Fair and Efficient Compensation for Taking Property under Uncertainty

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Abstract

Existing mechanisms for managing eminent domain suggest that, when there is uncertainty about whether a government will take property, efficiency requires that the property owner receive at most partial compensation. We argue that announcing the possibility of a taking is itself a taking when this implies that further investments will not be compensated. We argue that it is both fair and efficient to require governments to compensate owners for losses in asset value from such announcements. We propose a mechanism that provides incentives for both efficient investment and efficient takings, while paying full compensation for expected losses under efficient behavior.

1. Introduction

When governments take private property under eminent domain, owners do not relinquish their property voluntarily. Efficiency requires that the allocation of resources from such a taking be identical to the allocation that would have been chosen by an omniscient utility-maximizing social planer. The commonly accepted standard of fairness requires that owners receive full compensation for property that is taken. Is there a taking procedure that leads to efficiency and is also fair?

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The task of designing such a procedure is complicated by the fact that governments often announce that they may take a piece of property at some time in the future and property owners need to determine the best use of their property in the meantime. For example, when Congress and the states develop plans for a new interstate highway, many years pass between the time when property owners learn of the possibility that the highway will be built and the time when the exact corridor of private property that will be taken is determined. Suppose that there are three possible routes for a particular highway. One of the routes cuts through a farm, including the place where the farmer was planning to erect a storage building, and the farmer can locate the building off the possible highway corridor only at some cost. Another route will demolish a thriving retail store. The owner would like to expand the store, and would find it fairly costly to postpone expansion until the route is settled. The third route would destroy the home of a growing family that would like to put an addition on their house. An efficient and fair taking procedure needs to provide such persons with incentives to invest efficiently in their properties, taking account of the possibility that the property will soon be needed for a public purpose, while providing appropriate compensation for losses.

Blume et al. (1984) offered the startling conclusion that the designer of a taking procedure to deal with the uncertain corridor of a future highway faces a no—win situation. Owners who receive full compensation when their property is taken will wastefully overinvest because they have no incentive to take the prospect of a taking into account. On the other hand, governments that are not required to pay compensation will be insensitive to the losses of private asset value that result from takings (i.e, they suffer from "fiscal illusion") and will take property wastefully. This insight spurred a string of papers offering compensation rules that improve social welfare. Blume and Rubinfeld (1984) pointed out that if private taking insurance is not available, then compensation payments implicitly provide such insurance to risk-averse owners. Fischel and Shapiro (1989) argued that compensation payments may improve efficiency even if owners are risk neutral and governments do not suffer from fiscal illusion, because majoritarian governments have an incentive to ignore the losses that accrue to members of the minority. The obligation to pay compensation gives such governments an incentive to take these losses into account.[1] Burrows (1991) suggested that not requiring governments to pay compensation leaves additional funds for public projects, which results in the overemployment of resources in the public sector. Miceli (1991) showed that not requiring compensation provides an incentive for private overinvestment if the likelihood of a taking falls with the level of investment, even if the government acts so as to maximize social welfare.[2] Similarly, Riddiough

[1]Nosal (2001, pp. 441–442) made a similar point.

[2]Blume et al. (1984) also mention this possibility.

(1997) demonstrated that the lack of full compensation provides an incentive for the owner to develop property prematurely.[3] Hermalin (1995) developed an efficient compensation rule for non-benevolent governments that gives owners an incentive to use their property efficiently by requiring that the payments to the owner vary dollar-for-dollar with the social benefit of a taking.

Except for proposals in which compensation for owners is related to the social benefit of the taking (e.g., Hermalin 1995) or owners are permitted to reject takings (and thus veto a project that could be socially beneficial) if they consider the compensation offered to be too low, the amount paid as compensation in previously published proposals that motivate efficient investment is always less than full compensation. We define "full compensation" as compensation for the value that property would have had in the absence of the government's announcement of the possibility of a taking. Other authors define "full compensation" as compensation for the value that property has at the time when the government makes the taking decision. We describe this as partial compensation, because it does not include compensation for the decrease in the property's value that results from the announcement of the possibility that the government might take the property.

Requiring governments to pay only partial compensation has two disadvantages. First, it does not follow the accepted standard of fairness that prescribes that, if a government takes private property, it should compensate the owner for all of his losses. Second, it induces the government to take property in a manner that is efficient *ex ante* only under the assumption that the government seeks to maximize net social benefit. If the required compensation equals only the value of property at the time of a taking, then owners will generally experience uncompensated losses when they respond to the incentive to invest less. Governments with the objective of minimizing the cost of projects can lower the value of the properties they take by announcing artificially inflated probabilities of taking. This leads to two inefficiencies: property owners will invest inefficiently little, and contrived reductions in the value of property permit governments to undertake projects at artificially reduced costs. In some cases, these artificially reduced budgetary costs of projects will be less than the benefits of the projects, even though the full social costs, including the reductions in the value of property resulting from the announced probability of a taking, are greater than the benefits. Thus the lack of compensation can lead to the appearance that a project has a positive net value when it does not.

An efficient taking procedure therefore needs to account for two forms of moral hazard: first, it must eliminate the owner's incentive to invest an

[3]Innes (1997) argued that inefficient development arises not because of a lack of full compensation but rather because owners of developed and owners of undeveloped parcels are treated unequally. He showed that the right quantity of tradable development rights can provide incentives for potential land developers who face a prospect of taking to act efficiently.

inefficiently large amount, and second, it must eliminate the incentive of a cost-minimizing government to announce an incorrect probability of taking. In this paper, we describe such an efficient taking procedure that also leads to full compensation to property owners. We therefore characterize our procedure as being "fair and efficient."

Efficiency requires that every agent bear the marginal cost of his actions, and our taking procedure is a straightforward application of the principle of marginal cost pricing. The government reduces property values at two different points in time: first when it announces the probability of a taking, and second when it decides to take the property. We show that requiring the government to pay compensation for both reductions in value provides the incentive to announce the correct probability of a taking, because announcing an artificially inflated probability increases the first payment by an amount that exceeds the reduction in the expected second payment, while announcing an artificially low probability increases the expected second payment by an amount that exceeds the reduction in the first payment.

The property owner has an incentive to invest the socially optimal amount only if his compensation in the event of a taking is independent of his actual investment between the time when the possibility of a taking is announced and the time when the taking occurs. But a government will make efficient taking decisions only if it makes them on the basis of the actual value of property at the time of a taking. This implies that if the value of property at the time of a taking exceeds the value of the property under optimal investment, then the government must pay the difference to someone other than the owner.[4] The compensation that the owner receives for each reduction in value restores his wealth exactly to the level before the government undertook the action that reduced the value, which means that he receives full compensation.

An important aspect of the design of an efficient taking procedure is the assumption one makes about a government's objective regarding taking decisions. We treat the government as an entity that seeks to minimize the budget cost of the projects that it undertakes, and undertakes a project only if its expected benefits exceed its budget cost. Although alternative government objectives are imaginable, for example, a democratic government's maximization of the probability of being reelected, the assumption of as much rationality on the part of governments as we assume seems necessary for there to be a possibility of efficiency.[5]

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[4]This "lack of budget balance" arises often in the mechanism-design literature (see, e.g., Tideman and Tullock 1976). We show below that, if the government announces the correct probability and the owner invests efficiently, then no budget imbalance arises.

