Do Urban Redevelopment Incentives Promote Asset Deterioration?
A Game-Theoretic Approach

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Abstract

The elapsed time between a government's announcement of its intention to redevelop and the launch of the new construction may often be quite lengthy. This study uses a game-theoretic framework to examine the effect of the option to redevelop on the quality of the existing housing stock during this extended pre-redevelopment period. We show that the benefits that accompany future redevelopment may lead to accelerated deterioration in the pre-redevelopment period. Moreover, we identify circumstances under which there exists a unique perfect Nash equilibrium where, in order to discourage objections by other homeowners, those who support redevelopment intentionally promote structural deterioration during the pre-redevelopment period. Our results highlight the need to shorten the period of time between the announcement of the option to redevelop and its implementation.

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1. INTRODUCTION

In order to promote redevelopment initiatives, policymakers across the world use various measures to incentivize entrepreneurs and homeowners to redevelop designated areas. Cities in the United States, for example, commonly leverage their regulatory power by up-zoning (i.e., changing the zoning regulations to allow for higher-value and/or denser land use) in order to attract developers (see Amirtahmasebi *et al.*, 2016). In China, the Shanghai municipal government provides assistance to developers, including density bonuses and reduced administrative and acquisition costs (Wang, 2011; Fu *et al.*, 1999). Similar 'property-led' incentives that take different forms are implemented in other countries, including the United Kingdom (Tallon, 2013; McGuirk, 2000), Singapore and Hong Kong (Hui, Wong, and Wan, 2008), South Korea (Shin and Kim, 2015), the Netherlands (Priemus, 2004), Israel (Israel Planning Administration, 2016; Geva and Rosen, 2019; Margalit, 2014; Mualem et al., 2019), and Iran (Mohammadi and Khayambashi, 2014).[1]

Despite the potential advantages of redevelopment and the economic incentives offered by regulators, it is often the case that some of the property owners object to the redevelopment activity (see, for example, Kuyucu and Ünsal, 2010; Fassmann and Hatz, 2006; Shin and Kim, 2015; and Priemus, 2004). In fact, Kuyucu and Ünsal (2010) report that objections to redevelopment programs are a major factor in delaying their implementation.[2] Thus, in some cases, in order to

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[1] It should be noted that while in some countries (including the U.S., Singapore, China, and Hong Kong) redevelopment programs commonly involve the collective sale of homeowner rights to the developer, in others (for example, Israel and Korea) the owners commonly maintain their ownership, and the additional allowable floor area/ housing units are used as a financing tool for incentivizing the redevelopment.

[2] In cases of programs that require the developers' acquisition of the majority of properties, multi-ownership further complicates the issue of land assembly and the multi-party bargaining problem. Strange (1995) and Eckart (1985) model the assembly of land from multiple landowners as a game among rational agents, and find that owners of smaller parcels of land demand a greater price per acre. Fu, McMillen, and Somerville (2002) offer empirical evidence of premiums extracted by owners of smaller properties. There is an expectation that the negotiation process that follows the announcement of a redevelopment program will delay the implementation of the redevelopment.

circumvent local resistance and to increase homeowners' motivation to participate in redevelopment, regulators offer them economic incentives to redevelop. Further, to facilitate the redevelopment process, the supermajority of homeowners required to support the redevelopment is often well below unanimity. For example, in Australia, Singapore, Hong Kong, and Israel, the share of supporting homeowners required in order to authorize redevelopment is 75–90%, 80%–90%, 80%, and 67%–80%, respectively (see Hui *et al.*, 2008; Zakiah and Khadijah, 2017).[3,4]

Following an objection to redevelopment on the part of some homeowners, and the extended time typically required to implement redevelopment, we study the effect of economic incentives to redevelop on the behavior of those homeowners who wish to promote the implementation of redevelopment. Specifically, we develop a game-theoretic framework by which we show that, during the period between the announcement of potential future redevelopment and its delayed implementation, homeowners who support the redevelopment initiative may attempt to "persuade" their reluctant property-owning neighbors to agree to the redevelopment by strategically promoting deterioration of their housing units. In particular, they cease to invest in maintenance of their properties so as to further deteriorate the housing stock, thereby reducing the

[3] Note that legislative initiatives indicate that owners often impose barriers to redevelopment. Examples include Singapore's Land Title Act of 4 May 1999, which abandoned the statutory requirement to obtain unanimous consent from owners, and replaced it with an 80–90% threshold (depending on the age of the structure) in order to minimize delay in the collective sales process (see Foo Sing and Wan Jenny Lim, 2004); and recent legislation in Israel that allows owners, in some cases, to file a claim for damages against property owners opposing the implementation of redevelopment (see http://www.moch.gov.il/English/regeneration_and_renewal/urban_renewal/Pages/opposing_property_owners.aspx, last accessed Jan. 2019). Also, the share of supporting homeowners required in order to authorize redevelopment in Israel (either 67% or 80%) depends on the type of the project.

[4] According to Carmon (1999), redevelopment phases may extend over more than a decade; Geva and Rosen (2018) discuss the risk of extended and/or failed negotiations among owners and developers in the context of "Raze and Rebuild" projects; further, Shin and Kim (2015) and Fassmann and Hatz (2006) report low levels of implementation of redevelopment programs; Adair et al. (2007) provide interview-based evidence indicating that investment fund managers expect a minimum of 20 years from the time of initiation of a regeneration project to its completion; finally, August (2016) provides various explanations for the limited tenant resistance to mixed-income social housing redevelopment, yet reports on a implementation phase that lasts 15–20 years.

value not only of their own units, but also of those owned by the anti-redevelopment homeowners. In effect, they turn the potential redevelopment initiative into an even more profitable activity that leads, in most cases, to a decrease in resistance to redevelopment on the part of the objecting homeowners. Moreover, by examining a redevelopment incentive schedule that inversely depends on the quality of the housing stock, we show that the latter might further support housing deterioration as homeowners strive to be included in the redevelopment incentives program. These outcomes sustain under a number of plausible perfect Nash equilibria.[5] It thus follows that the announcement of a program, incentivizing future redevelopment effectively sets the stage for neighborhood deterioration.

