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DEVELOPMENT MORATORIA

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Abstract

Under a strict no-takings rule governments can regulate development timing only after evidence of an externality arises. Regulation remains a threat until (or if) such evidence arises, thereby hastening optimal development plans for all land in the spatial market. On the other hand, the effect on capital density varies systematically following demand growth conditions at different locations. Further, vacant land that does not generate the externality is developed more rapidly than is efficient ex post and its capital density systematically affected. The efficiency gap is greater both for land with a greater risk of being associated with the externality when vacant and the longer the threatened moratorium.

Keywords: greenspace, land development holiday, development moratorium, regulatory taking

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1 Introduction

This paper is concerned with how a development holiday or moratorium alters development incentives in an urban land market. It is not known with certainty at the outset whether or not a particular parcel of vacant land is a source of a greenspace externality; evidence of the externality, if present, is revealed over time.¹ A constitutional prohibition on regulatory takings, however, prevents regulators from imposing the moratorium on a particular land parcel unless it is known to generate the greenspace externality. Therefore, the moratorium remains only a threat until such time as evidence of an externality arises. The analysis shows that, while the prohibition on takings protects landowners' property rights, it also cannot eliminate regulatory uncertainty, which in turn has a deleterious effect on land development. Government behavior under the no-takings rule constraining policy-makers creates an incentive for owners to plan more rapid development, regardless of whether or not the externality is present.

Blume, Rubinfeld, and Shapiro (1984), Fischel and Shapiro (1989), and Miceli (1991) examine the effects of the risk of takings on investment incentives. These papers study takings in the form of eminent domain to obtain property for public use. The main focus of these papers is on how compensation rules react with the risk of takings to alter investment incentives. Innes (1997) introduces dynamic elements within a two period model to examine investment timing issues while setting aside the earlier papers' concerns with the capital-land input mix. Riddiough (1997) and Turnbull (2002) are closer antecedents to this paper. Unlike the above studies, Riddiough (1997) and Turnbull (2002) do not consider the risk of losing property through eminent domain. Instead, they analyze how the risk of different types of regulation can affect planned investment timing when the government is free to exercise takings. These papers also differ from this study in terms of modeling and policy focus. The land regulations in these papers are envisioned as exogenous stochastic processes; nei-

¹An alternative interpretation of the the model is that the externality itself is stochastic and may or may not arise as time passes. In this view, whether or not a particular parcel of undeveloped land becomes a source of the greenspace externality depends in part upon how (and when) surrounding parcels are developed over time.

ther provides an underlying model of government motivation for regulation. There are other differences as well. Riddiough (1997) applies an option value model to calculate how threatening to prohibit or postpone development alters asset values and investment timing. In contrast with the approach taken here, capital density plays no role in his model which, as explained below, limits its relevance for spatial land markets. And while Turnbull (2002) incorporates endogenous capital density, the focus of that study is on policies restricting allowed uses rather than the type of timing restrictions that are the focus of this paper.

The legal environment plays a key role in this analysis. In US case law, the distinction between the development regulation being interpreted as an unconstitutional taking in violation of the Fifth Amendment and being interpreted as a constitutionally acceptable exercise of police power rests with whether or not the government can provide justification based on a legitimate state interest.² In this paper, the development moratorium can be justified as the exercise of police power when applied in response to a known externality, in which case it is not an act of taking requiring compensation. Note that while this simple rule serves as the basis of our model of regulator behavior, this does not imply that such a clear cut rule exists in actual practice. Instead, the bright line no-takings rule assumed here can be viewed as a situation explaining why governments would exhibit what has been described as “Pareto behavior” in the law and economics literature (Fischel and Shapiro, 1989; Miceli, 1991) even when governments’ goals are not necessarily the pursuit of efficiency.

This paper examines the implications of threatening a moratorium postponing development. The underlying externality that provides the justification for the moratorium is a greenspace externality, an external benefit from undeveloped land that disappears once the land is developed. Such externalities include the benefits from undeveloped land as recharge basins for watersheds, temporary flood plains, greenbelt noise or wind barriers, as well as wildlife habitat or simply scenic locales. Following the eminent domain literature, it is not known with certainty whether or not a particular parcel is (or will be) the source of an externality that subsequently draws the

²For a statement of this police power exception see, for example, *Lucas v. South Carolina Coastal Council*.

attention of regulators. It is the resultant threat of regulation that is the important factor altering the owner's development strategy.

