Journal of Housing Economics 19 (2010) 243–254

Contents lists available at ScienceDirect

Journal of Housing Economics

journal homepage: www.elsevier.com/locate/jhec

Irreversible development and eminent domain: Compensation rules, land use and efficiency

Geoffrey K. Turnbull

Georgia State University, Department of Economics, 14 Marietta Street NW, Suite 426, Atlanta, GA 30303, USA

ARTICLE INFO

Article history:
Received 4 August 2010
Available online 6 September 2010

JEL Classification:
K11
R14
R52

Keywords:
Eminent domain
Compensation
Green space
Land value

ABSTRACT

This paper examines the efficiency of eminent domain used to acquire green spaces, situations in which private investment permanently destroys the ecological externality value of land. The real option approach takes into account this irreversibility and changes established conclusions for the reversible investment case. Under irreversibility, eminent domain efficiency is more sensitive to compensation rules than previously thought. Setting compensation equal to what market value would be in the absence of eminent domain—the approach taken in the US and many other countries—reduces efficiency relative to losing the ecological externality to private development. Compensating at the market value under eminent domain threat increases efficiency, but not as much as compensation at social value does.

1. Introduction

Economists justify government use of eminent domain as a means of preventing strategic hold-out behavior by private property owners when assembling land parcels needed to provide a public good. The ability to condemn private land for public use solves the hold-out problem, but the threat of eminent domain can distort private investment incentives—which raises its own efficiency concerns. Perhaps not surprising, the investment incentives effects of threatened eminent domain are inextricably tied to the way in which erstwhile owners are compensated when a government takes their property.

The Fifth Amendment to the US Constitution ties the exercise of eminent domain to "just compensation," but does not spell out the nature of the required compensation. US case law defines just compensation as fair market value, what the eminent domain literature labels "full compensation." Notwithstanding the fact that compensation at fair market value is a settled doctrine in the US and applied in other countries, it turns out that compensation at fair market value is inefficient. This surprising conclusion arises because paying full compensation to private landowners for both land and capital improvements creates an incentive for owners to use more capital than is efficient; full compensation allows owners to ignore the possibility that the social value of their private improvements will be zero if the property is taken for public use (Blume et al., 1984). To complicate matters further, Innes (1997) finds that full compensation also distorts the land development timing decision of private owners, biasing the market toward inefficient early development of vacant land. Once again, this inefficiency arises because full compensation cushions owners from having to take into account the possibility that their improvements will have no social value if the underlying land is taken for a public use in a future period.

These and subsequent studies assume that the private property owner's investment in buildings or other improvements to the land is fully reversible[1]; the government

[1] See Miceli and Segerson (1996) for a comprehensive review of the relevant concepts and literature.

E-mail address: g.k.turnbull@gmail.com

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doi:10.1016/j.jhe.2010.08.001

taking the underlying land by eminent domain faces no impediment (other than demolition costs) to removing the private structures and infrastructure when making the land usable for the intended public use. This is a reasonable characterization for a wide range of public uses, like police and fire stations, schools, transportation infrastructure and urban parks. But this is not generally the case when the social purpose of the land is to preserve ecological enclaves to sustain externalities arising from the indigenous flora or fauna peculiar to an existing undeveloped green space. While roads and government buildings can be constructed on land that has been previously developed for private use, this type of green space cannot. In this case the green space externality is the social value of the ecological system embodied in undeveloped land, whether a contiguous tract of riverside land, undisturbed prairie or forested growth, or wetlands. Since it is not possible to restore such land to its true pre-development state once it has been developed, any potential future ecological or aesthetic benefit from the green space is permanently extinguished when the land is initially developed for urban use. This type of irreversibility, when coupled with uncertainty, is best analyzed within a real option framework. The real option approach fundamentally differs from the expected value models prevalent in the eminent domain literature. The unanswered question is: does this difference matter? Or, do the existing policy conclusions regarding eminent domain and compensation survive unaltered?

This paper applies a simple option value model to examine how the threat of eminent domain affects property markets when investment in structures and infrastructure is irreversible in the sense that private development destroys any potential value of the land as an ecological enclave or green space. It adapts Titman's (1986) vacant land option value model to incorporate an uncertain green space externality. This provides a tractable framework that captures the essence of the development irreversibility problem without having to rely on numerical solutions or specific functional forms to derive theoretical conclusions.[2] This paper also embeds the partial equilibrium option value model within the market for building units to incorporate the feed-back effects of endogenous land and building prices on land development decisions in market equilibrium. It turns out that these feed-back effects from the endogenous market adjustment to eminent domain compensation rule play a key role in the analysis and drive interesting new results.

The analysis reveals that the policy implications for the irreversible investment case systematically differ from the simpler reversible investment situation considered in the previous literature. Section 2 presents the partial equilibrium option framework. This model leads to land development timing results resembling what Innes (1997) found for the reversible improvements case. In particular, the threat of eminent domain with full compensation has no effect on the market development pace when vacant land prices are exogenous, that is, when the land taken for green space preservation represents a small portion of that type of vacant land in the local market. But the market development pace is too fast to begin with, so this neutrality result means that full compensation leads to inefficient investment. This does not, however, imply that full compensation is meaningless. After all, as the regulation literature shows, even threatening to impose regulation or development moratoria without compensation tends to speed the development pace (Turnbull, 2002, 2005), which further reduces efficiency. It follows that just the threat of eminent domain without compensation would hasten investment timing even more, with commensurate reductions in economic efficiency.

Sections 3 and 4 extend the partial equilibrium framework to model the option value of vacant land as endogenously determined in equilibrium asset markets (i.e., when the land taken for ecological or green space preservation represents a large enough portion of that type of vacant land to affect the price of the remaining developable land). Eminent domain in this framework leads to conclusions surprisingly different from both the partial equilibrium case in this paper and in the reversible investment case examined in previous studies. Here, the details of the compensation scheme matter profoundly. If full compensation is defined to mean that erstwhile private owners are compensated with the prevailing opportunity cost of land, as measured by land value in the market under eminent domain threat, then eminent domain slows development relative to the partial equilibrium result. Although slower than indicated by the partial equilibrium analysis, development nonetheless remains inefficiently rapid under such compensation in market equilibrium. On the other hand, if owners are compensated with how the land would be valued in an unregulated market (i.e., when eminent domain is not a threat), then threatening eminent domain speeds development. In this situation using eminent domain to capture the social ecological benefits of the green space actually decreases market efficiency. These market equilibrium results are new and arise because eminent domain affects the future supply of land to private developers, which, in turn, affects the dispersion of future building prices—a key determinant of the option value of vacant land in the initial period.