Key to our model is the assumption regarding the externality effect of one's maintenance on the value of the surrounding properties. Yau and colleagues (2008) provide direct empirical evidence of the maintenance externality effect. They find that property values increase by 6% on average following the redevelopment of an adjacent structure. Other studies show that the quality and aesthetics of the surroundings have an effect on property values (see, e.g., Hamilton and Schwann, 1995; Boyle and Kiel, 2001; and De Sousa, Wu and Westphal, 2009). Relatedly, Rosenthal (2008, 2014) suggests that deterioration in housing quality may lead to a tipping point at which prices decline to a degree that draws private investment to the neighborhood, spurring a redevelopment process. However, the deterioration may also lead to an unwelcome, prolonged

[5] The notion of "Nash Equilibrium" captures a steady state of play of a strategic game in which each player holds the correct expectation about the other players' behavior and acts rationally. In other words, no player can profitably deviate, given the actions of the other players. For the equilibrium to qualify for a perfect Nash equilibrium (or a subgame perfect equilibrium), each player must therefore pursue her optimal actions and, as a result, "non-credible threats"— in which a player's strategy negatively affects not only another player's payoff but her own as well—are eliminated [see, e.g., Osborne and Rubinstein (1994)].

decay accompanied by negative social repercussions, as evidenced in actions taken by central and local governments around the world to support and promote redevelopment processes.[6]

While our study focuses on homeowner decision to under-maintain as a strategic tool to incentivize agreement to redevelop, other real estate studies analyze non-optimal levels of maintenance in different contexts. Ben-Shahar (2004), for example, argues that the seller-buyer asymmetric information regarding the quality of the repeat-sale housing unit may result in over-maintenance (and false-unproductive maintenance) prior to the sale. Pavlov and Blazenko (2005) argue that, given the externality effect of maintenance, it is necessary to subsidize maintenance expenditures in order to reach socially optimal maintenance levels. A number of studies deal with issues related to maintenance of common property and conflict of interests among owners in multi-owned housing (see, for example, Yip and Forrest, 2002; Arkcoll et al., 2013; Gao and Ho, 2016; and Geva and Rosen, 2018). Other related studies use a game-theoretic setting to justify the need for intervention in redevelopment processes (see O'Flaherty, 1994; Davis and Whinston, 1961) and model the process of land assembly under a game theoretic framework played by owners and developers (Strange, 1995; Eckart, 1985).[7]

Also, there is a critical discussion on redevelopment in the literature. The literature, for example, highlights the negative effects of the relocation of low-income households and communities (Carmon, 1999; Chan and Lee, 2007; and Shin, 2009) and the relocation of elderly residents (Chui, 2001; and Cameron, 1980) that follows a redevelopment program. It also casts doubt on the justification for intervention and its efficiency (Arrow, 1970; Anderson, 1964).

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[6] In this context, see also Amirtahmasebi *et al*. (2016); Hui *et al.* (2008); Gordon (2003); Carmon (1999); and Alterman (1995). Amirtahmasebi *et al*. (2016), for example, argue that the prevalence of poor quality and underutilized urban areas weaken the city's image, livability, and productivity.

[7] Fu, McMillen, and Somerville (2002) offer further empirical evidence of premiums extracted by small landlords. The negotiation process that follows the announcement of a redevelopment program may be another source of delay in the implementation of the project.

Finally, the critical literature further emphasizes the environmental costs associated with the demolition and reconstruction process (see, e.g., Assefa and Ambler, 2017; Weiler, Harter and Eicker, 2017). Our analysis, however, focuses not on the effects of redevelopment *per se*, but rather on regulatory issues that allow for an extended period in which owners have the incentive to redevelop yet are prevented from executing it, resulting in a deliberate asset deterioration.[8]

Finally, the means by which housing policies may promote physical deterioration has been explored—both empirically and theoretically—in the rent control literature (see, among others, Alborn and Stafford, 1990; Olsen, 1988; Moon and Stotsky, 1993; Rydell and Neels, 1982). Redevelopment, however, typically associates with a-priori (pre-redevelopment) low-quality housing conditions and low socio-economic neighborhoods. It is thus not surprising that the redevelopment literature focuses mainly on the tenants and the social consequences of redevelopment policies. Nevertheless, as undeveloped land in major cities becomes increasingly scarce and redevelopments fill an increasing share of total development (Baum-Snow and Han, 2019), the redevelopment policy effect on pre-redevelopment housing quality deserves specific attention—which serves as a motivation for our theoretical analysis.

The paper proceeds as follows. In Section 2, we construct the model. In Section 3, we present the analysis and the equilibria under various plausible conditions. Section 4 provides a summary and concluding discussion.