The model shows that a threatened moratorium speeds the pace of planned development, generalizing the simulation result found by Riddiough (1997) to the setting with endogenous capital density. At the same time, the effect of a threatened moratorium on planned capital density varies according to the growth pattern in the underlying land use demand. The threatened moratorium decreases or increases the planned capital-land ratio when capital density and waiting time are complementary or substitute inputs in the land profit function, respectively. Ironically, since developers respond to the risk of regulation, it also follows that land not associated with the externality is developed more rapidly than is efficient *ex post*. Further, the gap between the realized and the efficient development times is larger the greater the perceived risk of the greenspace externality. This efficiency gap also is larger the longer the threatened development holiday.

Drawing upon the above distinction between taking and police power, the explicit "no-takings" restriction on government behavior creates the *ex ante* uncertainty over the development moratorium policy as regulators attempt to keep the externality regulation from being deemed an unconstitutional taking. According to this interpretation, the property rights protection offered by the no-takings rule cannot eliminate the incentive to inefficiently develop property not subject to regulation *ex post*. The notion that ensuring private property rights increases the efficiency of investment has broad appeal as a general principle (North and Thomas, 1973; Rosenberg and Birdzell, 1986; Torstensson, 1994; Besley, 1995; Alston, et al., 1996; Tornell, 1997; Bohn and Deacon, 2000). Yet, this paper identifies an inefficiency that persists even when land development regulations are constrained by the no-takings clause in the Constitution protecting property rights.

The discussion proceeds as follows. Section 2 presents a partial equilibrium model of land developer behavior in the absence of the uncertain externality as a basis for later comparisons, summarizing the relevant aspects of a version of the model widely used in the urban development literature. Section 3 introduces the uncertain externality and derives the *ex post* efficient development pace and timing which define

the regulator’s credible development moratorium policy under the no-takings rule. Section 4 extends the developer model, using the dynamic programming approach to derive developer response to the moratorium policy. Section 5 presents a summary and conclusion.

2 Developer Behavior

Consider a single parcel of undeveloped land in an urban area land market. Agricultural or nonurban land rent at time t is $w(t) \geq 0$. Development is irreversible. This does not preclude, however, a succession of different types of urban land uses once the fixed capital improvements and buildings have been put on the site. For example, the developed state envisioned here can be thought of as buildings finished to stud, which are then appropriate for a variety of residential, commercial, or industrial uses in succession, with the rent return in the developed state reflecting the rent net of the interior finishing costs required by specific individual users. There is no need to explicitly model the spatial structure of the market other than to index the location characteristics of the land by x . In the monocentric urban land market, for example, x would be the distance of the land parcel from the single central business district (Fujita 1982, Wheaton 1982, Turnbull 1988). Denote the rent at time t for land at x that has been developed with capital k by $R(k, x, t)$, which is assumed to be differentiable to the second degree. The rent for developed land is increasing over time ($R_t > 0$) and is strictly concave in the capital density ($R_k(0, x, t) > 0$ and $R_{kk} < 0$). Further, to ensure that the land will eventually be developed at some future time in the absence of a moratorium, rents in the developed state increase faster than agricultural rents over time ($R_t - w_t > 0$).³

In this model there is no restriction on the sign of $R_{kt}(k, x, t)$. Different factors, one possibly being the location of the plot of land within the spatial land market, yield different patterns of growth in the marginal rent returns to capital density over

³This is a partial equilibrium model so endogenous changes in the timing or density of development elsewhere in the market do not alter the form of the rent function $R(k, x, t)$.

time.⁴ As a consequence, the sign of R_{kt} generally varies across locations x within a single spatial land market. In general, $R_{kt} > 0$ ($R_{kt} < 0$) indicates a location at which the rent-maximizing capital-land intensity is rising (falling) over time, that is, the demanded density is increasing (decreasing) over time.⁵ $R_{kt} = 0$ indicates an unchanging demanded density over time, but is not very interesting in spatial markets. For example, Turnbull (1988) shows that $R_{kt} = 0$ holds only on a set of measure zero in the monocentric spatial land use model. This further implies that conclusions from fixed density models focusing on development timing alone (e.g., Riddiough, 1997) should not be expected to extend to spatial markets, since the $R_{kt} = 0$ case pertains to an invariant or exogenous capital density.

The developer's objective function is the sum of the discounted rental returns in the undeveloped and in the developed states net of the cost of the irreversible capital improvements constructed on the land when developed at time τ . Let r denote the appropriate discount rate and assume that the cost of the capital input is unity. The objective function is

$$F(k, \tau) = \int_0^\tau w(t)e^{-rt} dt + \int_\tau^\infty R(k, x, t)e^{-rt} dt - ke^{-r\tau} \quad (1)$$

The necessary conditions for development density and timing are, respectively:

$$F_k = \int_\tau^\infty [R_k(k, x, t) - r]e^{-rt} dt = 0 \quad (2)$$

$$F_\tau = [w(\tau) - R(k, x, \tau) + rk]e^{-r\tau} = 0 \quad (3)$$

Condition (2) is the development density or capital-land input mix condition. It implies that the optimal capital density is that which equates the present value of the marginal return to capital with the marginal cost of capital when developed, or

⁴See Fujita (1982), Wheaton (1982), and Turnbull (1988) for analyses of the underlying economic factors that lead to different growth patterns in marginal rents.