Section 4 also discusses how the compensation policy affects the density of initial development. These results are also new. The eminent domain literature concludes that full compensation leads to either inefficiently high or efficient structural densities, depending upon how marginal capital improvements are compensated (Blume et al., 1984; Miceli, 1991). In contrast, this study finds that when development is irreversible, full compensation—regardless of how defined—inevitably leads to inefficient structural density. The precise effects are determined by how full compensation is calculated. Compensation at the regulated or post-eminent domain market value tends to increase the initial structural density, but not enough to attain efficiency. On the other hand, compensation at the unregulated market value tends to decrease structural density, driving an even greater wedge between the market and efficient outcomes.

Section 5 summarizes and discusses the main results.

[2] See, for example, Williams (1991) for a partial equilibrium real option model and Williams (1993) for a market level model in continuous time.

2. Eminent domain with exogenous prices

This section presents the partial equilibrium model which assumes exogenous building prices. Land value is endogenous. Since the analysis applies to situations in which government taking land by eminent domain does not change market prices of building units, it applies to situations in which the jurisdiction takes only an infinitesimal part of the overall market supply of vacant land. Although appropriate for land taken for many types of public goods (for example, a single new police station or a small neighborhood urban park), it only applies to the problem of ecological or green space externalities in limited situations. Green space externalities arise from habitat for nonurban flora and fauna or threatened species, watershed, or undeveloped park land. We therefore expect green space benefits to be associated with relatively large contiguous tracts of land (or relatively large tracts of a type of land that is not in great supply in or around urban areas to begin with). Since removing significant supply from the local land market affects prices of developed real estate, the assumption of exogenous building prices used in this section is likely tenuous for the green space case. For example, consider a corridor of undeveloped riverfront land in or on the fringe of the urban area. The total supply of this type of land is, by its very nature, limited, so that even modest acreage taken out of the private sector would represent a relatively large portion of the available supply, possibly affecting the price of the remaining tract, hence the price of riverfront building units. Nonetheless, the results presented in this section assuming exogenous building prices tie the option value framework more closely to the existing eminent domain compensation literature and also present intermediate relationships that are useful for the market level model presented later.

Assume that the demand for developed real estate (building units) is stochastic so that the future price of building units is uncertain. The framework is a simple option pricing model extending over two periods based on Titman (1986). It is nonetheless useful to diverge from Titman's approach for several reasons. First, of course, we need to adapt the framework to incorporate the social option value. Second, unlike Titman (1986), the approach taken here closely follows the construction of the hedge portfolio in order to make the nature of the underlying valuation concept as straightforward as possible; the popular martingale approach to deriving the price relationships is not as transparent as the approach taken here to readers not fully familiar with real option pricing frameworks. Third, the approach taken here simplifies the introduction of endogenous building unit prices into the option value model, an important complication that turns out to be essential to the eminent domain issues being studied in this paper.

2.1. Private option value of vacant land

The general setting is as follows. There are two periods, current and future. In the absence of regulation, in the current period an investor is free to construct structures on his land, with the number of building units per unit of land q, at the cost $c(q)$. Building units can be sold outright in the initial period for the market price p_0 or retained as rental property. With the riskless interest rate r and no depreciation, rented units earn rp_0 during the period. The market price of a building unit in the second or future period is uncertain. It will either rise to p_1 or fall to p_2 (i.e., $p_2 < p_0 < p_1$). Land left vacant in the first period can be developed in the second period; land developed in the first period cannot be redeveloped in the second period.

The indirect profit function for a given unit of land is derived in the usual way. Define the profit-maximizing quantity

$$q_i^* \equiv \arg\max \pi = p_i q_i - c(q_i)$$

so that this solution $q_i^* = q(p_i)$ is the usual competitive firm supply function for which it can be shown $q' > 0$ satisfying the law of supply. Substituting the profit-maximizing quantity into the profit function yields the indirect profit function

$$\pi(p_i) \equiv p_i q(p_i) - c(q(p_i))$$

with the standard properties

$$\pi'(p_i) = q(p_i) > 0 \tag{1}$$

$$\pi_i''(p_i) = q'(p_i) > 0 \tag{2}$$

The maximum profit to the owner of land developed in the first period is $\pi(p_0)$ while the maximum profit to the owner of vacant land in the second period is either $\pi(p_1)$ or $\pi(p_2)$ depending upon the realized price of building units in the second period. The indirect profit function property (1) implies $\pi(p_1) > \pi(p_0) > \pi(p_2)$.

When cast this way, vacant land in the first period represents an option on future buildings. The portfolio comprising one building unit coupled with selling short h units of vacant land (options on future buildings) has the initial value $p_0 - hV$ and the portfolio value evolves following according to one of the two indicated outcomes

$$p_0 - hV \rightarrow \left\{ \begin{matrix} rp_0 + p_1 - h\pi(p_1) \\ rp_0 + p_2 - h\pi(p_2) \end{matrix} \right\} \tag{3}$$

Of course, which outcome will obtain is unknown at the outset. Nonetheless, the hedge ratio is constructed to ensure a riskless portfolio, that is, the portfolio with the same value in the second period regardless of realized building price. Setting the two second period portfolio values equal to each other and solving for the riskless hedge ratio h^* yields[3]

$$h^* = \frac{p_1 - p_2}{\pi(p_1) - \pi(p_2)} \tag{4}$$

Since h^* yields a riskless portfolio, the initial portfolio must earn the riskless rate of return r in a no-arbitrage equilibrium, so that

$$(p_0 - h^* V)(1 + r) = rp_0 + p_1 - h^* \pi(p_1) \tag{5}$$

[3] This does not mean that agents are risk neutral, as is often needlessly assumed in many applications of option value models to property markets. Here, agents can be assumed to be risk averse throughout the analysis. An innovation of real options theory is that the use of constructed riskless portfolios and the no-arbitrage condition together sidestep the need to incorporate direct measures of risk aversion in the derivation of the valuation formula.

Solving the above for the first period option value of vacant land yields

$$V^m = \left(\frac{p_0 - p_2}{p_1 - p_2}\right)\frac{\pi(p_1)}{(1+r)} + \left(\frac{p_1 - p_0}{p_1 - p_2}\right)\frac{\pi(p_2)}{(1+r)} \tag{6}$$

This is the value of vacant land as a real option on future building units. Note that the option value can be constructed without reference to the underlying probability distribution of future states. The two weights in the right-hand side expression, $(p_0 - p_2)/(p_1 - p_2)$ and $(p_1 - p_0)/(p_1 - p_2)$, are the synthetic probabilities for the possible future states and do not in general equal the underlying probabilities of the respective states arising when agents are risk averse.[4]

In equilibrium, land is developed in period one up to the point where the value of land developed (and sold with its building units) during the first period equals the value of land left undeveloped, or $\pi(p_0) = V^m$. This condition, of course, requires further specification of the demands for building units in the various states in order to find the equilibrium building prices in both $\pi(p_0)$ and V^m, the extension undertaken in the next section. Before doing so, however, we consider the social value of vacant land when there is an ecological or green space externality.