[5]We assume that the government that participates in the taking event differs from the entity that decides about the adoption of our taking mechanism. This entity could either be a benevolent social planner or a constitutional convention that adopts the mechanism as a general framework within which a cost-minimizing government must make its taking decisions. Separating the cost-minimizing government from the social planner eliminates

Our taking procedure differs from procedures that have been proposed in the literature in three important aspects. First, earlier procedures did not consider the announcement of a probability that property will be taken as a taking, but rather as a mere regulation for which no compensation needs to be paid. Courts have consistently ruled that government actions that remove only a fraction of the value of property do not require compensation, and that apart from physical invasions, only actions that remove all or nearly all of the value of property require compensation (though not in nuisance abatement cases).[6] While this may be an accurate description of the state of law, Epstein (1985) has argued that governments should provide compensation for all regulations that reduce the value of property. One example that Epstein(1985, pp. 157–158) mentions is that if a state decrees that further investments in the corridor of a planned highway will not be compensated, then the state should compensate owners for the resulting loss of value of their property. Apart from considerations of administrative cost, or improvements in moral understanding that lead societies to decide that things previously regarded as property (such as human beings) should not be property and that people should have known better than to regard them as property, we accept Epstein's view. Thus, we argue for a rule that if a government reduces the value of property by announcing that there will be no compensation for some new investments in the event of a taking, this announcement should be regarded as a taking that requires compensation. Indeed, our paper can be regarded as an elaboration, refinement, and generalization of Epstein's point with respect to investment in a highway corridor.

Second, earlier taking procedures have assumed that the probability with which a piece of property might be taken is a common knowledge. This assumption is innocuous if the government seeks to maximize net social benefit, because such a government has an incentive to report the probability of a taking as accurately as possible to enable property owners to use the right probability when making investment decisions. But if the government has a different objective, for example, if it seeks to minimize the cost of public projects, then it might have an incentive to report this probability inaccurately. To be able to address such strategies, we assume that the true probability of a taking is the government's private knowledge, and ensure that our compensation mechanism provides an incentive for the government to reveal this probability accurately.

Third, the literature on taking procedures has generally assumed that governments are able to assess the true value of the property that they wish to take with sufficient precision. Initially, we make the same assumption so

any ambiguity about the government's motivation to adopt our mechanism despite being a cost-minimizer.

[6]This is an example of the generalization enunciated by Michelman (1967) in an exhaustive analysis of "just compensation" law.

that we can compare the results of our procedure with results reported in the literature. In practice, however, it is difficult for governments to accurately assess the value of property if neither the property itself nor any other similar near-by property has been sold recently. A solution to the assessment problem is to employ a system in which the government offers insurance against takings, at a price equal to the expected cost to the rest of society of the value that the owner insures; in combination with marginal cost pricing such a system leads to efficient investment and taking decisions even if the true value of the property is unknown to the government.[7]

In the following section, we offer our conception of the important components of a taking event and the margins where it is important to achieve proper incentives. Section 3 contains the description of a mechanism based on marginal cost pricing that provides incentives to property owners as well as public officials to act efficiently if property values are known. In this section, we analyze the special case when the probability of taking is independent of the value of investment in the property that might be taken. In Section 4, we consider the general case when the probability of taking depends on the value of investment. In Section 5, we analyze the contributions that insurance against takings can make to the efficiency and fairness of takings in the case of uncertain values. Section 6 concludes.

2. The Relevant Anatomy of a Taking Event

A taking event, as we understand it, is a six-step process. Step 1 is the identification by a public official of a noticeable probability that some subset of a particular collection of private property will be needed for a public purpose. At this point there may be uncertainty about whether a taking will occur, and if a taking is to occur, there may be uncertainty about which private rights will be taken. In some cases it may be against the public interest for the potential taking to become public knowledge, because the knowledge that a public project may be undertaken may drive up land prices and increase the cost of the project. On the other hand, if investment decisions are to be made efficiently during the span of time while there is uncertainty about whether a taking will occur, then those who must make decisions about whether or how much to invest must know the true probability of a taking. Thus the first requirement of an efficient taking procedure is that it must provide an incentive for public officials to identify correct probabilities that property will be taken.

Step 2 is the government announcement of the probability with which each property in question might be taken. A standard assumption in analyses

[7]Kanner (1973) provides a detailed analysis of how courts have dealt with eminent domain cases in which the value of the property being taken is not obvious.

of takings is that this probability is a common knowledge, that is, that either the government honestly discloses the probability of a taking, or that the process that generates the probability is as visible to the public as to the government. However, if public officials have private knowledge that bears on the probability of a future taking, then their reports of the probability of a taking depend on their objectives. They may or may not have an incentive to report this probability correctly, so the announced probability of taking may differ from the true probability. Thus the second requirement of an efficient taking procedure is that it must provide an incentive for public officials to honestly announce their belief about the probability of taking each property.

Step 3 is compensation of property owners for the announced probability of a taking. This step is not a part of any of the taking procedures that have been proposed in the wake of Blume et al. (1984), although it is implicit in the rule proposed by Epstein (1985, pp. 151–158). The announcement of the correct probability of a taking leads, with proper incentives, to reductions in optimal investment and therefore in the value of private property. Efficiency requires that the government pay for the marginal cost of its action and therefore for these reductions in property value. Fairness requires that owners be the recipients of these payments.

Step 4 concerns the span of time after the probability of a taking has been announced by the government and before the uncertainty about whether there will be a taking is resolved. Owners will have opportunities to invest in assets whose values will be either reduced or eliminated by the taking if it occurs. Efficiency requires that owners take appropriate account of the probability of a taking when making investment decisions. This requires that owners know the true probability of a taking and that they have incentives to make efficient investment decisions.

Step 5 is resolution of the uncertainty about whether a taking will occur. Efficiency requires that property to be taken be valued correctly by the government in making the decision about whether and how to go forward with the project that will result in a taking.

Step 6 is compensation of owners for the property that is taken. Fairness requires that the owners of taken property receive this value if the taking occurs. The taking event ends with this compensation.

The requirements for an efficient and fair taking procedure that emerge from this anatomy can be summarized as follows: Efficiency requires that the government be motivated to identify the probability of a taking accurately and report this probability honestly. Fairness requires that owners be compensated for their immediate losses that result from the announced probability of a taking. Efficiency requires that owners be motivated to take appropriate account of the probability of a taking, and efficiency also requires that the government value property appropriately in deciding whether and how to proceed with a project that requires the taking of property. Fairness requires that owners of property be compensated for what is taken.