⁵As an example, suppose that townhouses are the most profitable use if the land parcel must be developed immediately and single family detached houses on quarter acre lots the most profitable use if the land must be developed five years from now. Then the demanded density is falling over time at this location in the market. Of course, the choice of when to develop (now or five years from now) is endogenous. But this example also illustrates why waiting time and structural density can be thought of as substitutes in the land profit function when demanded density is falling over time: the slower the development pace at this location (that is, the greater the waiting time), the lower the developer's chosen structural density.

$\int_{\tau}^{\infty} R_k(k, x, t)e^{r(\tau-t)}dt = 1$. Condition (3) is the usual investment timing condition. In this application it requires that the land be developed when the rent increment that can be obtained from developing the land equals the rental cost of capital, $R(k, x, \tau) - w(\tau) = rk$.

The second order conditions are assumed to be satisfied as well: $F_{kk} < 0$, $F_{\tau\tau} < 0$, and $F_{kk}F_{\tau\tau} - F_{k\tau}^2 > 0$. These conditions are satisfied by the concavity of the rent function in capital density, the assumption that rent for developed land is growing faster than rent for undeveloped land at the time of development, and the usual characterization that, when viewed as inputs in the land profit function, capital density and waiting time each are better substitute inputs for themselves than for the other.

Before proceeding further, it is convenient at this point to draw attention to an intermediate result that provides useful interpretations throughout the paper. First, differentiate (2) to find $F_{k\tau} = -[R_k(k, x, \tau) - r]e^{-r\tau}$. Apply integration-by-parts to F_k in (2) to obtain

$$rF_k = [R_k(k, x, \tau) - r]e^{-r\tau} + \int_{\tau}^{\infty} R_{kt}(k, x, t)e^{-rt}dt$$

Setting $F_k = 0$ and substituting $F_{k\tau}$ for the first right hand side term reveals that

$$F_{k\tau} = \int_{\tau}^{\infty} R_{kt}(k, x, t)e^{-rt}dt \quad (4)$$

This shows that *capital density and waiting time are complementary (substitute) inputs in the land profit function $F(k, \tau)$ as the demanded density is increasing (decreasing) over time: $F_{k\tau} \gtrless 0$ as $R_{kt} \gtrless 0$.*⁶

The solution to the developer's problem is the strategy $\{\hat{k}, \hat{\tau}\}$ satisfying the density and timing conditions (2) and (3). This is also the efficient strategy when there is no externality associated with the land in its undeveloped state.

⁶This is the usual relationship found in density-timing land development models that either explicitly or implicitly take into account a spatial land market. See Wheaton (1982), Turnbull (1988), or Miceli, Sirmans, and Turnbull (2000) for various versions of this relationship in a variety of settings.

3 The Ex Post Efficient Moratorium

Suppose the local government can impose a moratorium, postponing development of any sort until a specified date. There are basically two broadly defined situations in which development moratoria are threatened. One example is provided by the Portland, Oregon, Metropolitan Council. The Metro, as it is known, is a regional authority charged with the responsibility of delineating the urban service boundary (growth boundary) for the Portland metropolitan area, and acting as a venue for local governments to coordinate their own zoning and land use regulations. Its long range planning envisions an urban land preserve in the interior of the metropolitan area, a large tract of land that is to be left undeveloped until 2020, after which private owners will be free to develop their land for urban uses. While the Portland Metro provides the best known example, similar policies appear repeatedly throughout the US. For example, the City of Atlanta recently imposed local development moratoria in parts of the city where the aging sewer system fails to meet federal standards; other local governments are threatening moratoria in the metropolitan area for their own reasons as well. As in the Portland urban land preserve, Atlanta's development restrictions are not permanent; the moratoria will be lifted once the requisite repairs are in place for each affected area.