2. THE MODEL

Consider an "old" building consisting of two housing units ($i = 1, 2$), each of which is the property of a different owner. Suppose that there are two periods, each generating rent to its

[8] For example, according to Kiefer (1980), deterioration can lead to more frequent moves, which may come with both economic costs to households and social costs to communities.

respective owner. The rent price of unit *i*, $Rent_i$, maintains $Rent_i = \alpha Q_i + (1-\alpha)Q_j$, where Q_i and Q_j are, respectively, the quality of unit *i* and its neighboring unit *j*, and α is a constant, $0 \leq \alpha \leq 1$. That is, there is a quality externality effect such that the rent price of *i* is a function of the quality of both units, where a greater α associates with a smaller externality effect.[9]

Let $Q_i = Q^l$ be the quality of both units coming into the first period (where Q^l stands for *low* quality due to past deterioration). Also, in the beginning of the first period, owner *i* may choose to invest in maintenance and thus upgrade her/his unit to $Q_i = Q^m$ ($Q^m > Q^l$) at an investment cost equal to C_i^m; alternatively, she/he may choose not to invest in maintenance and leave the quality of the unit at Q^l (at no cost).[10]

In the second period, however, owners face an opportunity to redevelop, which effectively upgrades the quality of each unit to Q^h ($Q^h > Q^m$). The owner cost that is associated with redevelopment (Q^h) is C_i^h. Importantly, unlike the first-period investment in maintenance, which depends solely on the decision of an individual owner, the implementation of redevelopment is contingent on unanimous agreement on the part of owners. Finally, without loss of generality, we suppose that $Q^l = 0$; Owner 1 exhibits a higher subjective redevelopment cost than Owner 2 (i.e., $C_1^h \geq C_2^h$); and owners have no time preference, so that the discount factor of future cash flows equals 1.

[9] Pavlov and Blazenko (2005) use a similar representation of neighborhood effect.

[10] That the cost of maintenance may vary from individual to individual follows from, for example, different skills or the ability to undertake construction activities themselves (see Reschovsky, 1992). It may also follow from heterogeneity in budget constraints and subjective non-monetary costs associated with upkeep activity (such as noise, dust, and risk aversion). Finally, the cost of redevelopment may vary by tenure mode and homeowner age (for detailed discussion see, respectively, Geva and Rosen, 2018; and Chui, 2001).

Figure 1 depicts the extensive-form game that follows the above-described framework.[11] "Owner 1" and "Owner 2" are the players, and each node corresponds to a possible action by one of the players, where *I* and *NI* respectively denote investment and no-investment in (first-period) maintenance and *R* and *NR* respectively denote investment and no-investment in (second-period) redevelopment. The figures at the terminal nodes are the players' payoffs—the first (second) in each pair is the payoff of Owner 1 (2).

As shown in Figure 1, in the first period owners sequentially choose whether to invest in maintenance (*I*) or not (*NI*). An investment in maintenance increases quality to Q^m; however, it associates with a cost of C_i^m, whereas no investment (*NI*) maintains the quality at Q^l and is associated with no cost . Hence, owner *i*'s payoff in the first period is equal to either $Q^m - C_i^m$ (if both owners choose *I*), $\alpha Q^m - C_i^m$ (if i chooses *I* and *j* chooses *NI*), $(1-\alpha)Q^m$ (if i chooses *NI* and *j* chooses *I*), or zero (if both owners choose *NI*; recall that we assume that $Q^l = 0$).

Similarly, in the second period, owners sequentially choose whether to invest in redevelopment (*R*) or not (*NR*). Owner *i*'s cost of redevelopment equals C_i^h. If any of the owners chooses *NR*, redevelopment is rejected, and the quality (and thus rent) of both units remains at the first-period level. If, however, both owners choose to invest in redevelopment (*R*), then owner *i*'s second-period payoff is equal to $Q^h - C_i^h$.[12]

[11] For ease of presentation, the choices made at each period by Owner 1 and Owner 2 are represented as sequential rather than simultaneous. However, it should be noted, in that regard, that an analysis of a similar model, though one in which each period's choices are made simultaneously, or the order is reversed between the players, yields similar results. Also, in a parallel setting, Varian (1994) shows that in the case of contribution to a *public good* (rather than the externality case under our setting), a sequential game allows the agent who plays first to exploit his position in the game and shift the burden to the players that follow. Importantly, while we do not suggest that our setting does not allow for an owner to exploit his/her position in the game, our focus is on the externality effect of maintenance rather than free ridership within a public-good context.

[12] It is clear that even if investment in maintenance were allowed in the second period, it would have been dominated by the prior choice to do so in the first period; thus the option to invest in maintenance in the second period becomes redundant.

It further follows from Figure 1 that owners face 8 possible outcomes from 12 possible paths. If, for example, both players choose *NI* in the first period, and at least one of them chooses *NR* in the second period, then owners' rent will equal Q^l in both periods; thus payoffs of both owners equal zero. If instead both players choose *NI* and then *R*, then payoffs will be Q^l during the first period and Q^h in the second period, net of the associated cost of C_i^h. If Owner 1 chooses *I* and Owner 2 chooses *NI* in the first period, and at least one of them chooses *NR* in the second period, then payoffs in both periods will be αQ^m (net of C_1^m) for Owner 1 and $(1-\alpha)Q^m$ for Owner 2. Finally, if Owner 1 chooses *I* and Owner 2 chooses *NI* in the first period, while both owners choose *R* in the second period, then the payoffs in the first period will be αQ^m (net of C_1^m) for Owner 1 and $(1-\alpha)Q^m$ for Owner 2 and Q^h (net of C_i^h) for both owners in the second period.

3. ANALYSIS AND RESULTS

In this section we analyze the game and derive the possible attained equilibria. We differentiate between two plausible scenarios: (*a*) redevelopment is exogenously imposed by the authorities; or (*b*) redevelopment is endogenously determined by the players (owners). Our focus in both scenarios is on the attained investment/no-investment in maintenance as it may be affected by the option to redevelop in the second period.

Exogenously Imposed Redevelopment

We argue:

Result 1: Provided that redevelopment is exogenously imposed, then there exists a unique perfect Nash equilibrium under which owner *i* opts for investment (no investment) in maintenance in the first period for all $C_i^m < \alpha Q^m$ ($C_i^m > \alpha Q^m$).

Proof: See Appendix.