3. Fair and Efficient Taking When Governments Can Assess Property as Well as Owners Can, and the Probability of Taking Is Constant

Suppose that at Time 1 a government considers undertaking a project at Time 2 that will require the use of some private property, for example, a piece of land. At Time 1, the government is uncertain about whether the project will be undertaken at all and which particular piece of land is best suited for the project. Efficiency requires that public projects be undertaken only if their social benefits exceed the costs of the resources required for the project, including reductions and eliminations in the value of private property implied by the project.[8] Efficiency also requires that properties be taken in such a way as to maximize the net social benefit of the public project, taking account of the value of the properties that are taken.[9]

A property's value at the time of the taking depends on its initial value at Time 1 as well as on the improvements to the property that the owner makes until Time 2 when the government decides whether to take the property or not. Because a property's value increases with the extent of the improvements, such investments may reduce the probability that the property will be taken, if governments behave efficiently.[10] In practice, it might be impossible for the government to estimate a nonzero slope for such a probability schedule with sufficient precision, so that a constant probability might be the best guess that the government can make. Although a constant probability is the limiting case of the more general probability schedule, we examine both cases separately because the intuition of our proposed solution to the problem of taking compensation may be somewhat obscured by the need to consider the additional complexity of a probability schedule. In the current section, we treat the probability as a constant, and relax this assumption in Section 4.

At Time 1, the government identifies a probability $\bar{p}$, $0 \leq \bar{p} \leq 1$, that it will take a particular parcel at Time 2. Probability $\bar{p}$ depends on the government's beliefs about the (exogenously determined) social benefit of the public project and about the possibility that a variation on the project using alternative parcels will prove more beneficial. We refer to $\bar{p}$ as the "true probability." We assume that the government's objective is to minimize the cost of implementing the public project, so that it might have an incentive to

[8]We assume that the project's social benefit is determined exogenously. Our model applies equally to partial takings, such as changes in zoning.

[9]If, for example, two properties are equally well suited for a public project, efficiency requires that the less valuable property be used for the project.

[10]Improvements to a property increase the probability that either another property with fewer improvements that requires a lower compensatory payment becomes better suited for the project, or that the values of the properties that need to be taken exceed the expected social value of the project.

announce a probability p, $0 \leq p \leq 1$, that is different from the true probability. We refer to p as the "announced probability."[11]

The (risk neutral) owner of the parcel must decide how much to invest in his plot, given profit opportunities and the compensation that he will receive if the government decides to take his plot. Let I_p be the amount of investment after the government has announced p as the probability of a taking, and let $V(I_p)$ be a random variable that describes the value of the property at Time 2 if the owner has invested I_p and the government does not take the parcel. We assume that the property's expected value at Time 2, $v(I_p)$, increases with the amount invested at a decreasing rate, that is, $dv(I_p)/dI_p > 0$ and $d^2v(I_p)/dI_p^2 < 0$. In this and in the following section, we also assume that the government observes $v(I_p)$, but we will relax this assumption in Section 5. In addition to determining the property value at Time 2, investment also determines the amount of revenue that the owner receives between Time 1 and Time 2, $f(I_p)$, and we assume $df(I_p)/dI_p > 0$ and $d^2f(I_p)/dI_p^2 < 0$. To simplify the notation, we measure all future values in present value terms.

If the owner believes that the government did not announce the true probability of a taking, then he will base his decisions not on the announced probability p but on what he believes to be the true probability. To be able to analyze the owner's behavior in such cases, it would be necessary to know how the owner forms such expectations. Because our compensation mechanism provides an incentive for the government to announce the true probability $\bar{p}$, irrespective of the owner's investment decision, a rational owner will believe that the announced probability is the true probability. In the following analysis, we focus exclusively on the owner's equilibrium behavior. We believe that formalization of the owner's out-of-equilibrium behavior would complicate the model without yielding interesting additional insights into the economics of our proposed mechanism, and that the additional complexity would obscure the relevant differences between our mechanism and earlier analyses of compensation.

Assume that the property is worth v_0 before the possibility of a taking has been announced, and that it will be worth $v(I_p)$ at Time 2 after the owner has invested I_p in response to the government's announcement that it will take his property with a probability of p. If the government does not take the property at Time 2, then the (present value of the) expected net return from owning the property, $\pi(I_p)$, is

$$\begin{aligned}\pi(I_p) &= v_0 + \left[v(I_p) - v_0\right] + f(I_p) - I_p \\ &= v(I_p) + f(I_p) - I_p,\end{aligned} \tag{1}$$

[11] The government identifies and announces probabilities for each parcel that it considers taking. Our procedure does not require that all properties are identical *ex ante*, as for example the taking procedure described by Nosal (2001).

where the term in brackets represents the capital gain or loss between Time 1 and Time 2. As long as there is uncertainty about whether the government will take the property at Time 2, the owner expects to keep his property with probability $(1-p)$, and expects to receive compensation $C_T(I_p)$ for the taking with probability p, so that the expected net return becomes

$$\pi_p(I_p) = (1-p)v(I_p) + f(I_p) - I_p + p\,C_T(I_p). \tag{2}$$

The optimal level of investment I_p^* for the announced probability p solves the first-order condition

$$\frac{dv(I_p)}{dI_p}(1-p) + \frac{df(I_p)}{dI_p} - 1 + p\frac{dC_T(I_p)}{dI_p} = 0. \tag{3}$$

Investment is efficient if the sum of the first three terms is 0, that is, if the contribution of the last dollar of investment to the value at Time 2, discounted by the probability that the property will be used privately after Time 2, plus the contribution of the last dollar of investment to the flow of income between Time 1 and Time 2, minus the one dollar cost of the last dollar of investment is 0.[12]

Condition (3) shows how inappropriately designed compensation rules distort investment decisions. If $dC_T(I_p)/dI_p$ is positive, that is, if the owner's compensation depends positively on his investment, then he will receive a positive expected net return (including compensation) from investments with negative expected net present value, and therefore has an incentive to overinvest. Efficiency in investment therefore requires that $dC_T(I_p)/dI_p = 0$, which implies that any lump-sum compensation (including no compensation) provides an incentive for the owner to invest efficiently.

That lump-sum compensation rules lead to efficient investment has been a general conclusion in the literature. However, the literature has ignored the fact that, while lump-sum compensation induces the owner to invest efficiently, it provides neither an incentive for the government to announce the true probability of a taking nor an incentive for the government to make efficient taking decisions. This implies that lump-sum compensation does not lead to overall efficiency.

A cost-minimizing government whose sole obligation is to pay a lump-sum amount has an incentive to announce a probability that minimizes the expected cost of the taking. It does so by announcing $p = 1$, which results in the minimum compensation $v(I_1^*)$,[13] where I_1^* maximizes Equation (2) for

[12]If the investment and takings decisions were made by the same party, that is, if the government owned the property, then the government would choose the efficient level of investment that maximizes $v(I_p)(1-p) + f(I_p) + I_p + pS$, where S is the expected value of the public project. The derivative of this function with respect to I_p yields the first three terms in Equation (3).

[13]The assumptions that $v(I_p)$ and $f(I_p)$ are strictly concave imply that the level of investment I_1^* that solves $df(I_1)/dI_1 - 1 = 0$ exceeds the level of investment I_p^* that solves $dv(I_p)/dI_p(1-p) + df(I_p)/dI_p - 1 = 0$.

$p = 1$. The government has an incentive to announce the true probability $\bar{p}$ only if it must bear the cost of underinvestment, which in this case is $v(I^*_{\bar{p}}) - v(I^*_1)$.