Another example of local development moratoria passing constitutional muster is addressed in the recent 2002 Supreme Court decision, *Tahoe-Sierra Preservation Council v. Tahoe Regional Planning Agency*. The Court decided that what had turned into a six year moratorium on land development was not an unconstitutional regulatory taking as the plaintiff's claimed, but was instead an example of permissible police power allowing the planning agency a respite to ponder its overall development policy. Such moratoria are not unusual, as the Court notes that "the consensus in the planning community appears to be that moratoria, or 'interim development controls' as they are often called, are an essential tool of successful development." In any event, the Supreme Court did not set a bright line rule for how long a "temporary" moratorium must extend in order for it to fall into the category of a taking in the form of an effective lease-hold requiring compensation for affected owners. The notion of

threatened regulation offered in this paper clearly pertains to the *Tahoe-Sierra* case. While the Court pointed out that property owners should have “known” that some sort of regulation was “in the works”—the moratorium that finally occurred years later in 1981—the precise date of the regulation was nonetheless uncertain to investors during the time leading up to its actual imposition.

These examples illustrate that development moratoria are feasible policies for local governments. The question addressed here is how the threat of such a moratorium alters development incentives. To answer the question, this section characterizes the ex post efficient development strategy under the conditions of externality uncertainty. The solution provides a benchmark policy for evaluating how a justifiable development moratorium can affect the behavior of private investors in the land market. In order to focus on the investment incentive effects of the uncertainty introduced by the regulation, this paper envisions the externality and its attendant regulatory uncertainty as the sole risk facing the developer. Land rents and the other relevant factors are nonstochastic in this model.⁷

The externality envisioned here falls broadly into the category of a greenspace externality in that the land yields an external benefit only while in its undeveloped state. The externality disappears once the land is developed, regardless of how or at what capital density the land is developed. On the other hand, the presence of the externality for a particular plot of land is uncertain ex ante; a specific land parcel might or might not be the source of such an externality. The evidence that the externality does or does not pertain to a particular plot of land is revealed stochastically over time. The assumption that the externality reveals itself only after the passage of time follows the standard approach of Blume, Rubinfeld, and Shapiro (1986), Fischel and Shapiro (1989), Innes (1997), Miceli (1991) and others in the eminent domain literature, where the higher value governmental use for land—whether developed or vacant—arises stochastically over time.

Denote the probability that the externality is discovered to pertain to this particular plot of land by t as $\theta g(t)$. The nonstochastic parameter $\theta > 0$ is a shift parameter

⁷See, for example, Capozza and Li (1994), Clarke and Reed (1988), and Miceli, Sirmans, and Turnbull (2000) for analyses of other sources of uncertainty affecting the land development process.

that is used to capture changes in the probability distribution, explained below.⁸ The probability that there is no externality discovered by t is $1 - \theta g(t)$. The probability of the externality being discovered during the infinitesimal time period $[t, t + dt]$ is $\theta g_t(t)dt \geq 0$. The cumulative probability of the externality discovered by the initial time (given it has not been discovered before the initial time in this model) is zero, $g(0) = 0$. The law of probability is reflected in the limiting condition $\lim_{t \rightarrow \infty} g(t) = \lambda$, where $0 \leq \theta\lambda < 1$.

The parameter θ is an index of the (perceived) likelihood that the plot of land will be identified as being a source of the greenspace externality. A higher θ implies a greater probability that the land will be discovered to have the greenspace externality at any given t , hence, a greater probability that such a discovery will be made by t . We can therefore identify individual parcels of land not only by their location x , but also by their θ -type, with a greater θ indicating land with a greater likelihood of being externality land, or alternatively, land with a greater likelihood of being subject to the moratorium policy before it is developed.

This section derives the efficient development moratorium, conditional upon the land having been revealed to be a source of the greenspace externality. This condition—that the moratorium is imposed only on land that is revealed to generate the externality—recognizes the constitutional constraint on land use regulators against regulatory taking. A regulatory taking occurs when the individual retains ownership of the property in question but nonetheless suffers an uncompensated loss of property value as a result of the regulation. Recall that not all regulations that reduce property value are takings, however. When justified by a legitimate government interest (for example, enhancing social welfare by correcting externalities), regulation that reduces property value does not constitute an unconstitutional taking. Thus, to fall within the constitutional constraint, the land regulation in this model is imposed only when evidence arises that the land is associated with the greenspace externality. Until (and only if) such time, the land is not subject to the moratorium. Other regulatory rules could be employed in the absence of the no-taking restriction imposed here, but are not

⁸In general, θ is a function of location (distance from the CBD as well as perhaps direction with respect to an arbitrary coordinate system). This functional notation is suppressed in what follows.

considered.