Result 2: Provided that no-redevelopment is exogenously imposed, there exists a unique perfect Nash equilibrium under which owner *i* opts for investment (no investment) in maintenance in the first period for all $C_i^m < 2\alpha Q^m$ ($C_i^m > 2\alpha Q^m$).

Proof: See Appendix.

Result 1 (Result 2) presents the conditions under which an owner opts to either invest or not invest in maintenance in the first period, given that redevelopment (no-redevelopment) is exogenously imposed. Note that under these circumstances, each owner faces a single decision: either invest in maintenance or not. Under this base-case of the model, the intuition underlying Results 1 and 2 is immediate. Investment in maintenance occurs if its associated additional rent exceeds its cost. It thus follows from Result 1 (Result 2) that when redevelopment (no-redevelopment) is exogenously imposed, an owner's decision as to whether or not to invest in maintenance is independent of the other owner's decision regarding the same choices.

Results 1 and 2 further highlight the role of the maintenance externality in our model—namely, the greater the share of maintenance benefits that is not incurred by the owner (i.e., the smaller is α), the lesser his incentive to invest in maintenance.[13]

Following Results 1 and 2, we argue:

Result 3: Exogenously imposing redevelopment in the second period, as opposed to exogenously imposing no-redevelopment, may discourage (but never encourage) owners from investing in maintenance in the first period.

[13] Note, however, that this is not to be confused with a "free rider" phenomenon. The rent effect of an investment in maintenance by the homeowner of unit *i* splits between units *i* and *j* such that their total value remains fixed for any level of α. Therefore, when α is relatively low, the homeowner of unit *i* is *less* affected by the maintenance and, consequently, less motivated to invest in maintenance.

Proof: See Appendix.

Result 3 suggests that investing in maintenance in the first period is less attractive for owners who face redevelopment in the second period, as compared to a situation in which no-redevelopment is expected. The intuition is the following: if the structure is to be redeveloped in the second period, owners may enjoy the fruits of their investment in maintenance only in the first period. However, if no-redevelopment is imposed, then the fruits of their maintenance investment extend into the second period. Hence, redevelopment—as compared to no-redevelopment—may serve only to discourage the investment in maintenance.

Redevelopment Is Endogenously Determined

We argue:

Result 4: Allowing for endogenously determined redevelopment, as compared to imposing no-redevelopment in the second period, may sometimes discourage (but never encourage) owners from investing in maintenance in the first period.

Proof: See Appendix.

Result 4 suggests that granting a redevelopment option to the owners, rather than exogenously imposing redevelopment, may lead to no-investment in maintenance, which in turn may accelerate asset deterioration. Intuitively, as with Result 3, in cases where investment in redevelopment is supported by both owners, the increased rent that follows the investment in maintenance holds for only one period, which may discourage owners from investing in maintenance. Note that the latter is more likely to occur when the incentive to invest in maintenance is low (i.e., for low positive values of $Q^m - C_i^m$).[14]

We further argue:

Result 5: *Ceteris paribus*, the lower the level of $Rent_i$ in the first period, the more likely that investment in redevelopment will occur under any perfect Nash equilibrium.

Proof: See Appendix.

Intuitively, owners opt for redevelopment when its marginal net benefit is positive. Hence, *ceteris paribus*, the lower the rent level in the first period, the more likely that redevelopment (net of its associated cost) is profitable in the second period. Following the externality effect of one owner's investment in maintenance (or lack thereof) on the other owner's rent level, Result 5 indirectly implies that an owner may strategically use the no-investment in maintenance as a tool that affects the other owner's support in the implementation of redevelopment. Specifically, we argue:

Result 6: There exists a perfect Nash equilibrium under which Owner 2 strategically opts for no-investment in maintenance in the first period, despite its accompanied profit loss in the short run (i.e., when $C_2^m < \alpha Q^m$), in order to "persuade" Owner 1 to support redevelopment in the second period.

Proof: See Appendix.

[14] Low positive values of $Q^m - C_i^m$ are more likely, for example, in lower socio-economic and deteriorated neighborhoods (see, for example, the assumptions underlying theoretical model by Kiefer [1980]).

The intuition underlying Result 6 is as follows. Recall that we assume that $C_1^h \geq C_2^h$. Consider a situation in which the cost of investing in maintenance is relatively low for both owners; however, the cost of investing in redevelopment in the second period differs between owners. In particular, suppose that, following an investment in maintenance in the first period, the cost of investment in redevelopment is such that Owner 1 objects to, but Owner 2 supports, the investment in redevelopment. As Owner 2 cannot redevelop without Owner 1's approval, he may optimally choose to forgo the investment in maintenance, thus decreasing Owner 1's first-period rent and thereby rendering the investment in redevelopment a profitable choice for Owner 1.[15]

The redevelopment alternative under Result 6 decreases Owner 1's payoff, as compared to the case where there is no option to redevelop. It thus follows that the payoff to Owner 1—who prefers no-redevelopment—decreases in the face of endogenously determined redevelopment, even though (or, in fact, because) redevelopment requires her assent. Moreover, note that the payoffs of both owners under the equilibrium of Result 6 are smaller than their payoffs under an alternative path—one that includes both owners investing in maintenance in the first period and in redevelopment in the second—which does not sustain a Nash equilibrium under the conditions of Result 6. In that sense, the equilibrium under Result 6 is Pareto inferior. Interestingly, the superior alternative path described above would have resulted under exogenously imposed redevelopment.

Finally, it follows from the proof of Result 6 (see Appendix) that the described "strategic" no-investment in maintenance equilibrium is more likely, the lower is Owner 2's investment cost in redevelopment (C_2^h) and the greater is the maintenance externality effect (i.e., the lower is α).

