S. Supreme Court decision in *Kelo v. New London* 2005).

If all persons are allowed to buy, then the government cannot control the probability of sale and cannot establish the exact relationship between the probability of sale and the tax bill that induces truthful self-assessments. People who believe that the probability of sale at the true value of their property is less (more) than the marginal tax rate at that value have an incentive to underassess (overassess) their property. The government can alleviate the problem by announcing a probability schedule that it considers likely not to be lower than the true schedule and use a stochastic mechanism to acquire the necessary number of properties at the end of a time period if private buyers purchase fewer properties than predicted by the government's probability schedule.

6.3. Real Estate Taxation

The property tax is the primary source of revenue for most local governments in the United States. In most jurisdictions, the sales of a few pieces of real estate each year are used to assess the values of those properties that were not sold. The quality of real estate assessment varies widely across jurisdictions, and it is not uncommon that two apparently identical neighboring homes are assessed differently after one home has been sold but the other has not. Our mechanism would provide data that would permit real estate assessments that were more objectively meaningful.

To ensure that governments and owners have identical beliefs about the probability of a sale at different reservation prices, only the government might be allowed to purchase properties at the self-assessed values. At certain times, every owner would be allowed to reevaluate his property, he would have to pay the tax, and the government would determine whether to buy the property at the self-assessed price. Because the government can set a very low probability with which it purchases property, it can ensure that such purchases will not occur frequently. But because the owner has an incentive to report his reservation price truthfully, and because the government purchases the property at the price that the owner reports, the government will be unable to find a buyer at this price if the previous owner is the person who values the property highest. The government cannot sell the property back to the previous owner because this would make the threat of buying the property at the self-assessed price less costly for the owner. In such a case, the government needs to sell the property to somebody else, with the requirement that the new owner not sell the property back to its previous owner for some time. The government incurs a loss equal to the difference between the valuation of the previous owner and the highest bid that it receives for the property. The requirement that the government occasionally acquire private properties is a true cost of applying the mechanism to the assessment of real estate. Whether citizens are willing to incur these costs depends on the value that they attach to transparent and more accurate real estate assessment.

Recall that the purpose of the valuation tax is to provide an incentive to reveal the reservation price, not to generate government revenue. To be able to impose a property tax whose purpose is to generate government revenue, the government can estimate each property's taxable value from the self-assessed values of all surrounding comparable properties. Using conventional assessment software, one can use the self-assessed values of the surrounding properties to estimate the contributions to value from building characteristics like garages and bathrooms, and then incorporate the differences between the structures into the estimate. This ensures that each property's taxable value depends only on the reservation prices of the owners of the surrounding parcels and on the property's observable characteristics, but not on the reservation price of the property's owner; it therefore does not distort the owners' incentives to reveal their true reservation prices.

One might object that the owner of a parcel whose neighbors value their properties highly would then be given a higher taxable value than the owner of a parcel whose neighbors place lower values on their properties,

regardless of the two owners' own reservation prices. This occurs, how-ever, under any assessment method that interpolates a parcel's value from the values of neighboring parcels (for example, the assessment method based on recent real estate sales that is currently used to assess properties). Because our self-assessment mechanism provides values for *all* neighbor-ing parcels, it leads to reliable assessments of properties even in neighbor-hoods in which sales occur very infrequently. In addition, because our mechanism bases assessments on more information, a few unusual values do not have as great an impact on assessed values. It is always possible to maintain the same property tax breaks that communities use currently to ameliorate tax burdens that are considered inappropriately high (for exam-ple, lower property tax rates or partial exemptions for senior citizens).

6.4. Torts

Our mechanism would be useful in tort cases in which the owner con-siders his expected loss substantial and has reason to believe that a court would be unable to correctly appraise the full loss. Because self-assessment for torts would be voluntary, it would not require owners to assess the value of their properties when they feel that they have insufficient informa-tion to do so. An example of an application is the loss of a business or home as the result of negligence by a construction company that engages in repairs of this or a neighboring property. Another example may be the loss of business due to trademark infringements. As long as the mechanism is applied before the tort occurs, the plaintiff's true monetary loss is obser-vable even in cases in which it is impossible to determine the property's market value. Although it may be difficult to estimate the true individual probability of a loss, we believe that it is not impossible. Private companies already offer insurances against thefts and accidents, and consumers pur-chase these insurances at the premiums offered. This suggests that both parties of a private insurance contract are able to make sufficiently similar estimates of the probability that an insurance case will occur to be able to agree on the premium (the equivalent of our valuation fee).

7. Conclusions

We describe a mechanism that provides an incentive for owners to reveal their reservation prices of their properties honestly. Our mechanism has a wider range of applications than the other self-assessment mechanisms that

have been proposed so far. The usefulness of our mechanism depends on the importance that one attaches to knowing how a person values his property. The law often states that people are entitled to compensation for losses they incur through the actions of others. What is the appropriate amount of compensation? If one argues that a person should be compensated not only for the amount that others consider reasonable (for example, the property's market price, which can often only be estimated with high variance) but also for his subjective loss, then the price at which the owner would have voluntarily relinquished the property is the appropriate measure of value. For indivisible goods that are rarely traded and for goods for which buyers are monopsonists, an estimate of the market price is likely to fall short of the owner's true reservation price. To our knowledge, our mechanism is the only known way of determining the amount that compensates the owner for all his losses in such cases.