Suppose that the land is revealed at time t to generate the greenspace externality time path E . The optimal density and waiting time $\{K, T\}$ maximizes the present value of net social returns to the land, the sum of the private rental returns (the first two integral terms) and the greenspace externality generated by the undeveloped land (the last integral term):

$$W(K, T, t) = \int_t^T w(s)e^{-rs} ds + \int_T^\infty [R(K, x, s) - rK]e^{-rs} ds + \int_t^T E(x, s)e^{-rs} ds \quad (5)$$

The requisite necessary conditions for capital density and development timing are

$$W_K = \int_T^\infty [R_k(K, x, t) - r]e^{-rs} ds = 0 \quad (6)$$

$$W_T = [w(T) + E(x, T) - R(K, x, T) + rK]e^{-rT} = 0 \quad (7)$$

The first condition is recognizable as the usual input mix or capital-land density condition. The second condition is the modified investment timing condition, which requires that the land be developed when the increase in rents from developing the land, $R - w$, equals the rental cost of the capital used to develop the land plus the opportunity cost of the foregone greenspace externality, $rK + E$.

Several aspects of the solution to the above problem, $\{K, T\}$, are worth emphasizing at this point. First, the efficient solution is implicitly a function of location x . Second, the land development policy is expressed as the timing condition, $T(x)$. The moratorium merely stipulates that the private investor with land at x cannot develop his land prior to T once the policy is imposed. As shall be shown below, the investor confronting such a restriction will always develop the land at T with the corresponding ex post efficient capital density K . Thus, the moratorium is a sufficient policy. Third, the moratorium by its construction satisfies the constraint that it not represent an unconstitutional taking; T is imposed only on land at x that is revealed to exhibit the externality. In this sense the ex post efficient moratorium is a second best policy, constrained to satisfy the constitutional restriction on the

regulator.⁹ Fourth, this policy strategy represents a credible ex post efficient strategy for the land use planner; rational developers know that any other announced policy will not satisfy ex post efficiency (or equivalently, the no-takings rule). Fifth, from the developer's perspective, the moratorium is imposed stochastically, following the cumulative probability distribution $\theta g(t)$ specified above.

4 Developer Response to the Moratorium

Now consider the private investor's behavior under the policy in which the planning authority imposes a development moratorium on the land when (and if) it is revealed to engender the greenspace externality. This policy, although efficient ex post on affected land, creates a risk of regulation for all landowners in the locale, whether or not ultimately affected by the moratorium. This section examines how the threat affects developer planned behavior.

In order to modify the objective function from the developer's model under no threat of a development holiday, begin by noting that the developer enjoys unfettered development options until (and if) the planning authority discovers that his particular parcel of land is a source of the greenspace externality at some time t . Until it actually occurs, the development timing restriction is only probable; the point in time at which it might be imposed (if ever) is not known with certainty by the developer. A greater θ implies a greater probability of the development moratorium being imposed during any given time interval $[t, t + dt]$, a lower probability of the moratorium not being imposed by t , and a greater probability of the moratorium being imposed at some time through the indefinite future. In what follows, as in the preceding section, θ also serves as the index identifying the land type according to its likelihood of being the source of the greenspace externality, hence the moratorium risk.

From the developer's perspective, at t one of two states can occur given that

⁹The no-takings restriction assumed in this model is much stricter than the actual position adopted by US courts. See, e.g., Turnbull (2002) for a non-technical summary for land use regulations that do not involve seizing property via eminent domain, the case considered here. The *Tahoe-Sierra* decision appears to provide a weaker restraint on local government regulatory behavior than that suggested by earlier cases summarized in Turnbull (2002).

the moratorium has not yet been imposed. The first, which occurs with probability $\theta g_t(t)$, is that the development moratorium is imposed. The second, which occurs with probability $1 - \theta g_t(t)$, is that the moratorium is not imposed. Consider, in turn, each possible outcome at t .

This is recognizable as a dynamic programming problem. As is often the case, the structure of the problem allows for solution as nested nonlinear programming problems. It is most instructive to derive the solution sequentially as follows.

Step 1. First, note that if the moratorium is imposed at t then the developer's problem becomes at that point:

$$\max_{\tau, k} \int_t^\tau w(s)e^{-rs} ds + \int_\tau^\infty R(k, x, s)e^{-rs} ds - ke^{-r\tau} \quad \text{s.t. } \tau \geq T \quad (8)$$

The Kuhn-Tucker conditions are both necessary and sufficient for optimality in this case. The conditions reduce to:

$$\int_\tau^\infty [R_k(k, x, s) - r]e^{r(\tau-s)} ds = 0 \quad (9)$$

$$[w(\tau) - R(k, x, \tau) + rk] \leq 0; \quad (\tau - T) \geq 0; \quad (\tau - T)[w(\tau) - R(k, x, \tau) + rk] = 0 \quad (10)$$

The first condition requires that the optimal capital density for improvements built upon the land maximize the present value of net rents from the development time forward.