[15] As shown in the proof of Result 6, this strategy of Owner 2 is effective only if the externality effect of an unmaintained unit 2 on the rent of unit 1 is sufficient to change the optimal second period action of Owner 1 from no-redevelopment to redevelopment. Note also that during the first period, the outcome for Owner 2 is negatively affected as well if he chooses to act "strategically," since he avoids investment in profitable maintenance. Therefore, Owner 2 must be better off giving up rent at the first period in return for redevelopment in the second period.

Furthermore, the equilibrium of Result 6 attains only when Owner 1's investment cost of redevelopment (C_1^h) falls "just above" the marginal rent effect that follows from redevelopment (i.e., when C_1^h is "just above" $Q^h - Q^m$). In other words, "strategic" no-investment in maintenance may be profitable for Owner 2 when Owner 1 is close to being indifferent about investing or no-investing in redevelopment. Otherwise, the externality effect would not be sufficient to change Owner 1's preferences with regard to redevelopment. The latter implies that policymakers should carefully craft the incentives for redevelopment in such a way that they compare the public cost of the incentives to the possible negative externality of accelerated deterioration.

Finally, we argue:

Result 7: There exists a perfect Nash equilibrium under which Owner 1 opts for no-investment in maintenance in the first period in order to "persuade" Owner 2 that she (i.e., Owner 1) intends to invest in redevelopment in the second period.

Proof: See Appendix.

Result 7 illustrates another possible case in which the option to invest in redevelopment may lead to strategic no-investment in maintenance in the first period. In this case, Owner 1—acting on the expectation that Owner 2 will strategically choose no-investment in maintenance (in order to "persuade" Owner 1 to invest in redevelopment, as in Result 6)—optimally chooses no-investment in maintenance. By doing so, Owner 1 turns the investment in maintenance by Owner 2 into an optimal action. Similar to the case of Result 6, the option to redevelop under Result 7 decreases both owners' payoffs (Owner 1's payoff), compared to the case in which there is an exogenously imposed redevelopment (no option to redevelop). Moreover, the payoffs of both owners under the equilibrium of Result 7 are smaller than their payoffs under an alternative path that includes owners investing in maintenance in the first period and in redevelopment in the second, actions that sustain a Nash equilibrium and would have resulted under exogenously imposed redevelopment. Hence, the equilibrium under Result 7 is again Pareto inferior.

4. Model Extension: Quality-Dependent Redevelopment Incentives Policy

Based on the model developed above, let us now consider a case wherein the owners believe that their structure may, at some probability, be subjected in the future (i.e., in the second period) to a redevelopment incentive program. In fact, from the homeowners' perspective, it is reasonable to assume that the probability of seeing future redevelopment incentives is a function of the first-period condition of the structure, where it is more probable to receive redevelopment incentives when the structure is of lower quality. To examine this case, we let p^l be the perceived probability of redevelopment incentives in the second period, when both units are of low quality; and, similarly, we let p^{ml} (p^m) be the probability of redevelopment incentives when one unit is of low quality while the other is of medium quality (both units are of medium quality).[16] This framework is depicted in Figure 2. The figure suggests that the first period is followed by an additional new stochastic step that represents the government's decision.

We then argue that:

Result 8: Provided that the probability of redevelopment incentives inversely depends on the first-period quality of the structure (such that $1 \geq p^l \geq p^{ml} \geq p^m \geq 0$; however, excluding the case where $p^l = p^{ml} = p^m$), then there exists a perfect Nash equilibrium under which *both* owners strategically opt for no-investment in maintenance in the first period—despite its short-term loss

[16] For simplicity, the analysis below assumes risk-neutral homeowners. Nevertheless, as the analysis is parametric, adjustments in the probability values can be made in order to account for risk aversion as long as there are no differences in the attitudes toward risk across owners. In addition, it should be noted that p^l, p^{ml}, and p^m are the probabilities as perceived by the owners (rather than actual probabilities).

of profits (i.e., when $C_i^m < \alpha Q^m$)—in order to increase the probability of being included in a redevelopment incentive program in the second period.

Proof: See Appendix.

Intuitively, it follows from Result 8 that if homeowners support redevelopment—and the latter is more likely when structure quality is low—then they might strategically choose to limit investment in maintenance (and "sacrifice" the associated rent loss in the first period) in order to increase the likelihood of redevelopment incentives in the second period. Following Results 6 and 7 above, both homeowners may opt for this strategy. Moreover, the higher the rent that is associated with redeveloped units and the greater the sensitivity of the probability of redevelopment incentives to the quality of the units, the greater the likelihood that both homeowners avoid maintenance, *ceteris paribus*.

The redevelopment policy under Result 8 decreases homeowners' payoff, as compared to the case in which the option to redevelop is granted to the owners regardless of the quality of the structure. From the homeowners' perspective, this is not surprising, since they are now granted an uncertain option rather than a certain one (i.e., with a non-negative value). Interestingly, however, from the government's perspective (provided that the government's policy is intended to increase the quality of the housing stock), it follows that quality-dependent redevelopment incentives might lead to an adverse outcome—namely, increased deterioration. Moreover, Result 8 further implies that, under certain circumstances, the government should require a minimum (rather than maximum) level of pre-redevelopment structure quality in order to be granted redevelopment incentives. Such a policy may attain increased pre-redevelopment quality in cases where homeowners' motivation to redevelop is anticipated.[17]

5. Discussion and Summary

In this paper, we develop a theoretical framework through which we explore the effect of redevelopment policies on the quality of existing housing stock during the pre-redevelopment period and on the likelihood of implementing redevelopment under complete information. We examine the sequential decisions to invest in maintenance and to redevelop in a game-theoretic framework, accounting for potential diverse interests of the homeowners under different conditions. We show that there exist perfect Nash equilibria under which the government's announcement of the option to redevelop may lead to a decreased investment in maintenance which, in turn, leads to deterioration of the housing stock. Moreover, the requirement of a supermajority of supporters among landlords may lead those who support redevelopment to "strategically" avoid any investment in maintenance in order to affect the rent of the objecting owners, thereby turning the redevelopment into a profitable course of action. We demonstrate that the attained equilibrium under this strategic behavior may be inefficient, as the owners' payoff is lessened when compared to off-equilibrium outcomes.