With respect to the self-assessment of real estate, we do not want to suggest that our mechanism is a perfect solution to the assessment problem. If, however, a community chooses to impose a tax on real property whose market value is often unknown, then its method of determining the appropriate tax bases must be acceptable to taxpayers. Because citizens often criticize the assessment efforts of local governments, it is useful to entertain alternative methods. Even if citizens ultimately decide not to implement our mechanism, they will have a better understanding of why they are willing to bear the costs of current methods.

Notes

1. To our knowledge, self-assessment of property was implemented first by Peter Stuyvesant, the last governor of the Dutch colony New Amsterdam (now New York), in 1658. To reduce land speculation and to provide an incentive to develop vacant lots, he imposed a 15 percent tax (the fifteenth penny) on the self-assessed value of undeveloped lots and permitted the city to purchase such lots at the self-assessed value and sell them to anybody who was willing to develop them. Once developed, the lots ceased being subject to the tax (see Fernow 1897, 302-3). The government of New Zealand adopted a similar mechanism for developed and undeveloped land in 1891 (Condliffe 1959, 200). Self-assessment has also been implemented at various times in India, Korea, Spain, and Taiwan.

2. Muth (1975, 342) wrote the following of self-assessment: "like most simple ideas, even if good, few people are likely to take it seriously."

3. See Woo (1992) for a review of various concepts of value. Woo (1992, 28) pointed out that there is very little discussion of "value" in neoclassical economic analysis and that even the seminal works of Hicks (1939) and Debreu (1959) do not contain explanations of value beyond mathematical definitions.

4. If transaction costs are not ignored, then there might be a person who values the good higher than its owner but who decides against acquiring it because his valuation minus the cost of acquisition is lower than the price for which the owner is prepared to sell the good. We argue below that the owner's transaction costs are part of his reservation price.

5. One might object that the owner may not always be the person with the highest reservation price, because the subjective valuations of owners and persons who submit bids are conditional on their respective information about the good's characteristics and about prices. If, however, free exchange is possible and transaction costs are sufficiently low, then it is unlikely that a situation will prevail in which the owner is not the person who values the property most. One can therefore expect the average owner to have at least as much information about his property as potential buyers have, which implies that the owner is generally the person with the highest reservation price.

6. The market price reflects both reservation prices if and only if both reservation prices are identical, that is, if the buyer is indifferent between buying and not buying and the seller is indifferent between selling and not selling the good.

7. Niou and Tan (1994) assumed that the owner does not know the government's estimate of the value of the property but is able to estimate the probability of an audit.

8. The probability that the good might get stolen or damaged might increase with the value at which the perpetrator assesses it, but it is unlikely that this probability depends on the value that the owner reveals to the government.

9. Because we define v as the price at which the owner is willing to sell his property, v includes all transaction costs that the owner considers relevant.

10. Our mechanism induces truthful self-assessment only either if $U''(\pi) < 0$ and $dp(x)/dx = 0$ or if $U''(\pi) \leq 0$ and $dp(x)/dx < 0$ (see footnote 11). It therefore fails either if owners are risk loving (such owners will find the valuation tax to be a valuable lottery) or if owners are risk neutral and the probability of a loss is independent of the self-assessed value.

11. First, assume that $dp(x)/dx < 0$ and $U'' \leq 0$. If $x > v$, then the first term is negative because of the assumptions $dp(x)/dx < 0$ and $U' > 0$, and the second term is nonpositive because of the assumptions $0 < p(x) \leq 1$ and $U'' \leq 0$, which implies that dV/dx is negative. The same assumptions imply that, if $x < v$, then the first term is positive and the second term is nonnegative so that dV/dx is positive. Second, assume that $dp(x)/dx = 0$ and $U'' < 0$, in which case the first term is always zero. If $x > v$, then the second term is negative, and if $x < v$, then the second term is positive. It is straightforward to verify that $dV/dx = 0$ if $x = v$. It follows that $dV/dx = 0$ if and only if $x = v$.

12. It is also possible that an owner's marginal utility of money falls so rapidly that he is willing to pay a small amount to avoid selling his property but does not want to sell for any amount. Ng (1979, 105-10) suggested measuring the appropriate monetary property value to such owners by the "marginal dollar equivalent," which he defines as the product of the marginal utility of a dollar of a person who has ownership over his property and the total loss in utility when he loses this ownership. This measure is theoretically attractive because its calculation by the methods of either compensating variation or equivalent variation yields the same value, but it requires that the government be able to measure the owner's marginal utility of a dollar as well as his utility loss if he loses his property, and Ng did not suggest a way that this might be done. Our mechanism fails in such extreme cases.

13. Alternatively, the government can pay to each owner a lump-sum "assessment compensation" that is independent of the amount at which he assesses his property. The disadvantage of lump-sum assessment compensation is that it is not directly tied to the revenue

from the valuation tax, so the government might need to raise additional funds if the tax revenue falls short of the promised total compensation.

14. Two properties are equivalent if the owner of each, were he to own the other, would value the other at what he now values his own property.

15. We thank an anonymous referee for bringing this application of self-assessment to our attention.

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