The second set of conditions are the timing conditions. Recall the developer's timing decision in the absence of the moratorium threat is $\hat{\tau}$ satisfying $R(k, x, \hat{\tau}) - w(\hat{\tau}) = rk$ by (3). Note that $T > \hat{\tau}$ by (7), which also ensures $[w(\tau) - R(k, x, \tau) + rk] < 0$ for all $\tau \geq T$. As a consequence, the timing constraint in the moratorium problem above always will be binding when the greenspace externality exists. That is, once it is known that the externality exists and as a consequence the development moratorium has been imposed, the development timing decision is straightforward: the owner of land at location x develops the land at T , which has been set by the policy makers.¹⁰

Given that the investor's optimal development time is T when the moratorium is imposed, the development density condition therefore reduces to $W_k = 0$, which im-

¹⁰This means that it will never be the case that the moratorium is imposed and expires *before* the planned development time τ^* .

licitly defines the developer's investment density response function $K(T)$ satisfying

$$\int_T^\infty [R_k(K(T), x, s) - r]e^{-rs} ds = 0 \quad (11)$$

Thus, in the event that the development moratorium is imposed at some t prior to the land being developed, the maximum present value of returns to the land is $\int_t^T w(s)e^{-rs} ds + \int_T^\infty [R(K(T), x, s) - rK(T)]e^{-rs} ds$.

Step 2. Now note that the second possibility at t is that the moratorium is not imposed. In this case the developer's optimal strategy is to wait until τ^* determined in step 4 below, at which time (if no moratorium is imposed prior) the land will be developed with capital density k^* .

Step 3. At the initial time $t = 0$ the developer's expected returns to the plot of land takes into account the possible conditional development strategy $\{K(T), T\}$ in the event the restriction is imposed at some $t \leq \tau$. Under this threat of the development moratorium, the developer's objective function is

$$\begin{aligned} \Phi(k, \tau) = & \int_0^\tau [1 - \theta g(t)]w(t)e^{-rt} dt + [1 - \theta g(\tau)] \int_\tau^\infty [R(k, x, t) - rk]e^{-rt} dt \\ & + \int_0^\tau \theta g_t(t) \left\{ \int_t^T w(s)e^{-rs} ds + \int_T^\infty [R(K(T), x, s) - rK(T)]e^{-rs} ds \right\} dt \quad (12) \end{aligned}$$

The first integral term is the present value of returns to the land parcel in its undeveloped state, with the returns in each time period weighted by the probability that the land survives to that point without having been revealed to be a source of the greenspace externality. The second term is the expected present value of the land in the developed state, from the planned development time τ forward, which is weighted by the probability that the land is not revealed to have an externality prior to τ . The last term takes into account the likelihood of the externality being revealed at some time between the initial time and the planned development time τ . The term $\int_t^T w(s)e^{-rs} ds + \int_T^\infty [R(K(T), x, s) - rK(T)]e^{-rs} ds$ is the present value of returns from t forward, given that the evidence of the externality arises at t . Weighting by the probability of the externality being revealed at t and integrating over $[0, \tau]$ yields the last term as the expected value of the private returns to the land as a greenspace externality source.

Step 4. We can now derive the individual's optimal planned development strategy $\{k^*, \tau^*\}$ as that maximizing $\Phi(k, \tau)$. The optimal strategy satisfies the capital density and waiting time conditions

$$\Phi_k = [1 - \theta g(\tau)] \int_{\tau}^{\infty} [R_k(k, x, t) - r] e^{-rt} dt = 0 \quad (13)$$

$$\begin{aligned} \Phi_{\tau} = & -[1 - \theta g(\tau)][R(k, x, \tau) - rk - w(\tau)]e^{-r\tau} - \theta g_t(\tau) \int_{\tau}^{\infty} [R(k, x, t) - rk]e^{-rt} dt \\ & + \theta g_t(\tau) \left\{ \int_{\tau}^T w(s)e^{-rs} ds + \int_T^{\infty} [R(K(T), x, s) - rK(T)]e^{-rs} ds \right\} = 0 \end{aligned} \quad (14)$$

and the sufficient conditions $\Phi_{kk} < 0$, $\Phi_{\tau\tau} < 0$, and $D = \Phi_{kk}\Phi_{\tau\tau} - \Phi_{k\tau}^2 > 0$.