Requiring the government to bear the cost of its actions is an application of the principle of marginal cost pricing. During a taking event, the government imposes costs on the property owner on two different occasions. The first is when it announces that it might take the property and that some further investments will not be compensated if there is a taking. Even if the government does not take the property later, the announcement of p at Time 1 reduces the expected net return to the owner by $\pi(I^*_0) - \pi(I^*_p)$. The second occasion when the government imposes costs on the property owner is when it takes possession of the property. This action reduces the owner's wealth by $v(I_p)$. The principle of marginal cost pricing suggests that the government will make efficient decisions if it is required to pay the costs that these actions cause, that is, if it is required to pay "announcement compensation" $C_A(I^*_p) = \pi(I^*_0) - \pi(I^*_p)$ when it announces p, and a fee $G_T(I_p) = v(I_p)$ when it takes the property.

Fairness as we understand it requires that the property owner receive $C_A(I^*_p)$ as announcement compensation. Because $C_A(I^*_p)$ is independent of the owner's actual investment, this payment does not distort the owner's incentive to invest efficiently. Fairness might seem to require that the owner receive $v(I_p)$ as taking compensation, but such a rule would give the owner an incentive to disregard the possibility of a taking. Efficiency therefore requires that the owner receive taking compensation of not more than $v(I^*_p)$. Efficiency in incentives for the government requires that $G_T(I_p) = v(I_p)$, which will be less than $v(I^*_p)$ if the owner invests less than I^*_p. Therefore efficient taking compensation cannot be a lump-sum payment of $v(I^*_p)$. Such a payment would require the government to overcompensate the owner if he has invested less than I^*_p and would induce the government to forego worthwhile takings for which the social benefit was larger than $v(I_p)$ but smaller than $v(I^*_p)$. It follows that efficiency and fairness require that an owner who invests less than the efficient amount not be compensated for this omission, and that the efficient taking compensation rule is $C_T(I_p) = \min\{v(I_p), v(I^*_p)\}$.[14]

If the owner invests more than I^*_p so that $G_T(I_p) > C_T(I_p) = v(I^*_p)$, then the government should pay the remainder, $v(I_p) - v(I^*_p)$, to someone other than the owner. One possibility is to redistribute this amount among all members of the community other than the owner and the officials who make the taking decision. An alternative solution is to require that the government sell the right to receive all such surpluses to an insurance company.

Efficient investment after $p > 0$ has been announced, I^*_p, is less than efficient investment if there is no possibility that the property might be taken,

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[14]Note that $C_T(I_p) = \min\{v(I_p), v(I^*_p)\}$ implies $dC_T(I_p)/dI_p = 0 \ \forall \ I_p \geq I^*_p$ as required by Equation (3) for efficient investment.

I_0^*.[15] It follows that $v(I_p^*) < v(I_0^*)$, so that the efficient compensation rule for the actual taking leads to less than full compensation. That efficient lump-sum compensation rules lead to less than full compensation has been a general conclusion in the literature.[16] We will show next that our mechanism provides full compensation and also leads to efficiency in investment and takings.

The efficient taking compensation rule leads to efficient *investment* decisions, because an owner who knows that only efficient investments will be compensated has an incentive to invest as long as $I_p < I_p^*$, or[17]

$$\frac{d\pi(I_p)}{dI_p} > 0. \tag{4}$$

He also knows that he will not be compensated for investments for which the contribution to expected profits does not offset the expected value of the loss from taking, that is, investments for which $I_p > I_p^*$ and therefore

$$\frac{d\pi(I_p)}{dI_p} - p\frac{dv(I_p)}{dI_p} < 0. \tag{5}$$

Because compensation is limited to investments that do not exceed the efficient level, the owner's profit function has a kink at the efficient level of investment, and the relations 4 and 5 represent the right and the left derivative, respectively, of $\pi_p(I_p)$ at I_p^*. For the efficient level of investment, the contribution to expected profits exactly offsets the expected value of the loss from taking, which implies that Relation (5) holds with equality at I_p^*.

The requirement that $G_T(I_p) = v(I_p)$ leads to efficient *taking* decisions because the government uses the correct social cost of a taking (the value of the property, given the actual investment) when it decides whether the taking will generate a net social benefit. We will show next that the described payment rule also removes the incentive for the government to announce a probability of taking that differs from the true probability $\bar{p}$.

Even if the government announces probability p and expects the owner to invest efficiently, it still expects to take the property with probability $\bar{p}$. The expected payment for taking the property is therefore $G_T^e(I_p) = \bar{p}\,v(I_p^*)$. The expected total cost of the taking event, T_p^e, is the sum of the announcement compensation payment and the expected taking payment,[18]

[15]The assumptions that $v(I_p)$ and $f(I_p)$ are strictly concave imply that the level of investment I_0^* that solves $dv(I_0)/dI_0 + df(I_0)/dI_0 - 1 = 0$ exceeds the level of investment I_p^* that solves $dv(I_p)/dI_p(1-p) + df(I_p)/dI_p - 1 = 0$.

[16]See Blume et al. (1984, p. 81), Fischel and Shapiro (1989, p. 123), Miceli (1991, p. 359), Hermalin (1995, p.70), and Innes (1997, p. 414).

[17]Note that $d\pi(I_p)/dI_p, = dv(I_p)/dI_p, + df(I_p)/dI_p, -1$ and that $dC_T(I_p)/dI_p = dv(I_p)/dI_p$, $\forall\, I_p < I_p^*$.

[18]The last step follows because $C_T(I_p^*) = v(I_p^*)$.

$$\begin{aligned}
T_p^e &= C_A\left(I_p^*\right) + G_T^e\left(I_p^*\right) \\
&= \left[\pi\left(I_0^*\right) - \pi_p\left(I_p^*\right)\right] + \bar{p}\, v\left(I_p^*\right) \\
&= \left[\pi\left(I_0^*\right) - \pi\left(I_p^*\right) + \bar{p}\, C_T\left(I_p^*\right) - \bar{p}\, v\left(I_p^*\right)\right] + \bar{p}\, v\left(I_p^*\right) \\
&= \pi\left(I_0^*\right) - \pi\left(I_p^*\right) + \bar{p}\, v\left(I_p^*\right). \qquad (6)
\end{aligned}$$

Once the government has announced probability p, the owner chooses the amount of investment that maximizes his profit. The government's total costs of the taking event are minimized if the owner invests an amount I_p^* so that $dT_p^e/dI_p^* = 0$, or

$$\frac{d\pi\left(I_p^*\right)}{dI_p^*} - \bar{p}\,\frac{dv\left(I_p^*\right)}{dI_p^*} = 0. \qquad (7)$$

This condition says that costs are minimized when the marginal decrease in announcement compensation due to additional investment, $d\pi\left(I_p^*\right)/dI_p^*$, equals the marginal increase in the expected taking payment. The change in optimal investment, dI_p^*, represents the owner's response to a change in the announced probability, and Equation (7) must hold if the announced probability is to minimize costs. The owner maximizes his net return by investing to the point where Relation (5) holds with equality, which implies that Equation (7) is satisfied only if $p = \bar{p}$.[19] Thus the government has an incentive to announce its true belief about p.