2.2. Social option value of vacant land

Following Blume et al. (1984), Fischel and Shapiro (1989), Miceli (1991) and Innes (1997), this paper focuses on the investment incentives effects of eminent domain when investors do not know until after initial investment decisions have been made whether or not the government will be taking their land. These studies all examine the effects of threatened eminent domain when private investment in structures and other improvements to land are reversible, for example, when the land is used for public roads, buildings, or other infrastructure. As argued at the outset, the ecological enclave or green space situation examined here requires a different approach.

Suppose that vacant land will have a social value of G_1 as a never-developed green space in the second period high demand state, where G_1 exceeds the private value in that state, $G_1 > \pi(p_1)$. This social value does not arise in the low building demand state. (Or, equivalently, $G_2 < \pi(p_2)$ in the low demand state.) We assume that the land is no longer habitat for specific flora and fauna once developed, or perhaps the topography is altered to accommodate urban use. In any event, once changed, the land cannot generate green space value even if cleared of all capital improvements; the potential green space value is extinguished for all land developed in the first period.

To find the social option value of vacant land from the perspective of the first period, imagine a social planner whose job it is to build structures and allocate land to achieve Pareto efficiency. The marginal social value of building units is given by the market price. The fictional social planner envisioned here, however, follows the Pareto rule, using vacant land in the second period for the purpose yielding the greatest social value: for green space in state 1 (since it yields a social return greater than the return to its use for buildings) and for buildings in state 2. The fictional social planner's problem resembles that of a private investor. In this case, though, vacant land in the first period represents an option on future buildings or green space. In the initial period the planner forms an activity portfolio by hedging each building unit constructed in the first period with h units of vacant land as options on future buildings or green space. The initial value of the social planner's portfolio $p_0 - hV$ evolves following one of the two indicated outcomes

$$p_0 - hV \rightarrow \left\{ \begin{array}{l} rp_0 + p_1 - hG_1 \\ rp_0 + p_2 - h\pi(p_2) \end{array} \right\} \tag{7}$$

Like the private investor, the planner does not know which outcome will obtain in the second period. Once again, the hedge ratio is defined as that which ensures a riskless portfolio. Setting the two second period portfolio values equal to one another and solving for this riskless hedge ratio

$$h^* = \frac{p_1 - p_2}{G_1 - \pi(p_2)} \tag{8}$$

In order for the social investment in green space options to meet the opportunity cost of capital, the socially efficient riskless portfolio must earn the riskless rate of return, so that

$$(p_0 - h^*V)(1+r) = rp_0 + p_1 - h^*G_1 \tag{9}$$

Solving for the social option value of vacant land, we have

$$V^s = \left(\frac{p_0 - p_2}{p_1 - p_2}\right)\frac{G_1}{(1+r)} + \left(\frac{p_1 - p_0}{p_1 - p_2}\right)\frac{\pi(p_2)}{(1+r)} \tag{10}$$

Comparing (6) and (10) reveals the essence of the policy maker's concern. For the same set of market building unit prices $\{p_0, p_1, p_2\}$, the social option value of land exceeds the unregulated market value, $V^s > V^m$, which suggests that the market will initially develop more land than is efficient. This is not at all surprising as it merely reflects that fact that the market does not capture the green space option value in the vacant land value.

2.3. Full compensation effects

The social planner's problem envisioned above only establishes an efficiency benchmark for comparison purposes and does not fully capture the policy maker's problem. Here, we envision the policy maker as a government following the Pareto rule, taking land only when its social value as a green space exceeds its private value for buildings.[5]

[4] These synthetic probabilities can also be interpreted as Arrow–Debreu security prices, with $(p_0 - p_2)/(p_1 - p_2)$ the initial period price of a security that pays \$1 in the high building demand state and zero in the low state while $(p_1 - p_0)/(p_1 - p_2)$ is the initial period price of an Arrow–Debreu security that pays \$1 in the low building demand state and zero in the high demand state. These two prices sum to one.

[5] The Pareto behavior assumption is popular and can be justified by Fischel's (2001) homevoter hypothesis in which local governments adopt policies that yield non-negative net fiscal impacts on voters, hence their property values. The appropriate positive model of government eminent domain behavior, however, is unsettled. See Blume et al. (1984), Fischel and Shapiro (1989), and Miceli (1991) for additional theoretical discussion. Turnbull and Salvino (2009) offer empirical evidence that state and local governments do not exercise eminent domain efficiently unless constrained (by constitution or case law) to do so. In this study, the Pareto rule behavioral assumption is in part justified by the desire to compare these results with the previous literature using that assumption.

The vacant land is taken only in state 1, the high building demand state. Further, the government pays full compensation equal to market value of the land in that state when exercising its power of eminent domain. Thus, in state 1, the government takes the land and pays the landowner $\pi(p_1)$. Since we are assuming that building prices are exogenous in this section, this full compensation leaves V^m unchanged in the face of the threat of taking. Comparing (6) and (10) reveals a result reminiscent of Innes' (1997) for the reversible investment case with exogenous prices: *eminent domain with full compensation does not affect the development pace*, *but the presence of the externality that motivates the eminent domain slows the efficient development pace so that the market generates an inefficiently fast development pace under full compensation*. This result is consistent with Hermalin (1995) in that efficiency requires something more than full compensation. Efficiency requires that the private landowner be compensated with the full social value of the land in its public use.

This discussion has laid out the general problem of eminent domain in a simple dynamic context when the social value of land arises from the undeveloped nature of land, in which case private investment creates an irreversible outcome. The next section extends the framework by endogenizing the market prices of buildings and vacant land.

3. Market equilibrium and eminent domain

3.1. The unregulated market

This section introduces endogenous building unit prices into the option value framework. Let the inverse demand for building units in state i be $Q_i = f(p_i)\theta_i$, where $\theta_0 = 1$ and $\theta_1 > 1 > \theta_2 > 0$ underlies our earlier assumption $p_1 > p_0 > p_2$ in the partial equilibrium analysis. With n parcels of land initially developed with q_0 building units per parcel, equilibrium in the market for building units requires that each developer is building the profit-maximizing number of building units (recall $q_0 = \pi'(p_0)$ using the properties of the indirect profit function) and that the price of building units equates demand and supply for building units, or

$$n\pi'(p_0) = f(p_0) \tag{11}$$

Given the total supply of this type of land to the market is N, the quantity of newly built building units in the second period high demand state is $(N-n)\pi'(p_1)$. Adding this number to the $n\pi'(p_0)$ units previously built, the building unit price in the high demand state, p_1, satisfies the equilibrium condition

$$(N-n)\pi'(p_1) + n\pi'(p_0) = f(p_1)\theta_1 \tag{12}$$

Similarly, the price of building units in the low demand state, p_2, satisfies the equilibrium condition

$$(N-n)\pi'(p_2) + n\pi'(p_0) = f(p_2)\theta_2 \tag{13}$$

Land market equilibrium in the initial period (11) drives the current building price and future building prices via (12) and (13) to equate the return of developed land, $\pi(p_0)$, and vacant land (6).