Our results carry important implications for public policy. In particular, if policymakers wish to promote redevelopment initiatives and avoid existing housing stock deterioration in the pre-redevelopment period, they should design the incentives to redevelop in such a way that they

[17] In this case, the excessive private investment in maintenance should be weighed against the social benefits from the externalities that are associated with the expected increased quality in the first period. It can be a mechanism that overcomes a possible "prisoners' dilemma" situation (say, across different buildings in the neighborhood), where each owner faces an incentive to avoid investment in maintenance, while owners are collectively better off if they all make such investment.

minimize the time that elapses between announcing the intention to redevelop and its exercise. Moreover, our analysis supports new legislation that aims to decrease the supermajority among homeowners required for promoting redevelopment, as the need for an agreement may act as a driving force for pro-redevelopment homeowners' strategic avoidance of investment in maintenance during the pre-redevelopment period. Our analysis further indicates that, in some cases, a small increase in the incentives to redevelop may prevent deterioration in the pre-redevelopment period. The latter implies that policymakers should carefully design the incentive tools used in promoting redevelopment programs.

We also show that in a situation in which the likelihood that the government will grant redevelopment incentives decreases with the quality of the structure, homeowners might strategically avoid investment in maintenance. The motivation here is to increase the likelihood of receiving governmental redevelopment incentives rather than gaining neighbors' support for redevelopment. It follows that homeowners' expectation that the government is more likely to incentivize redevelopment when the quality of the structures is poor may lead to accelerated deterioration. Governments, in turn, should be cautious about the signals that they convey to the market in this context.[18]

Finally, to the best of our knowledge, the phenomenon analyzed in this study—the increased rate of pre-redevelopment deterioration that may follow a redevelopment incentive policy—has yet to receive sufficient empirical attention. Future research should therefore empirically examine our theoretical findings. In addition, as our model results reveal a possible

[18] Wong et al. (2005), for example, find that while age negatively correlates with building performance, there are older (newer) buildings that perform well (poorly). Consequently, they suggest that policies should replace the building age cutoff criterion with a case-specific examination. In contrast, however, as shown in our analysis, case-specific examination in the framework of redevelopment policies may change the level of maintenance. The advantage of a general criterion (such as age cutoff) is that it is exogenous and cannot be changed by the owners' actions.

inefficient housing stock deterioration motivated by property-led redevelopment intervention, future research might explore whether and how the market (if operated freely) may overcome this undesirable outcome.[19] Potential paths may be inspired, for example, by the theoretical work of Coase (1960) and Varian (1994) and the findings of Geva and Rosen (2018).[20]

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[19] In this context, it should be noted that redevelopment-related issues have contributed considerably to the normative debate that pertains to regulators' intervention in the market. It has been argued that redevelopment projects facilitated through public-private partnerships (PPP), for example, have blurred the line between the regulator as a guardian of the public interest and the private entrepreneur, who serves his own interest (see, e.g., Margalit, 2014; and Sager, 2011). For a related critical view of intervention in the context of urban planning, see, e.g., Webster and Lai (2003); and Pennington (2000).

[20] It is important to note that while our model focuses on an externality effect of maintenance investment as a possible tool used by homeowners to achieve redevelopment, for ease of presentation and comprehensiveness, it ignores many related aspects, such as extended and continuous time periods, continuous maintenance choices, homeowner discretion in expediting or delaying the implementation of redevelopment, and potential investment in maintenance by renters rather than owners (see Olsen, 1988).