If the government announces the true probability of a taking, takes the property, and pays the appropriate compensations described above, the owner's net return is

$$\begin{aligned}
\pi_p\left(I_{\bar{p}}^*\right) &= C_A\left(I_{\bar{p}}^*\right) + C_T\left(I_{\bar{p}}^*\right) + f\left(I_{\bar{p}}^*\right) - I_{\bar{p}}^* \\
&= \left[\pi\left(I_0^*\right) - \pi\left(I_{\bar{p}}^*\right)\right] + v\left(I_{\bar{p}}^*\right) + f\left(I_{\bar{p}}^*\right) - I_{\bar{p}}^* \\
&= \pi\left(I_0^*\right), \qquad (8)
\end{aligned}$$

which is his net return in the absence of the taking event if he invests efficiently. It follows that the described mechanism leads to taking events for which (1) the owner has an incentive to invest efficiently, (2) the owner receives full compensation equal to the return that he would have received in the absence of the taking event,[20] (3) the government has an incentive

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[19]This follows from the assumptions that $v(I_p)$ and $f(I_p)$ are strictly concave.

[20]Our model has followed the literature in not taking explicit account of possible changes in property values as time passes. This obscures the logic of the argument to some extent because property values can be expected to change as time passes and new information becomes available. It is therefore worthwhile to emphasize that the described mechanism yields full compensation with respect to values at each time when compensation is paid, but not necessarily with respect to the expected value of the property before the probability of a taking has been announced, $v(I_0^*)$. Once the government has announced the probability

to announce the correct probability of the taking, (4) the government has an incentive to make an efficient taking decision, and (5) if the government announces the true probability and the owner invests efficiently, then the amount that the government pays during a taking event is equal to the amount that the owner receives, and no budget imbalance arises.

An alternative mechanism that has been proposed in the literature is to require that the government purchase from the owner an option that permits the government either to buy the property at a price specified in the contract, or to take the property without paying any taking compensation for lost capital.[21] It has been pointed out that the sale of options might involve considerable transaction costs that might make such a program impractical,[22] but another disadvantage of "taking options" has not been mentioned in the literature. While it is true that requiring the government to buy such options improves efficiency because it gives the property owner an incentive to correctly take account of the risk of a taking when making investment decisions, the owner still bears the risk of a taking. If the value of his property increases between the time when the option is sold and the time when it is exercised, then the owner will not be compensated for the full value of his property and the government will not have to pay the actual cost of the taking. It is therefore more appropriate that the government bear the risk of the taking, because having the government pay the actual value of the property leads to efficient takings decisions.

4. Fair and Efficient Taking When Governments Can Assess Property as Well as Owners Can, and the Probability of Taking Depends on the Value of Investment

Efficiency requires that the government take private property only if the expected value of the public project, apart from the value of the private property, exceeds the value of the private property. As long as the owner's investment

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of a taking, it pays compensation equal to $v(I_0^*) - v(I_p^*)$, where $v(I_p^*)$ is the expected value of the property immediately after the probability of a taking has been announced. This value might change as time passes, and when the government needs to decide whether taking the property will improve social welfare, efficiency requires that it consider the property value at the time when it takes the property. For example, if due to the accidental spillage of hazardous chemicals the property has lost most of its value at the time when the government takes it, the government is only required to pay compensation equal to the new low value, even if $v(I_p^*)$ was high at the time when the probability of taking was announced. Otherwise the government would provide a costless insurance that would create incentives for the owner to ignore the possibility that such an accident might happen.

[21] The first type of option has been described by Knetsch and Borcherding (1979, pp. 244–245), and Cooter (1985, pp. 22–23), and the second type of option has been described by Fischel and Shapiro (1988, pp. 274–275).

[22] Knetsch and Borcherding (1979, p. 245), Cooter (1985, p. 23), and Fischel and Shapiro (1988, p. 275).

decision changes the property value only by an amount that is insignificant relative to the total value of the public project, it may be reasonable to ignore the impact of the investment decision on the probability that the government will take the property, and thus to assume that this probability is constant. But if investment changes the property value by a significant amount, then it is necessary to account for the fact that investment reduces the probability that the net value of the public project will be positive, which means that investment ought to reduce the probability with which the government will take the property. This might make it optimal for the owner to try to deter the government from taking his property by overinvesting to a point where a taking becomes socially inefficient.[23] In this section, we modify our model to take account of the relationship between the owner's investment and the probability of a taking.

To determine the efficient level of investment, we assume that the government owns the property and needs to decide how to use it efficiently, given the possibility that it might want to use the property in the future for another project. That is, the government needs to choose the level of investment, I_p^*, that maximizes its profit function,

$$\pi_G(I_p) = v(I_p) + f(I_p) - I_p + g(I_p), \tag{9}$$

where g is the expected net value of the new project as a function of the previous level of investment in the property.

The function $g(I_p)$ can be derived as follows: let S be a random variable that describes the "partial net value" of the public project at Time 2, which we define as the net value not counting the cost of the property that the government owns. Let $h(S)$ be the density function of S. The government will implement the project if S exceeds the value of the property, that is, if the project's full net value $S - v(I_p)$ is positive. The higher the value of the property, the less likely it is that the project will be implemented. Because the project will only be implemented if $S \geq v(I_p)$, its expected net value can be expressed as

$$g = \int_{v(I_p)}^{\infty} (S - v(I_p))\, h(S)\, dS = \int_{v(I_p)}^{\infty} S h(S)\, dS - \int_{v(I_p)}^{\infty} v(I_p)\, h(S)\, dS. \tag{10}$$

For any I_p, the integral of $h(S)$ over the interval $(v(I_p), \infty)$ is the probability $\bar{p}$ that the public project will be implemented if investment in the property is I_p. While $\bar{p}$ was a constant in Section 3, it is now the inverse of the function $I_{\bar{p}}$. To simplify the notation, we will continue to use the symbol $\bar{p}$ when we refer to the probability schedule. The first integral on the right-hand side of Equation (10) is the expected partial net value of the project, and the second integral is the expected loss from taking the property owned by the government.

[23]Innes (1997) analyzes the case of landowners who have an incentive to develop their land prematurely to reduce the risk of having their land taken by the government.

The derivative of Equation (10) with respect to I_p describes the change in the project's expected net value as investment increases, taking account of the decrease in the probability that the project will be implemented. Application of Leibnitz's rule yields

$$\frac{dg}{dI_p} = -v(I_p)\,h(v(I_p))\frac{dv(I_p)}{dI_p} + v(I_p)\,h(v(I_p))\frac{dv(I_p)}{dI_p} - \int_{v(I_p)}^{\infty}\frac{dv(I_p)}{dI_p}h(S)\,dS$$
$$= -\frac{dv(I_p)}{dI_p}\int_{v(I_p)}^{\infty}h(S)\,dS = -\frac{dv(I_p)}{dI_p}\bar{p}. \tag{11}$$

The profit-maximizing and socially efficient level of investment solves the first-order condition

$$\frac{d\pi(I_p)}{dI_p} - \bar{p}\frac{dv(I_p)}{dI_p} = 0, \tag{12}$$

which is identical to Relation (5) that holds with equality at I_p^* and that describes the socially efficient level of investment if the probability of a taking is constant.