The first condition reduces to the familiar input mix condition $\int_{\tau}^{\infty} [R_k(k, x, t) - r]e^{-rt} dt = 0$. The second condition represents the investment timing condition, which is significantly modified for the risk of regulation. This condition implies that the optimal time to develop that land is when the increase in rent from development, $R - w$, equals the user cost of the capital used to develop the land, rk , less the term

$$\left\{ \begin{array}{l} \int_{\tau}^{\infty} [R(k, x, t) - rk]e^{-rt} dt - \int_{\tau}^T w(s)e^{-rs} ds \\ - \int_T^{\infty} [R(K(T), x, s) - rK(T)]e^{-rs} ds \end{array} \right\} \frac{\theta g_t(\tau)}{[1 - \theta g(\tau)]}. \quad (15)$$

The expression $\theta g_t(\tau)/[1 - \theta g(\tau)]$ is the probability that the land will be identified as externality land if development is postponed past τ , given that it has not been so identified prior to τ . The expression in braces is the present value of net returns in the developed state that would be lost to the investor if the land were to be identified as externality land when postponing development past τ . The entire expression is therefore the expected opportunity cost of waiting to develop the land, in the form of the loss of value from the moratorium weighted by the probability that the moratorium is imposed. This term represents an additional marginal benefit of development forgone by waiting, which is positive at $\{k^*, \tau^*\}$.

The conditions (2) and (13) together imply

$$\Phi_k = [1 - \theta g(\tau)]F_k = 0 \quad (16)$$

at the private land developer's optimal development strategy. Equation (16) further implies $\Phi_{k\tau} = [1 - \theta g(\tau)]F_{k\tau} - \theta g_t(\tau)F_k$ so that

$$\Phi_{k\tau} = [1 - \theta g(\tau)]F_{k\tau} \quad (17)$$

and $\Phi_{k\tau} \begin{smallmatrix} \geq \\ \leq \end{smallmatrix} 0$ as $F_{k\tau} \begin{smallmatrix} \geq \\ \leq \end{smallmatrix} 0$ at the individual's optimal development strategy. Therefore, the threat of a development moratorium does not alter the relationship between capital density and planned waiting time as substitute or complementary inputs in the land profit function. Appealing to (4), $\Phi_{k\tau} \begin{smallmatrix} \geq \\ \leq \end{smallmatrix} 0$ as $R_{kt} \begin{smallmatrix} \geq \\ \leq \end{smallmatrix} 0$.

So how does the probability of the land being an externality source affect the individual's strategy $\{k^*, \tau^*\}$ for that particular plot of land at location x ? Totally differentiate (3) and (14) and evaluate at $\theta = 0$ to find

$$\frac{\partial \tau^*}{\partial \theta} = g_t(\tau) \left\{ \begin{array}{l} \int_{\tau}^{\infty} [R(k, x, t) - rk] e^{-rt} dt \\ - \int_{\tau}^T w(t) e^{-rt} dt - \int_T^{\infty} [R(K, x, t) - rK] e^{-rt} dt \end{array} \right\} \Phi_{kk} D^{-1} < 0 \quad (18)$$

$$\frac{\partial k^*}{\partial \theta} = g_t(\tau) \left\{ \begin{array}{l} \int_{\tau}^T w(t) e^{-rt} dt + \int_T^{\infty} [R(K, x, t) - rK] e^{-rt} dt \\ - \int_{\tau}^{\infty} [R(k, x, t) - rk] e^{-rt} dt \end{array} \right\} \Phi_{k\tau} D^{-1} \begin{smallmatrix} \leq \\ \geq \end{smallmatrix} 0 \quad \text{as } R_{kt} \begin{smallmatrix} \geq \\ \leq \end{smallmatrix} 0. \quad (19)$$

where the signs follow from $g_t > 0$, the second order condition $D > 0$, and

$$\left\{ \int_{\tau}^{\infty} [R(k, x, t) - rk] e^{-rt} dt - \int_{\tau}^T w(t) e^{-rt} dt - \int_T^{\infty} [R(K, x, t) - rK] e^{-rt} dt \right\} > 0.$$

These results show that the developer plans a shorter waiting time under the threat of a moratorium than would be planned without the threat, $\tau^ < \hat{\tau}$. Further, the planned capital density of development under the threat is lower (higher) than the no-threat density at locations at which the demanded density for developed land is rising (falling) over time, $k^* \begin{smallmatrix} \geq \\ \leq \end{smallmatrix} \hat{k}$ as $R_{kt} \begin{smallmatrix} \leq \\ \geq \end{smallmatrix} 0$. This effect of the moratorium threat on the planned development waiting time is intuitively appealing. Given the threatened loss of developed land rents during the moratorium, the developer's optimal response is to push the planned development date forward, sacrificing some development rents but at the same time increasing the probability that the planned development will actually be allowed to take place without delay. The planned capital density also changes in response to the threat, following the relationship between capital density and waiting time in the developer's profit function. Planned density decreases with the shorter planned waiting time when density and waiting time are complements in the land profit function, that is, when demanded density is rising over time. Similarly, the planned density increases with the shorter planned waiting time when density and*

timing are substitutes in the land profit function, that is, when demanded density is falling over time.