In order to characterize the market equilibrium graphically, first find the vacant land option value as a function of the amount of land developed in the first period (that is, the amount of land left vacant for the second or future period). To do so, begin with the implicit equilibrium price functions denoted $\{p_0^m(n), p_1^m(n), p_2^m(n)\}$ as follows, where superscript m indicates the market benchmark solution (i.e., without the threat of eminent domain in the second period). Solve Eq. (11) for $p_0^m(n)$ where implicit differentiation reveals that the first period equilibrium price of buildings decreases as the quantity of developed land rises

$$\frac{dp_0^m}{dn} = -\frac{\pi'(p_0)}{n\pi''(p_0) - f'(p_0)} < 0 \tag{14}$$

Now substitute this solution $p_0^m(n)$ into the system of Eqs. (12) and (13) and solve for $p_1^m(n)$ and $p_2^m(n)$, respectively. It turns out that we do not need the derivative properties of $p_1^m(n)$ or $p_2^m(n)$ for what follows.

To find the market option value of land as a function of the quantity of land developed in the first period, $V^m(n)$, substitute $\{p_0^m(n), p_1^m(n), p_2^m(n)\}$ into (6) to obtain

$$V^m(n) = \left(\frac{p_0^m(n) - p_2^m(n)}{p_1^m(n) - p_2^m(n)}\right)\frac{\pi(p_1^m(n))}{(1+r)} + \left(\frac{p_1^m(n) - p_0^m(n)}{p_1^m(n) - p_2^m(n)}\right)\frac{\pi(p_2^m(n))}{(1+r)} \tag{15}$$

This is the $V^m(n)$ curve depicted in Fig. 1. While the slope dV^m/dn is ambiguous a priori, none of the results derived herein depend upon the slope of this curve.

The initial period demand for developed land is easily derived. Substitute the implicit building price function $p_0^m(n)$ into the indirect profit function to get $\pi(p_0^m(n))$, where

$$\frac{d\pi}{dn} = q_0^m\left(\frac{dp_0^n}{dn}\right) < 0 \tag{16}$$

again using (1). The sign of this result follows from (14). Thus, the $\pi(p_0^m(n))$ curve is negatively sloped as drawn in Fig. 1.

The benchmark market equilibrium initial land development n_m is where the π and V^m curves intersect.[6] The amount of land left vacant in the first period in equilibrium is $N - n_m$. The total number of building units built in the first period is $n_m\pi'(p_0^m(n_m))$. The numbers of units newly built in the second period are $(N-n_m)\pi'(p_1^m(n_m))$ and $(N-n_m)\pi'(p_2^m(n_m))$ for the high and low demand states, respectively.

[6] Now we can see why the slope of the V^m curve does not matter in the analysis. Assume that the market will draw more land into current development when the return to land in current development exceeds the option value. Similarly, the market will draw more land out of current development when the option value of vacant land exceeds the return to land currently developed. This is a Marshallian quantity adjustment process (like the long run adjustment assumed in competitive goods markets: profits draw entry; losses prompt exit). Market stability requires that the π curve cuts the V curve from above. Therefore, when the V^m curve is negatively sloped, apply Samuleson's correspondence principle and only consider the stable case in which its slope is shallower than that of the π curve.

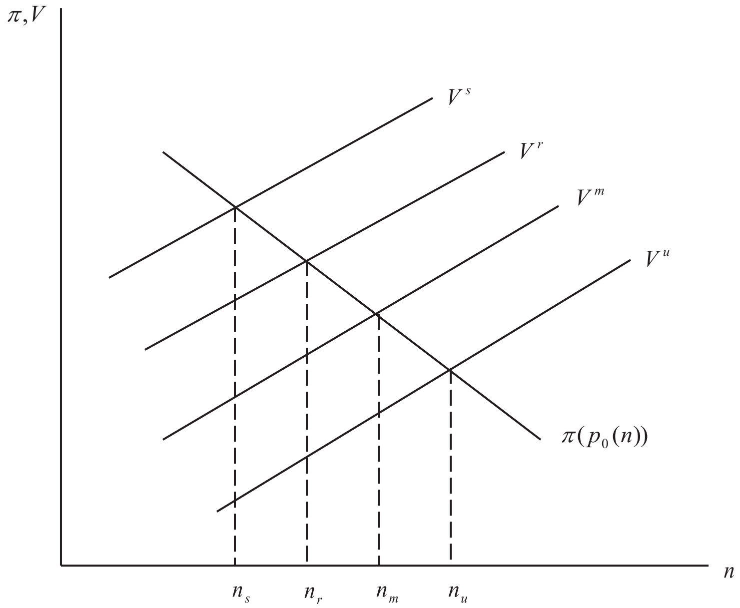

Fig. 1. Equilibrium land development rates in market without eminent domain (m) and with eminent domain compensation based on unregulated land value (u) and regulated land value (r), compared with socially efficient outcome (s).

3.2. An efficient benchmark

Following the earlier eminent domain literature, we use the socially efficient equilibrium as a normative benchmark. The social marginal values of building units, p_0^s, in the initial state equals the market price, since that is where the social surplus from building units is maximized in the first period, $n\pi'(p_0) = f(p_0)$. Similarly, for state 2, p_2^s is determined by the building market equilibrium condition (13) above. In state 1, however, only $n\pi'(p_0)$ building units are available. This is the number carried forth from the initial period development. All new construction in state 1 on this plot of land is forestalled since the land has greater value as a vacant green space. The social value of buildings in state 1 is therefore determined by the modified condition

$$n\pi'(p_0^s) = f(p_1^s)\theta_1 \tag{17}$$

Finally, the socially efficient allocation of land also satisfies the allocation condition that land be put to its highest valued social use in the first period, or

$$\pi(p_0^s) = V^s \tag{18}$$

in the first period, where the social option value of vacant land is (10) as before.