The government's profit function may have more than one maximum if the probability that the value of the public project exceeds the value of the property falls very quickly with additional investment. For example, if $\bar{p}$ has the shape of the right half of a bell curve, then the probability that the public project's value exceeds the property's value decreases only very little with initial investment, but decreases very quickly as investment increases. In such a case, Equation (9) can have two local maxima. One will be at a relatively low level of investment, where additional marginal investments do not contribute enough to the property's value to offset the substantial probability that they will be sacrificed later. If large additional investment produces a sufficient reduction in the probability that new investment will be sacrificed later, then there can be a second local maximum at a higher level of investment, where $\bar{p}$ is either very low or 0.[24] The shapes of $v(I_p)$, $f(I_p)$, and $\bar{p}$ determine which of the two maxima is the global maximum. In the following discussion, we mean by the "efficient level of investment," I_p^*, the level that yields the global maximum of Equation (9).

Now assume that someone other than the government owns the property. If some probability schedule p other than $\bar{p}$ maximizes the expected net value of the project when the property is valued at its cost to the government, then the government has an incentive not to announce the true probability schedule $\bar{p}$ but rather p. We will show next that the government can do no better than it does by announcing the true probability schedule if it is required to pay the marginal costs of its actions, that is, if it is required to pay

[24]The assumptions that $v(I_p)$ and $f(I_p)$ are concave and that the marginal cost of investment is constant ensure that the optimal level of investment is finite, which implies that the extremum with the highest level of investment is a maximum.

announcement compensation C_A equal to $\pi(I_0^*) - \pi(I_p^*)$ when it announces p, and a fee $G_T(I_p) = v(I_p)$ when it takes the property.

The owner of the property determines the level of investment that maximizes his profit as described by Equation (2), given the announced probability schedule, as the solution to the first-order condition

$$\frac{d\pi(I_p)}{dI_p} - p\frac{dv(I_p)}{dI_p} + p\frac{dC_T(I_p)}{dI_p} + [C_T(I_p) - v(I_p)]\frac{dp}{dI_p} = 0. \tag{13}$$

Equation (12) indicates that investment is socially efficient if the sum of the first two terms in Equation (13) is 0, which implies that efficient taking compensation must ensure that the sum of the last two terms is 0. If taking compensation is $C_T(I_p) = \min\{v(I_p), v(I_p^*)\}$, then the third term is 0 whenever investment is at or above its optimal level. The fourth term is 0 at the efficient level of investment because $C_T(I_p^*) = v(I_p^*)$. But the fourth term is greater than 0 if $I_p > I_p^*$. If the fourth term rises more slowly than the sum of the first two terms falls, then the non-constancy of p will not impair efficiency. But if dp/dI_p is so great that the fourth term rises faster than the sum of the first two terms falls, then the non-constancy of p gives the owner an incentive to overinvest. The overinvestment will continue until the positive magnitude of the fourth term no longer outweighs the negative magnitude of the sum of the first two terms.

This incentive to overinvest is removed if the owner is required to pay the marginal cost of his action, that is, if overinvestment to a level of I_p is subject to a tax $T(I_p)$, where

$$T(I_p) = \int_{I_p^*}^{I_p} -\frac{dp}{dz}\left[v(z) - C_T\left(I_p^*\right)\right] dz. \tag{14}$$

Because $dT(I_p)/dI_p$ equals the negative of the fourth term in Equation (13) when $I_p \geq I_p^*$, and $dT(I_p)/dI_p = 0 \; \forall \; I_p < I_p^*$, the tax provides an incentive to invest the socially efficient amount. If Equation (9) has more than one maximum, then the tax also ensures that the owner invests the amount that yields the absolute maximum.[25]

When the government announces the probability of a taking p and expects the owner to invest efficiently, it pays announcement compensation C_A and expects the project to have a net value of $g(I_p^*)$. This leads to an expected total net value of the taking event (the combination of the announcement payment and the net value of the project) of

[25] Assume that Equation (9) has two maxima, where the first maximizes the sum of the expected value of the property and the expected value of the public project, while the second maximizes the expected value of the property. If the first maximum is the absolute maximum, then the level of investment that corresponds to the first maximum is the efficient level, and the tax on socially inefficient overinvestments provides an incentive not to invest the amount that maximizes the value of the property.

$$
\begin{aligned}
B_p^e &= g\left(I_p^*\right) - C_A\left(I_p^*\right) \\
&= \int_{v(I_p)}^{\infty} Sh(S)\,dS - \int_{v(I_p)}^{\infty} v(I_p)\,h(S)\,dS - \left[\pi\left(I_0^*\right) - \pi\left(I_p^*\right)\right].
\end{aligned}
\tag{15}
$$

The net value to the government of the taking event is maximized if the owner invests an amount I_p^* so that $dB_p^e/dI_p^* = 0$; this condition is identical to Equation (7). Comparison of Equations (12) and (7) indicates that condition (7) can be satisfied only if $p = \bar{p}$. This implies that the government has an incentive to announce a schedule that leads to the optimal level of investment. Because the space of schedules has a potentially infinite number of dimensions while the space of investments has only one dimension, the government's optimization problem does not have a unique solution. But announcing the true probability schedule $\bar{p}$ is among the actions that give the owner an incentive to choose the optimal level of investment. As in Section 3, requiring the owner and the government to pay the marginal costs of their actions leads to efficient investment and efficient taking decisions, and to full compensation of the owner.

In the following section, we discuss a solution to the problem of compensation for takings when the government is unable to assess properties with sufficient accuracy.

5. Fair and Efficient Taking When Owners Can Assess Their Property Better than Governments Can

The mechanism described in Sections 3 and 4 provides incentives to invest efficiently by limiting taking compensation to the value of the property that results from efficient investment. This requires that the government know the efficient level of investment as well as the corresponding value of the property. If the government does not have this information, then it is unable to differentiate between efficient and inefficient levels of investment, and the compensation mechanism needs to be modified to take account of this asymmetric information.[26]

By definition, a taking event represents a transaction in which one party (the government) insists upon an exchange whether or not the other party (the owner) agrees. It follows that an appropriate measure of the value of the property, the owner's private valuation, cannot be determined through a mutually voluntary market transaction. Because the owner is the only one who knows his valuation and because efficiency requires that the government

[26]In these circumstances "taking options" have the problem that if the government overestimates the property value, it may agree to an option price that exceeds the true property value, and if it underestimates the true value it will not be willing to pay the price that the owner demands and will not purchase the option; in both cases the government takes property less frequently than what would be optimal.

take the true property value into account when making its taking decision, efficiency requires that the government use the value that the owner perceives. However, as long as announcing a value above his private valuation is costless, the owner has an incentive to announce a very high value, with the result that the government takes property less often than would be efficient.