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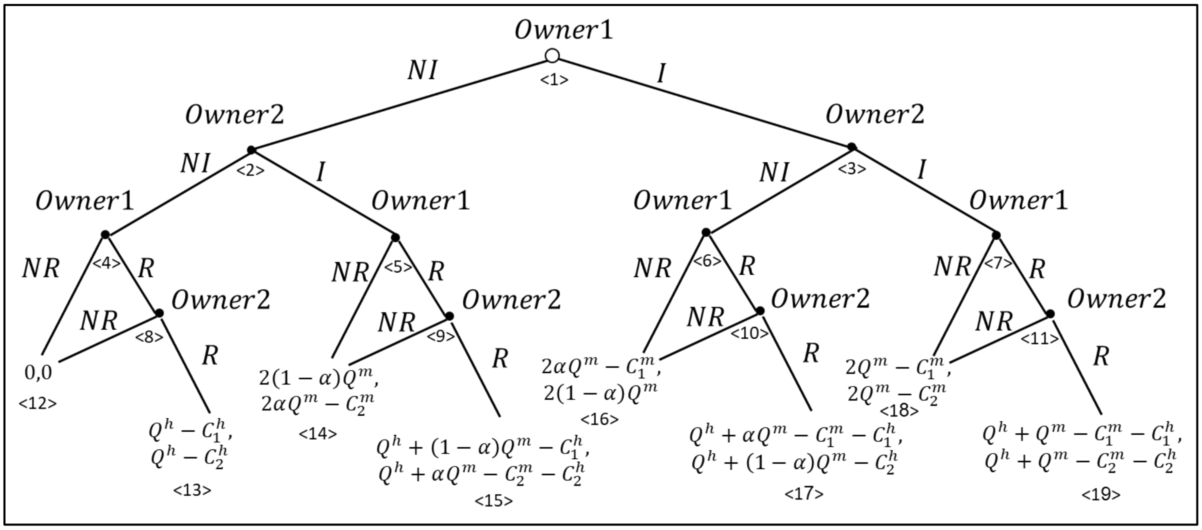
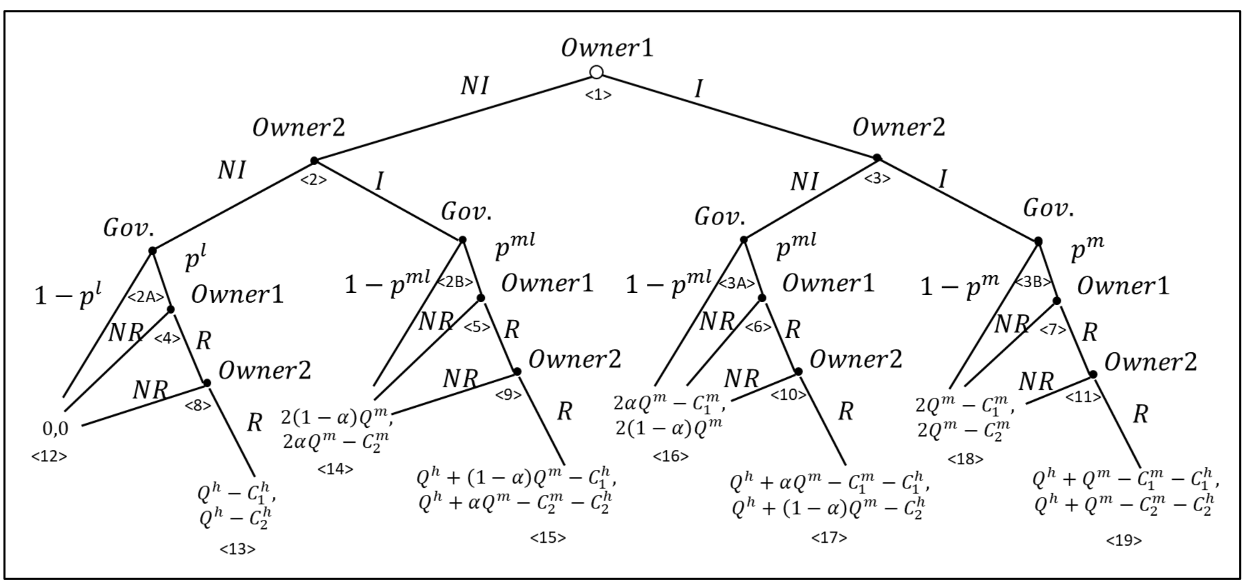
Figure 1: A Representation of the Extensive Form Game Framework



Notes: "Owner 1" and "Owner 2" indicate the player who makes a move. Each line segment corresponds to a possible action of the player, where *I* and *NI* respectively denote investment and no-investment in (first-period) maintenance, and *R* and *NR* respectively denote investment and no-investment in (second-period) redevelopment. The figures at the terminal nodes are the players' payoffs—the first (second) in each pair is the payoff of Owner 1 (2).

Figure 2: A Representation of the Extensive Form Game Framework with Quality-Dependent Incentives Policy



APPENDIX A– PROOFS AND A BACKWARD INDUCTION PROCESS

Proof of Results 1 and 2: If redevelopment is exogenously imposed on the owners, then regardless of the action of Owner 1 (see nodes <2> and <3> in Figure 1), if Owner 2 chooses *I*, his payoff increases by $\alpha Q^m - C_2^m$. Similarly, if no-redevelopment is exogenously imposed on the owners, then regardless of the action of Owner 1, if Owner 2 chooses *I*, his payoff increases by $2\alpha Q^m - C_2^m$. Hence, when redevelopment (no-redevelopment) is exogenously imposed, choosing *I* is Owner 2's dominant action if and only if $C_2^m < \alpha Q^m$ (if and only if $C_2^m < 2\alpha Q^m$); otherwise, *NI* is Owner 2's dominant strategy. Further, when redevelopment (no-redevelopment) is exogenously imposed, and given that Owner 2 follows his dominant strategy, Owner 1's payoff increases by $\alpha Q^m - C_1^m$ (by $2\alpha Q^m - C_1^m$) if she chooses *I* in the first period. Hence, choosing *I* is Owner 1's dominant action if and only if $C_1^m < \alpha Q^m$ (if and only if $C_1^m < 2\alpha Q^m$); otherwise, *NI* is Owner 1's dominant strategy □

Proof of Result 3: The condition for investment in maintenance under an exogenously imposed redevelopment ($C_i^m < \alpha Q^m$; see Result 1) is more restrictive than the condition for investment in maintenance in the absence of a redevelopment option ($C_i^m < 2\alpha Q^m$; see Result 2) □

Proof of Result 4: The backward induction process, presented in Appendix B, details the optimal choice at each node for any given set of model parameters. Specifically, Table B2 and Table B1 detail the conditions under which Owner 1 and Owner 2, respectively, opt for investing in maintenance in the first period. Recall that following Result 1, the condition for owner *i*'s investment in maintenance when no-redevelopment is exogenously imposed is $C_i^m < 2\alpha Q^m$. As can be seen, the conditions listed in Tables B1 and B2 are never less, but are sometimes more, restrictive than the condition $C_i^m < 2\alpha Q^m$. In other words, any owner who opts for no-investment in maintenance under an imposed no-redevelopment order, opts for no-investment in maintenance if redevelopment is endogenously determined. However, some owners who opt for investment in maintenance under an imposed no-redevelopment order opt for no-investment in maintenance if redevelopment is endogenously determined □

Proof of Result 5: Let $Rent_i^1$ be the first-period rent collected by owner *i*. Owner *i* therefore opts for redevelopment (*R*) if and only if $Rent_i^1 < Q^h - C_i^h$. Thus, the lower $Rent_i^1$, the more likely that owner *i* opts for *R* □