The efficient equilibrium is the implicit solution to Eqs. (10), (11), (13), and (17). In order to illustrate the relationships graphically, follow the general procedure used for the unregulated market model in the previous subsection. Solving (11), (13), and (17) for the implicit functions $\{p_0^s(n), p_1^s(n), p_2^s(n)\}$ we note that

$$p_0^s(n) \equiv p_0^m(n) \tag{19}$$

$$p_2^s(n) \equiv p_2^m(n) \tag{20}$$

while

$$p_1^s(n) > p_1^m(n) \tag{21}$$

This last inequality arises because the socially efficient supply of building units in the second period high demand state is less than the market supply when efficiency calls for all of the remaining vacant land to be used as green space. Substituting the implicit building value functions for the socially efficient outcome $\{p_0^m(n), p_1^s(n), p_2^m(n)\}$ into the social option value (10) yields

$$V^s(n) \equiv \left(\frac{p_0^m(n) - p_2^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{G_1}{(1+r)} + \left(\frac{p_1^s(n) - p_0^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{\pi(p_2^m(n))}{(1+r)} \tag{22}$$

Similar to the option value in the unregulated market case, the slope dV^s/dn is ambiguous in general. None of our conclusions is affected by concentrating on the upward sloped case in Fig. 1.

Since the price function $p_0^m(n)$ applies to both the benchmark market and the socially efficient equilibria, the $\pi(p_0^m(n))$ curve derived earlier also applies to the efficient benchmark. The intersection of the V^s and π curves in Fig. 1 gives the efficient quantity of land to be developed in the initial period, n_s.

3.3. Unregulated market efficiency

In order to compare the benchmark market and the socially efficient outcomes, the higher price of building units in the high demand state tends to lower V^s relative to V^m, but $G_1 > \pi(p_1)$ ensures that $V^s(n) > V^m(n)$ at each n, as shown in Appendix A. Therefore, the social option value curve lies above the unregulated market curve as drawn. Given that the same current period land profit curves apply to both cases, the figure reveals that the efficient development pace is slower than the unregulated market outcome without the threat of eminent domain: $n_s < n_m$ so that there will be fewer units of vacant land available in the second period should the high-state green space externality arise. Further, $n_s < n_m$ also implies that the price of building units is lower in the unregulated market than if the socially efficient outcome were pursued ($p_0^m(n_m) < p_0^m(n_s)$) so that the unregulated market structural density is less than the efficient structural density in the first period: $q_0^m < q_0^s$ from (2).

4. Full compensation

This section examines the implications of an eminent domain policy with full compensation awarded to owners of land taken by the government. Full compensation in this case means that the owner of vacant land taken by the government in the second period will either receive full value or full compensation for his lost land in the high demand state, $\pi(p_1)$. A problem arises, however, from the fact that the price of building units in the high demand state is generally higher than if the government did not take vacant land to preserve the original green space (recall $p_1^s(n) > p_1^m(n)$). This problem does not arise in the previous literature and in the preceding section because prices are exogenous in those applications. When prices are endogenous the rule is not so straightforward: there is a divergence between opportunity cost of the land in private use $\pi(p_1^s(n))$ and the landowner's loss from eminent domain $\pi(p_1^m(n))$. Further, the constitutional specification of fair compensation is not very helpful here. Although this requirement is usually interpreted to mean compensation at fair market value, when prices are endogenous the compensation question becomes one of choosing *which* market value to pay landowners: the value of land in private use when the supply of land has been reduced by the government's exercise of eminent domain or the value of land in the unfettered market? The opportunity cost of the land in the regulated market is its market value when the supply is constrained by the government, $\pi(p_1^s(n))$; this is the regulated market value case below. The compensation needed to cover the loss of landowner wealth, though, is measured by the market value of land in the absence of the taking threat, $\pi(p_1^m(n))$; this is the unregulated market value case considered later.

In both cases compensation is lump-sum in the sense that it cannot be affected by actual variation in the private owner's investment plans, a property generally thought to promote efficient private investment under the threat of taking (Miceli and Segerson, 1996, 47–60). In contrast, here it turns out that the two compensation measures lead to very different positive and normative results. In order to draw out these differences, consider the two compensation methods in turn.

4.1. Compensation at regulated market value

When the government follows the Pareto rule and only imposes eminent domain in the high demand state, the private value of vacant land under regulated or post-eminent domain market value is $\pi(p_1^s(n))$. With the threat of eminent domain and full compensation, the market equilibrium is determined by the building equilibrium conditions determining building prices in each state, (11), (13), and (17), the option value equation (6) with $\pi(p_1^s(n))$ for the high demand state return, and the initial land market equilibrium condition $\pi(p_0) = V^r$ where the superscript r indicates that compensation is being made at the regulated or post-eminent domain market prices. The building market equilibrium conditions are the same conditions as in the benchmark efficient outcome, and so yield the price functions $\{p_0^m(n), p_1^s(n), p_2^m(n)\}$. In order to take into account the endogenous price adjustments to differences in land and building unit supply in each state, substitute these price functions $\{p_0^m(n), p_1^s(n), p_2^m(n)\}$ and the compensation $\pi(p_1^s(n))$ into (6) to obtain the option value of vacant land

$$V^r(n) = \left(\frac{p_0^m(n) - p_2^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{\pi(p_1^s(n))}{(1+r)} + \left(\frac{p_1^s(n) - p_0^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{\pi(p_2^m(n))}{(1+r)} \tag{23}$$

The earlier result $p_1^s(n) > p_1^m(n)$ decreases V^r relative to V^m, but also leads to $\pi(p_1^s(n)) > \pi(p_1^m(n))$, which by itself increases the value of V^r relative to V^m. Even though the net effect of eminent domain on vacant land value appears to be ambiguous at this point, Appendix A shows that the higher price of building units in state 1 coupled with the higher compensation than without takings unambiguously increases the option value of land under threatened taking relative to the free market: $V^r(n) > V^m(n)$ at any given n and the V^r curve lies everywhere above V^m in Fig. 1.

On the other hand, by assumption the social value of land in the high demand state exceeds the private value of land, $G_1 > \pi(p_1^s(n_r))$, which justifies the taking by eminent domain in the first place. Comparing (22) and (23), it follows that $V^s(n) > V^r(n)$ and the option value with full compensation based on the regulated or post-eminent domain building price lies below the social option value of vacant land as pictured in the figure. Compensating owners with the private value of land in the high demand state, $\pi(p_1^s(n_r))$, leads to a lower land option value than is efficient, with the result that too much land is developed at the outset, $n_r > n_s$. Recall that Innes (1997) concludes that full compensation does not change the market determined development pace for the reversible development case with exogenous prices. In contrast, we see that *full compensation does change the market determined development pace when development is irreversible and prices are endogenous, further slowing development in the initial period* ($n_r < n_m$). *Nonetheless, full compensation still leads to an initial market development pace that is too rapid for efficiency*. This last aspect at least qualitatively resembles the efficiency conclusion in Innes (1997). Here, anything short of compensating at the full social value of land will leave the market at an inefficient outcome (Hermalin, 1995). Only in this broad conclusion does the inefficiency of the market under the threat of eminent domain appear to be robust across the reversible and irreversible development cases.