The valuation problem can be solved if the government offers the owner insurance against the risk of a taking, at a price equal to the expected cost to the rest of society of the value that he reports.[27] Unlike in the mechanism described in Sections 3 and 4, the actual level of investment is irrelevant for the taking decision once the owner has bought insurance, because the government bases this decision only on the amount for which the owner has insured his property. Once the property has been insured, the owner will receive the insured amount as a lump sum if the government takes his property. Because his investment does not affect the amount that he will receive if there is a taking, he has an incentive to invest efficiently. Because his actual level of investment does not affect the government's taking decision, he does not have an incentive to invest more than the amount for which he has insured his property, which implies that the taking compensation rule that we proposed earlier provides an incentive to invest efficiently.

The following argument confirms this claim. Given the probability of a taking and the price of insurance, the (risk neutral) owner must determine what amount of insurance will maximize his expected return. Let $v(I_p)$ be the value of the property to the owner, x be the value for which the owner insures his property, t_x be the price of insurance if the property is insured at x, $f(I_p)$ be the return from using the property until the government makes its taking decision, and p_x be the probability that the government will take the property if it is insured at x. The owner's expected net return from the property, $\pi_p(I_p)$, is

$$\pi_p(I_p) = (1 - p_x)v(I_p) + f(I_p) - I_p - t_x + p_x x, \tag{16}$$

where $(1 - p_x)v(I_p)$ is the expected future private return from the property given the probability of a taking, and $p_x x$ is the expected value of the insurance. Differentiating $\pi_p(I_p)$ with respect to x yields the first-order condition

$$\frac{d\pi_p(I_p)}{dx} = \frac{dp_x}{dx}[x - v(I_p)] + p_x - \frac{dt_x}{dx} = 0. \tag{17}$$

If the government sets $dt_x/dx = p_x$, then the only value of x that solves Equation (17) is $x = v(I_p)$. The solution to the differential equation $dt_x/dx = p_x$ is $t_x = \int_0^x p_z\, dz$, which is represented by the area to the left of the curve x_1p_1 between 0 and x in Figure 1. The line x_1p_1 shows the relationship between the insured amount x and the probability of a taking p_x. This line can

[27]This is a variation of the concept of a self-assessed property tax. The mathematics of a self-assessed property tax are derived in Plassmann and Tideman (2001).

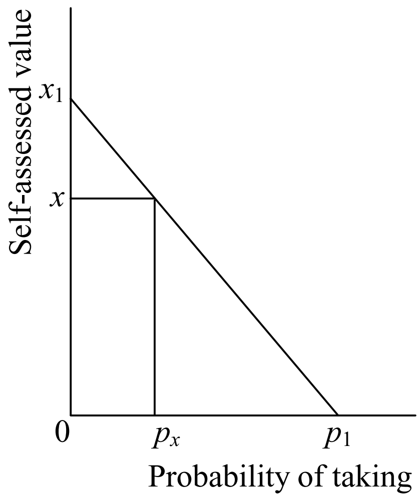

Figure 1: Public demand for private property as a function of x

be interpreted as the public's demand curve for the property that might be taken (the probability of taking it) as a function of the price x. The area underneath the curve ("the consumer's surplus") represents the expected net value of the taking if the property can be obtained at no cost. By reporting $x > 0$, the owner reduces the expected net value of the taking event by an amount equal to the area to the left of line $x_1 p_1$ between 0 and x. Requiring the owner to pay t_x is therefore equivalent to requiring the owner to pay the marginal social cost of announcing x. Of this amount, the triangle under the demand curve between p_x and p_1 is the cost to society of reducing the probability of a taking from p_1 to p_x, apart from any insurance payout, while the rectangle xp_x is the expected payout from choosing an insured value of x. Because we assume that the government knows p_x as a function of x and it observes x, it can set the price of insurance optimally, providing an incentive for the owner to insure his property at its true value.[28]

Maximizing the expected net return in Equation (16) with respect to I_p yields the first-order condition[29]

$$\frac{d\pi(I_p)}{dI_p} - p_x \frac{dv(I_p)}{dI_p} + \frac{dx}{dI_p}\left(p_x - \frac{dt_x}{dx}\right) + \frac{dp_x}{dx}\frac{dx}{dI_p}[x - v(I_p)] = 0. \qquad (18)$$

The owner has an incentive to set $x = v(I_p)$ if the government sets $dt_x/dx = p_x$, in which case Equation (18) simplifies to the version of optimality condition

[28]The analysis is couched in terms of expected income, thereby assuming that owners are risk neutral. In Plassmann and Tideman (2001), we show that the optimal price of insurance is the same if owners are risk averse.

[29]If the owner sets $x = v(I_p)$, then $dx/dI_p = v(I_p)/dI_p > 0$.

(3) that occurs when the government pays lump-sum compensation equal to the value of the property after optimal investment. This confirms that setting $dt_x/dx = p_x$ provides an incentive for the owner to invest the efficient amount I_p^*.[30]

While selling insurance against takings solves the problem of determining the value of the properties that the government decides to take, it does not motivate the government to announce the correct probability of a taking. Again, marginal cost pricing is required to generate incentives for governments to reveal private information regarding the probability of a taking and for individuals to take account of those probabilities when making investment decisions. As pointed out in Section 3, an efficient mechanism that leads to full compensation requires two separate compensation payments: The first payment when the probability of a taking is announced, and a second payment if the government decides that it wants to take the property.

First consider compensation for taking property. Once the government has sold taking insurance to every owner at a price equal to the expected cost to the rest of society of the value that the owner insures, it faces efficient incentives with respect to takings, because it will be required to pay the full cost (in terms of insurance claims) of whatever property it takes. Although this taking compensation rule differs formally from the efficient taking compensation that we identified in Section 4, the compensation payments for taking in the two cases are equal if the owner behaves optimally. If the government is able to assess the value of the property under its optimal use, the efficient compensation schedule is given by $C_T(I_p) = \min\{v(I_p),\ v(I_p^*)\}$, and the owner receives $C_T(I_p) = v(I_p^*)$ if he invests optimally. If the government cannot observe $v(I_p^*)$ but needs to take the insured value of the property into account when making its taking decision, then efficient taking compensation is $C_T(x) = x$. When the price of insurance is the expected cost to the rest of society of the value that the owner insures, the owner has an incentive to insure his property at $v(I_p)$, and he also has an incentive to invest the optimal amount I_p^*, because the insurance payment does not vary with actual investment but only with the amount of coverage bought. Compensation for taking is again $C_T(x) = x = v(I_p^*)$.

The efficiency of this mechanism depends crucially on owners not believing that they have better estimates than the government of the probability of a taking, or else being sufficiently risk averse that they do not act on such beliefs. If owners believe that the probability of a taking is greater than the government states, they have an incentive to overinsure that will deter the government from some efficient takings. If owners believe that the probability

[30]The second order condition for a maximum holds because $d^2\pi(I_p)/(dxdI_p) = dp/dx(dx/dI_p - dv/dI_p) = 0$, $d^2\pi(I_p)/dx < 0$, and $d^2\pi(I_p)/dI_p < 0$. Note that the tax rate $dt_x/dx = p_x$ provides an incentive not to invest more than the amount that is insured, which implies that, even if $dp_x/dI_p < 0$, no tax on overinvestments is required to provide an incentive to invest efficiently.

of a taking is less than the price of insurance, then they will have an incentive to underinsure, creating an incentive for wasteful takings.