Different types of property differ by their likelihood of being identified with the externality. The above results imply that *high θ -type land will have a more rapid planned development pace than otherwise identical low θ -type land. In addition, the planned capital density for high θ -type land will be greater than (less than) that for low θ -type land at those locations where the demanded density is decreasing (increasing) over time.*

Thus, from a normative perspective, the threatened moratorium can elicit the opposite effect than intended for land not generating an externality. Comparing the developer's planned development strategy, $\{k^*, \tau^*\}$, with the ex post efficient development pattern for such land, $\{\hat{k}, \hat{\tau}\}$, the ex post development proceeds more rapidly and at a lower density than is efficient when $R_{kt} > 0$; it proceeds more rapidly and at a greater density than is efficient when $R_{kt} < 0$. In this way, the uncertainty about the externality and the attendant development moratorium leads to inefficient development of non-externality land. Further, this gap between the actual and efficient outcomes is greater for high θ -type land than for low θ -type land.

Now consider how lengthening the development moratorium (when it is imposed) affects the investor's planned development strategy. Totally differentiate (13) and (14) solve for the comparative static results in the usual fashion to find:

$$\frac{\partial \tau^*}{\partial T} = \theta g_t(\tau)[R(K, x, T) - rK]e^{-rT} \Phi_{kk} D^{-1} < 0 \quad (20)$$

$$\frac{\partial k^*}{\partial T} = -\theta g_t(\tau)[R(K, x, T) - rK]e^{-rT} \Phi_{k\tau} D^{-1} \begin{cases} \leq 0 \\ \geq 0 \end{cases} \text{ as } R_{kt} \begin{cases} \geq 0 \\ \leq 0 \end{cases}. \quad (21)$$

making use of the fact that $K(T)$ is implicitly defined by (11). To evaluate the signs of the comparative statics, use (7): T satisfies $R(K, x, T) - rK = w(T) + E(T) > 0$. This implies $\partial \tau^* / \partial T < 0$ and with (4), (21) therefore yields $\partial k^* / \partial T \begin{cases} \leq 0 \\ \geq 0 \end{cases}$ as $R_{kt} \begin{cases} \geq 0 \\ \leq 0 \end{cases}$. In summary, the above comparative statics reveal that *a longer development moratorium speeds the planned development pace and decreases (increases) the planned capital density for land at locations where the demanded density is rising (falling) over time.*

These results have important implications. The greater the possible externality associated with the undeveloped land, the longer the ex post efficient development

holiday. This, in conjunction with the above comparative static results, suggests that land that might generate a larger greenspace externality will have a more rapid planned development pace than land that might generate a smaller greenspace externality. Therefore, the divergence between the investor's strategy $\{k^*, \tau^*\}$ and the efficient outcome $\{\hat{k}, \hat{\tau}\}$ for land not found to exhibit the externality is greater the greater the potential (but unrealized) greenspace externality, E . In this sense, a greater potential externality drives a larger wedge between the private investor's development timing and the ex post efficient development timing.

5 Conclusion

This paper examined how threatened land development moratoria can distort intertemporal investment incentives. It presented new results pertaining to the economic effects of land regulation used to enhance ex post efficiency. The positive analysis shows that the threat of a development moratorium generally speeds the planned pace of development for all property types. At the same time, though, the effects on planned capital density vary according to the relative growth in the demands for land by different types of users; threatening a moratorium increases or decreases the planned capital density for those sites at which the demanded structural density is falling or rising over time, respectively.

In this model the ex ante uncertainty in the development moratorium policy is a consequence of governments' attempts to keep courts from interpreting their regulations as takings, in which case owner compensation would be due. The normative implications of the policy are novel and extend previous work focusing on the loss of private property through eminent domain. This study finds that investors have an incentive to develop land not associated with the externality more rapidly than is efficient ex post. Further, the gap between the realized and the efficient development times increases with the likelihood of being associated with the externality and the longer the threatened development moratorium. This last result suggests another type of inefficiency that has not been formally addressed within a market comprising heterogeneous property. It seems reasonable to expect that land with the

greatest probability of generating an externality should be held undeveloped longer than land that is not likely to generate the externality in order to maximize the expected and ex post efficiency. Private landowners, however, have just the opposite incentive even under the no-takings policy constraint examined here; they develop the high externality probability land sooner than low probability land.

The restriction that the moratorium not be construed as a regulatory taking protects private property rights. The analysis here, however, also suggests that when externalities are uncertain, this type of property rights protection cannot eliminate the inefficient development of property that is not subject to the externality regulation. While much of the literature has focused on the beneficial consequences of protecting property rights with a strict constitutional clause prohibiting uncompensated takings, this paper identifies a source of welfare cost that can be expected to persist even in the face of such property rights protection.

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