How does compensation affect structural density of development? Not surprisingly, given that the initial quantity of land developed is greater than the efficient level, the price of building units is lower than what would exist in an efficient outcome and the number of units per land parcel is lower, too (since $p_0^m(n_r) < p_0^m(n_s)$) and the indirect profit function properties imply $q_0^r < q_0^s$. So, while Blume et al. (1984) find that full compensation leads to over-investment in structures and Miceli (1991) argues that full compensation can be designed to promote efficient investment, here we find that *compensation at the regulated or post-eminent domain price leads to a lower current or first period structural density than is efficient when investment is irreversible.*

Given this normative conclusion, why not have the government exercise eminent domain and take the land in the initial period? This model of government behavior, of course, diverges from the Pareto behavior assumption in which the government only takes land when the realized state indicates it is efficient to do so. Nonetheless, if the government were to take land in the initial period, it would have to remove enough land from the market in the first period to drive the value of developed land to equality with the social value of vacant land, or $\pi(p_0) = V^s$. There are several problems with this type of policy. One problem is that the efficient strategy requires that the government sells land to private developers in the second period if the demand for buildings is low enough. But using eminent domain to speculate in the land market in this fashion violates the public use clause in the US Constitution. Even though the courts have not established the public use rule as a bright line constraint, as a practical matter, a public use rule is essential to retain a reasonable degree of transparency in the eminent domain process and to forestall the potential corrupting effects of the government using its police power to manipulate the market in order to gain arbitrage profits or to transfer property to rent seekers at favorable below market prices.[7]

Another possibility is for the government to eschew eminent domain entirely and simply buy enough land in the initial period to ensure efficiency in the second period should the high externality value state arise. Efficiency then requires following the Pareto rule ex post: If state 1 obtains in the future period then the land is put to public use as a green space while if state 2 obtains then all of the land is sold to private investors. By not using eminent domain to acquire the land, the government avoids violating the public use doctrine.

But this scheme again raises the issue about keeping government actions as transparent as possible. Further, since it also likely that land purchased at a high price at the outset must be sold at a lower value at later date to ensure efficiency (e.g., $\pi(p_2) < V$ in the second period), one can easily imagine the public outcry against the government for selling vacant land to private investors at a loss, even when such behavior is efficient. Finally, the opportunities for rent seeking or outright political corruption in this type of land investment process are so immense that few would argue for such a governmentally managed dynamic land bank program. There are clear disadvantages to allowing local governments to speculate in their constituent land markets that could overshadow the potential efficiency advantages.

4.2. Compensation at unregulated market value

Now suppose that owners are compensated for takings at the unregulated market value, that is, what the private value of land would be in the absence of the eminent domain threat. Miceli (1991) argues that this type of compensation elicits an efficient structural density in the reversible investment case.

In the irreversible investment case considered here, the compensation scheme fulfills the usual interpretation of fair compensation because it compensates the land owner for the actual lost land value arising from both the threat of eminent domain and the act of taking by eminent domain. But because the market price of building units rises in the high demand state when land is taken out of private use, basing compensation on unregulated market value leads to lower compensation than in the regulated value case just considered: $p_1^m(n) < p_1^s(n)$ implies $\pi(p_1^m(n)) < \pi(p_1^s(n))$. It turns out that this method of compensation leads to an even faster development pace and lower density than found in the unregulated market.

To see why, notice that the building market equilibrium conditions take the same form as above and the general option formula remains (6). The option value of vacant land when compensation is based on unregulated market value is

$$V^u(n) = \left(\frac{p_0^m(n) - p_2^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{\pi(p_1^m(n))}{(1+r)} + \left(\frac{p_1^s(n) - p_0^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{\pi(p_2^m(n))}{(1+r)} \tag{24}$$

For a given n, the only difference between this and the option value formula under the regulated price based compensation V^r is the compensation term in the first right-hand side numerator: $\pi(p_1^m(n))$ versus $\pi(p_1^s(n))$. Recall that $p_1^s(n) > p_1^m(n)$ so that $\pi(p_1^m(n)) < \pi(p_1^s(n))$. This means that $V^u(n) < V^r(n)$ at any given n, that is, the option value of land under this compensation formula lies everywhere below the option value under compensation based on post-eminent domain prices. Not surprisingly, lower compensation for land taken by the government lowers the value of vacant land in the market.

But we can say more. Holding compensation unchanged, differentiate V^m at a given n to show that option value declines with a greater high demand state building price

$$\frac{\partial V^m}{\partial p_1} = \frac{\pi(p_2)/(1+r) - V^m}{p_1 - p_2} < 0 \tag{25}$$

using $\pi(p_2)/(1+r) < V^m$. Because V^u declines with greater state 1 prices when holding compensation unchanged, the option value under this lower compensation is also less

[7] For example, local governments sometimes use eminent domain to acquire land in order to transfer it to private investors as a part of their economic development policies. Whether such use passes the public use threshold is a matter of ongoing popular and legal debate. See Turnbull and Salvino (2009) for a summary of the issues and the development of relevant case law.

than the option value for the unregulated market: $V^u(n) < V^m(n)$ at any given n. Thus, not only does V^u lie below the V^r curve, it also lies everywhere below the V^m curve in Fig. 1.

Intuitively, the lower compensation by itself is not the only culprit lowering the option value of vacant land V^u. Market participants recognize that the future price of building units will rise in the high demand state should the government take all of the remaining vacant land for green space, that is, should the high demand state be realized. Driving up the market price in the high demand state reduces the state price of the high value outcome (i.e., the price of an Arrow–Debreu security for state 1) and increases the state price of the low value outcome (i.e., the price of an Arrow–Debreu security for state 2). This by itself shifts the state price-weighted expected value of second period earnings—and the option value of vacant land—toward the low demand state. In the scheme where compensation is based on the regulated market or post-eminent prices, the higher building price in the high value state increases compensation to the landowner. It turns out that this additional effect outweighs the state price effect and therefore is entirely responsible for increasing the option value under the threat of eminent domain in that compensation scheme. The unregulated market value compensation scheme, however, bases compensation on the value of vacant land in the absence of any eminent domain threat. This compensation does not respond to the eminent domain-induced price changes. Thus, the factor that increases option value in the post-eminent domain price compensation scheme is missing in the unregulated market price compensation considered here, and leads to the surprising situation in which the threat of takings drives the market even farther from the efficient outcome.

Summarizing the implications of these option value differences using Fig. 1, we have the following:

Proposition 1. $n_u > n_m > n_r > n_s$ *so that*:

(i) The development pace under the threat of eminent domain with compensation at the unregulated market value of the taken property exceeds that of the unregulated market without the threat of eminent domain ($n_u > n_m$).

(ii) The market development pace with no threat of eminent domain exceeds that under the threat of eminent domain with compensation at the regulated market value of the taken property ($n_m > n_r$).