The government has an incentive to reveal the true probability of a taking if it is obliged to bear the cost of announcing an incorrect probability. Because announcing the probability of a taking reduces the value of the property, efficiency requires that the government compensate owners whenever it announces the probability of a taking, by paying an amount equal to the loss in the value of property that arises from the need to buy insurance for the possibility of a taking. This reduction in value is the sum of the lost profits on the investments that are not worthwhile because of the need to insure them, plus the cost of insurance on the investments that are worthwhile despite the need to insure them, which implies that

$$C_A\left(I_p^*\right) = \pi\left(I_0^*\right) - \pi\left(I_p^*\right) + \int_0^x p_z dz. \tag{19}$$

One shortcoming of the suggested mechanism is that there is no simple way to identify $C_A(I_p^*)$. To achieve efficiency, the compensation for an announced probability of a taking must be independent of the actual insurance bought. If compensation were provided for the insurance actually bought, then property owners would perceive the cost of insurance as zero and would therefore have an incentive to overinsure. It is possible in theory to solve this problem by having owners self-assess against every conceivable announcement of a probability of a taking, but this seems impractical. Therefore one would need to rely on some form of professional appraisal to determine the amount of compensation for the announcement of a probability of a taking.

In practice, it can be expected to be difficult for the parties involved to agree on the appropriate appraisal, and we acknowledge that our mechanism does not solve the appraiser's incentive problem. However, errors in $C_A(I_p^*)$ that result from the professional appraisal of $v(I_0^*)$ and $v(I_p^*)$ lead to announcement compensation that is either more than or less than full compensation for the announced probability of a taking, but because the insurance against taking that the owner buys is independent of the appraisal, it does not distort the owner's investment decision. While overcompensation or undercompensation for the announcement of a taking does not affect the efficiency of the proposed compensation mechanism, it does affect its fairness. It is worth remembering, however, that the proposed mechanism induces efficient and fair compensation for the actual taking, which means that it represents an improvement over compensation mechanisms that simply provide lump sums that are determined solely by the government's assessment of the value of the property.

Defining x^e as the government's estimate of the value of the property, the government's expected total net cost of the taking event, T_p^e, is the sum of the announcement compensation $C_A(I_p^*)$ and the expected insurance payment, $\bar{p}_x x^e$, minus the expected revenue from selling insurance, $\int_0^x p_z\, dz$, or

$$
\begin{aligned}
T_p^e &= C_A(I_p) + \bar{p}_x x^e - \int_0^{x^e} p_z dz \\
&= \left[\pi\left(I_0^*\right) - \pi\left(I_p^*\right) + p_x x^e\right] + \bar{p}_x x^e - \int_0^{x^e} p_z\, dz,
\end{aligned} \tag{20}
$$

and the derivative of T_p^e with respect to p_x yields the first-order condition

$$
\frac{d\pi\left(I_p^*\right)}{dI_p^*} - \bar{p}_x \frac{dx}{dI_p^*} = 0. \tag{21}
$$

This condition says that the government's costs are minimized when the marginal increase in announcement compensation due to a higher p equals the marginal decrease in the expected insurance payout due to a higher p. For this condition to be satisfied, it must be true that $d\pi\left(I_p^*\right)/dI_p^* = \bar{p}_x\, dx/dI_p^*$. But investor optimization requires that $d\pi\left(I_p^*\right)/dI_p^* = p_x\, dx/dI_p^*$. Thus, as in Sections 3 and 4, the government's condition for cost minimization is satisfied only when the owner's condition for optimal investment is satisfied with $p_x = \bar{p}_x$, so that a cost minimizing government has an incentive to reveal the true $\bar{p}_x$.

If the property is taken and the government estimates its value perfectly, the owner's expected total return from compensation payments and optimal investing, net of the cost of insurance, is

$$
\begin{aligned}
\pi_p\left(I_{\bar{p}}^*\right) &= C_A\left(I_{\bar{p}}^*\right) + C_T(x) + f\left(I_{\bar{p}}^*\right) - I_{\bar{p}}^* - \int_0^x p_z\, dz \\
&= \left[\pi\left(I_0^*\right) - \pi\left(I_{\bar{p}}^*\right) + \int_0^x p_z\, dz\right] + x + f\left(I_{\bar{p}}^*\right) - I_{\bar{p}}^* - \int_0^x p_z\, dz \\
&= \pi\left(I_0^*\right) - \pi\left(I_{\bar{p}}^*\right) + v\left(I_{\bar{p}}^*\right) + f\left(I_{\bar{p}}^*\right) - I_{\bar{p}}^* \\
&= \pi\left(I_0^*\right),
\end{aligned} \tag{22}
$$

which equals the return he would have received in the absence of the taking event. It follows that the proposed mechanism of requiring the government to sell insurance against takings and pay the marginal costs of its actions also yields full compensation and provides incentives for making efficient investments and efficient taking decisions. Thus, apart from the fact that the government does not know the value of property and is therefore unable to check whether the owner has invested efficiently, which implies that the government will compensate for excessive as well as efficient investment, this mechanism produces essentially the same results as the mechanism described in Sections 3 and 4.

6. Conclusion

This paper describes two mechanisms that provide fair and efficient compensation for takings. These mechanisms are fair because the compensation that they require governments to pay to property owners equals the value that the property would have had in the absence of any government intervention. They are efficient because they provide incentives to property owners to take account of the possibility of a taking when making investment decisions, and they induce the government to consider the actual cost of its decisions in taking events.

One way of understanding the proposed mechanisms is as multi–faceted applications of marginal cost pricing. Consider the steps in reverse order. A governmental taking has a marginal cost that is measured by the value of the property that is taken. To motivate the government to efficiently take account of the cost of what it takes, it should pay according to that cost. If the government can observe the value of what it takes, then it should pay to the owner an amount that is not larger than the value that would have been the result of efficient investment, and it should pay any remainder to someone else. If the government cannot observe the value of what it takes, then it should pay the amount that the owner thinks his property is worth, and charge the owner a price for such insurance against taking that induces the owner to truthfully report the value of his property.

A person who invests raises the cost of a taking, if it occurs. To achieve efficiency, a property owner must be motivated to take account of the impact of investment on the cost of a possible future taking. The first mechanism achieves this motivation by providing compensation only for efficient investments, and by taxing the owner according to the marginal social cost of overinvesting when such overinvesting reduces the probability that the public project will be undertaken. The second mechanism achieves this motivation by requiring an owner who wishes to be compensated to pay an insurance premium equal to the marginal cost that investment has on the expected cost of taking.

A government that announces a probability of a future taking, thereby reducing optimal investment, causes costs for owners as potential investors. A cost-minimizing government is motivated to state the probability of a future taking accurately if it is required to pay the cost of the statement it makes, which is measured by the loss that owners experience by virtue of the statement. As usual, marginal cost pricing leads to efficient behavior.

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