(iii) The development pace under the threat of eminent domain with compensation at the regulated market value of the taken property exceeds the socially efficient land development pace ($n_r > n_s$).

Proposition 2. $q_0^u < q_0^m < q_0^r < q_0^s$ *so that*:

(i) The initial period structural density under the threat of eminent domain with compensation at the unregulated market value of the taken property is less than that of the unregulated market without the threat of eminent domain ($q_0^u < q_0^m$).

(ii) The initial period structural density with no threat of eminent domain is less than that under the threat of eminent domain with compensation at the regulated market value of the taken property ($q_0^m < q_0^r$).

(iii) The initial period structural density under the threat of eminent domain with compensation at the regulated market value of the taken property is less than the socially efficient structural density ($q_0^r < q_0^s$).

The second proposition follows from the first proposition using (14) and the convexity of the indirect profit function ($\pi'' = dq_0/dp_0 > 0$). The second proposition establishes a result that contradicts that found earlier for the reversible development case: full compensation either increases or decreases the initial structural development density, depending on whether the regulated or unregulated market value is used as the basis for compensation. Since the amount of land initially developed under the lower compensation, n_u, is even farther from the efficient level than is the market equilibrium without takings, n_m, eminent domain in this case unambiguously reduces the efficiency of the land market. In terms of Fig. 2, compensation at the regulated or post-eminent domain market value increases social surplus by area A while compensation at unregulated market price decreases social surplus by area B. The sum of these two areas therefore represents the social cost of compensating landowners at unregulated market value rather than at regulated market value.

Finally, we note that similar results hold for the case in which the ecological or green space value arises in the low demand state rather than the high demand state (i.e., when $\pi(p_1) > G_1$ and $G_2 > \pi(p_2)$).

5. Conclusion

This paper examined the consequences of eminent domain with full compensation when the land development decision is irreversible. The motivation for an option value framework originates with the nature of ecological or green space externalities and other types of public land uses for which any private improvements irreversibly extinguish any potential social value.

The existing literature focuses on reversible private investment and illustrates that the efficiency of eminent domain hinges upon the compensation rule employed in actual practice. Eminent domain compensation, like all taxes, subsidies, and land use regulations, affects investment incentives and therefore economic decisions. The threat of eminent domain introduces an incentive to develop or redevelop real estate sooner than is economically efficient when takings are compensated at market value (Innes, 1997). Since capital improvements must typically be removed from the land in order to ready it for its eventual public use, the more rapid development identified by Innes increases the social cost of taking land for public use by increasing both the necessary demolition costs and the foregone benefits of the still-useful structures and other improvements that must be destroyed to clear the land. Compensating owners for taken property at its social value rather than its lower private market value eliminates this distortion (Hermalin, 1995).

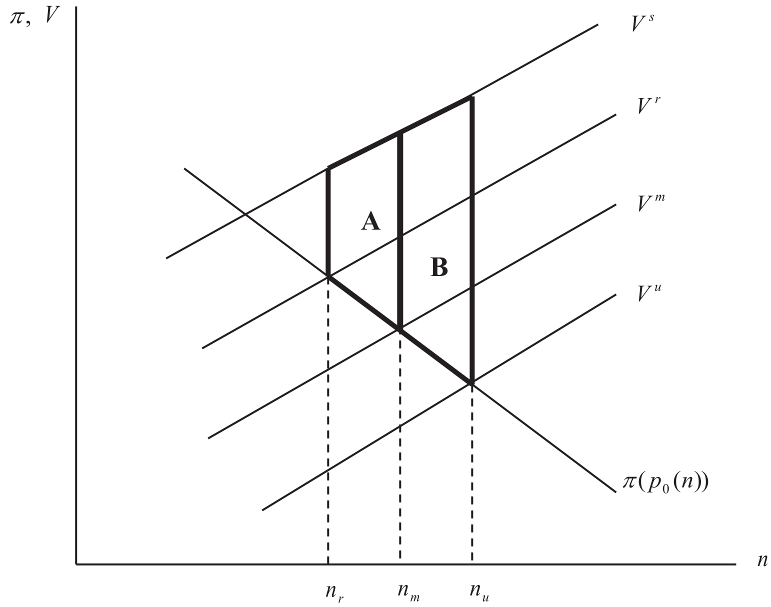

Fig. 2. Welfare effects of eminent domain compensation. Area A is the efficiency gain when compensation is set equal to regulated land value (r) and B is the efficiency loss when compensation is set equal to unregulated land value (u).

The situation is more complicated when real estate development is irreversible, as in the green space case considered here, but the policy lessons are surprisingly straightforward. When the amount of vacant land to be taken by the government is a very small part of the remaining vacant land in the market—the exogenous price case examined in this paper—the takings will have little effect on market price of the remaining vacant land. In this case, which is relevant to exurban or peripheral metropolitan municipalities and counties, compensation at the unregulated market value for vacant land taken by eminent domain will increase efficiency, but not as much as overcompensation at the social value of the land would. In other situations, however, the method of compensation becomes a crucial issue—to the extent that even the basic proposition of whether or not eminent domain can increase efficiency remains in doubt. For example, when the green space or ecological enclave removes enough vacant land from the private market then exercising eminent domain will increase the market price of the remaining parcels of comparably situated land. This case is relevant to local governments in collar communities or the interior of metropolitan areas with little remaining undeveloped land. In such situations, exercising eminent domain with compensation at the unregulated market value can actually reduce overall economic efficiency despite the fact that the land taken by the government is put to the highly valued social use. So it turns out that the same compensation rule applies to both cases, exogenous and endogenous property prices; compensating owners for the social value of their taken land is efficient, since it aligns private investors' incentives with the higher social benefits rather than the lower private benefits of vacant land.

Finally, although not addressed here, the real option framework also implies that the regulatory problem is complicated when *specific* parcels of land can be identified as potential sources of green space externality. The private market does not distinguish such land from all other land, so whether or not it is kept vacant is indeterminate at the market level. But even if the parcels that have potential green space value can be identified in advance, this does not mean that these parcels will be kept undeveloped for just such an eventuality. If the analysis of regulatory takings in Turnbull (2005) offers any clues to the eminent domain situation, then the individual land parcels with the greatest potential green space value (hence, the greatest risk of taking by eminent domain) will be developed more rapidly than otherwise identical parcels with less potential green space value. Although the formal analysis in not undertaken here, it appears that the compensation policy can play an important strategic role in this case as well. If owners expect overcompensation equal to the possible social value of the land then they have an incentive to hold such land in reserve. If they expect compensation at the unregulated market value then they have an incentive to develop their land even more rapidly in order to extinguish any potential future green space claims. What can the government do to ensure that such land will be kept available to realize its potential social ecological or green space value while allowing for the possibility that more valuable private uses may arise? Development fees, tax abatement or subsidies for these parcels or even carefully selected development moratoria can forestall development to keep the social green space option open. But it is not yet clear how feasible such policies would be given the realities of local land use politics nor is it clear how such policies will interact with the resource allocation effects of threatened eminent domain. These remain questions for further study.

Appendix A

The derivative properties of the social option value of vacant land (10) referred to in the text are

$$\frac{\partial V^s}{\partial G_1} = \left(\frac{p_0 - p_1}{p_1 - p_2}\right)\frac{1}{1+r} > 0$$
$$\frac{\partial V^s}{\partial p_0} = \frac{G_1 - \pi(p_2)}{(p_1 - p_2)(1+r)} > 0$$
$$\frac{\partial V^s}{\partial p_0} = \frac{G_1 - \pi(p_2)}{(p_1 - p_2)(1+r)} > 0$$

$$\frac{\partial V^s}{\partial p_1} = \frac{\pi(p_2)}{(p_1 - p_2)(1+r)} - \frac{V^s}{(p_1 - p_2)} = \left(\frac{1}{p_1 - p_2}\right)\left(\frac{\pi(p_2)}{1+r} - V^s\right) < 0$$

$$\begin{aligned}\frac{\partial V^s}{\partial p_2} &= \frac{V^s}{(p_1 - p_2)} + \frac{(p_1 - p_0)\pi'(p_2) - G_1}{(p_1 - p_2)(1+r)} \\ &= \left(\frac{1}{p_1 - p_2}\right)\left(V^s - \frac{G_1}{1+r}\right) + \frac{(p_1 - p_0)\pi'(p_2)}{(p_1 - p_2)(1+r)} \\ &= \left(\frac{(p_1 - p_0)}{(p_1 - p_2)^2(1+r)}\right)(\pi(p_2) - G_1 + (p_1 - p_2)\pi'(p_2)) \\ &= \left(\frac{(p_1 - p_0)}{(p_1 - p_2)^2(1+r)}\right)(\pi(p_1) - \varepsilon - G_1) < 0\end{aligned}$$

where the signs follow from $G_1/(1+r) > V^s$ and $G_1 > \pi(p_1)$ and the last equality uses the strict convexity of the indirect profit function to show $\pi(p_2) + (p_1 - p_2)\pi'(p_2) + \varepsilon = \pi(p_1)$ where $\varepsilon > 0$. Thus, $p_1^s(n) > p_1^m(n)$ by itself lowers V^s relative to V^m but at the same time $G_1 > \pi(p_1^m(n))$ raises V^s relative to V^m.

Claim 1. $V^s(n) > V^m(n)$.

Proof. Differentiate V^m with respect to p_1

$$\begin{aligned}\frac{dV^m}{dp_1} &= \left(\frac{\partial V^m}{\partial p_1}\right) + \left(\frac{\partial V^m}{\partial \pi'(p_1)}\right)\pi'(p_1) \\ &= -\left(\frac{(p_0 - p_1)}{(p_1 - p_2)^2(1+r)}\right)(\pi(p_1) + (p_2 - p_1)\pi'(p_1) - \pi(p_2)) \\ &= -\left(\frac{(p_0 - p_1)}{(p_1 - p_2)^2(1+r)}\right)(\pi(p_2) - \varepsilon - \pi(p_2)) \\ &= \left(\frac{(p_0 - p_1)}{(p_1 - p_2)^2(1+r)}\right)\varepsilon > 0\end{aligned} \tag{A1}$$

again using the convexity of the indirect profit function to find $\pi(p_1) + (p_2 - p_1)\pi'(p_1) + \varepsilon = \pi(p_2)$ where $\varepsilon > 0$ for the third line. See, for example, Fig. A1. It follows that

$$\begin{aligned}V^s(n) &= \left(\frac{p_0^m(n) - p_2^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{G_1}{(1+r)} + \left(\frac{p_1^s(n) - p_0^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{\pi(p_2^m(n))}{(1+r)} \\ &> \left(\frac{p_0^m(n) - p_2^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{\pi(p_1^s(n))}{(1+r)} + \left(\frac{p_1^s(n) - p_0^m(n)}{p_1^s(n) - p_2^m(n)}\right)\frac{\pi(p_2^m(n))}{(1+r)} \\ &> \left(\frac{p_0^m(n) - p_2^m(n)}{p_1^m(n) - p_2^m(n)}\right)\frac{\pi(p_1^m(n))}{(1+r)} + \left(\frac{p_1^m(n) - p_0^m(n)}{p_1^m(n) - p_2^m(n)}\right)\frac{\pi(p_2^m(n))}{(1+r)} = V^m(n)\end{aligned} \tag{A2}$$

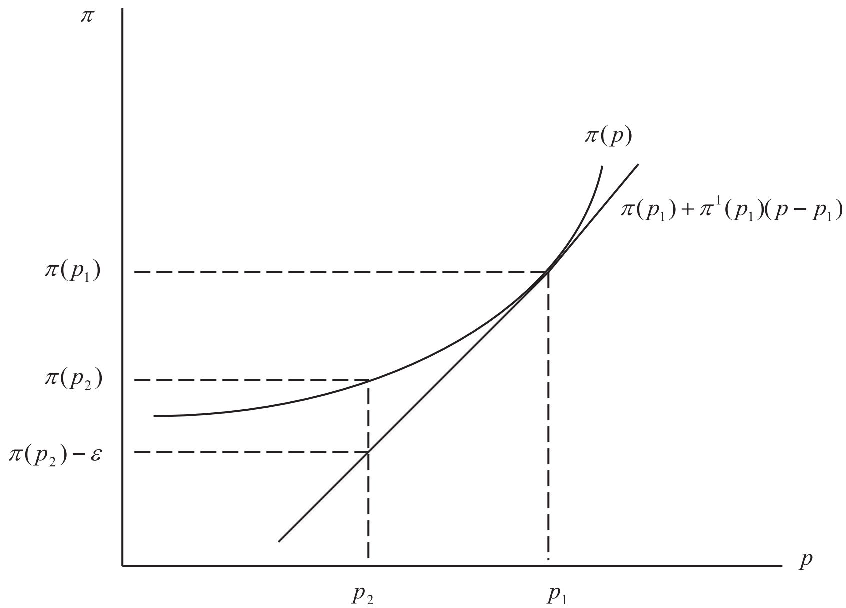

Fig. A1. Indirect profit value relationships implied by convexity.

where the second line follows from $G_1 > \pi(p_1^s(n))$, the third line from (A1) and $p_1^s(n) > p_1^m(n)$ with (1). Thus, $V^s(n) > V^m(n)$, which is the result to be shown. □

Claim 2. $V^r(n) > V^m(n)$.

Proof. $V^r(n)$ is the second line in (A2) so that the result immediately follows from the last line of (A2). □

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