Proof of Result 6: Consider the following conditions: (1) $Q^h - \alpha Q^m > C_1^h > Q^h - Q^m$; (2) $C_2^h < Q^h - Q^m$; (3) $C_1^m < (2\alpha - 1)Q^m$; (4) $C_2^m < \alpha Q^m$; and (5) $C_2^m < (\alpha + 1)Q^m - Q^h + C_2^h$. Under these conditions, according to the backward induction (see Appendix), Owner 2 at node <3> (node <2>) chooses between terminal nodes <17> and <18> (<15> and <13>), where $P_2^{17} > P_2^{18}$ $(P_2^{15} > P_2^{13})$.[21] He therefore opts for *NI* at node <3> (opts for *I* at node <2>). Accordingly, Owner 1 at node <1> chooses between terminal nodes <17> and <15>, where $P_2^{17} > P_2^{15}$. She therefore opts for *I* at node <1>. Note that in this case C_2^m is low enough for maintenance to be profitable for Owner 2, given exogenous implementation (or no implementation) of redevelopment. Yet by opting for *NI*, he reduces the rent of both units, and redevelopment thus becomes profitable for Owner 1□

Proof of Result 7: Consider the following conditions: (1) $Q^h - (1-\alpha)Q^m > C_1^h > Q^h - Q^m$; (2) $C_2^h < Q^h - Q^m$; (3) $C_1^m > (2\alpha - 1)Q^m$; (4) $C_2^m < \alpha Q^m$; and (5) $C_2^m > (\alpha + 1)Q^m - Q^h + C_2^h$. Under these conditions, according to the backward induction (see Appendix B), Owner 2 at node <3> (node <2>) chooses between terminal nodes <17> and <18> (<15> and <13>), where $P_2^{17} > P_2^{18}$ $(P_2^{15} > P_2^{13})$. He therefore opts for *NI* at node <3> (*I* at node <2>). Owner 1 at node <1>

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[21] P_i^k represents the payoff for owner *i* at terminal node *k*.

accordingly chooses between terminal nodes <17> and <15>, where $P_2^{15} > P_2^{17}$. She therefore opts for *NI* at node <1>. Note that in this case C_1^m is low enough for maintenance to be profitable for Owner 1, given the implementation of redevelopment. Yet by opting for *NI*, she assures Owner 2 that she will choose *R*, which in turn allows him to invest in maintenance □

Proof of Result 8: Consider the following conditions: (1) both owners have identical parameters such that $C_1^h = C_2^h = C^h$ and $C_1^m = C_2^m = C^m$; (2) $C^m < \alpha Q^m$; (3) $p^{ml} = p^m$; (4) $(p^l - p^m)\,(Q^h - C^h) > (1 + p^m)Q^m - C^m$. Under these conditions, given the opportunity, both owners opt for redevelopment in the second period. Nevertheless, their likelihood to receive the opportunity decreases if any of them opt for investing in maintenance. According to the backward induction (see Appendix B), Owner 2 at node <2> (node <3>) chooses between nodes <2A> and <2B> (<3A> and <3B>), where the payoff expectancy that follows investment is smaller (is larger) than the payoff expectancy that follows no-investment. He therefore opts for *NI* at node <2> (*I* at node <3>). Owner 1 at node <1> accordingly chooses between nodes <3B> and <2A>, where his payoff expectancy that follows investment is smaller than the payoff expectancy that follows no-investment. She therefore opts for *NI* at node <1>. Note that in this case C_1^m and C_2^m are low enough for maintenance to be profitable for both owners, given the implementation of redevelopment. Yet they both opt in equilibrium for *NI*, due to the associated increased likelihood for redevelopment □

APPENDIX B– A BACKWARD INDUCTION PROCESS

Owner 2's optimal action at nodes <8> through <11>:

- Node <11>

Owner 2 opts for *R* if $Q^h - C_2^h > Q^m$; otherwise he opts for *NR*

- Node <10>
  Owner 2 opts for *R* if $Q^h - C_2^h > (1-\alpha)Q^m$; otherwise he opts for *NR*
- Node <9>
  Owner 2 opts for *R* if $Q^h - C_2^h > \alpha Q^m$; otherwise he opts for *NR*
- Node <8>
  Owner 2 opts for *R* if $Q^h - C_2^h > 0$; otherwise he opts for *NR*

Owner 1's optimal action at nodes <4> through <7>:

- Node <7>
  Owner 1 opts for *R* if $Q^h - C_1^h > Q^m$; otherwise she opts for *NR*
- Node <6>
  Owner 1 opts for *R* if $Q^h - C_1^h > \alpha Q^m$; otherwise she opts for *NR*
- Node <5>
  Owner 1 opts for *R* if $Q^h - C_1^h > (1-\alpha)Q^m$; otherwise she opts for *NR*
- Node <4>
  Owner 1 opts for *R* if $Q^h - C_1^h > 0$; otherwise she opts for *NR*

Owner 2's optimal action at nodes <2> and <3>:

- Nodes <2> and <3>
  The backward induction process conducted above for the second period sub-game leads Owner 2 to essentially choose between 2 payoffs as he chooses *I* and *NI* at node <3> (node <2>). Table B1 below lists all possible outcome combinations and the conditions under which Owner 2 optimally opts for *I*. The shaded cells in the table indicate that no set of model parameters can lead Owner 2 to choose between these two alternative payoffs (given the analysis above); the values in gray correspond to the quality-dependent redevelopment incentives policy described in Section 4 and in Figure 2. The table suggests that, given that the strategy of both owners in all the following nodes is *R*, Owner 2 opts for *I* at node <3> (<2>) only if $C_2^m < \alpha Q^m$; if the strategy of at least one owner is *NR*, regardless of his current choice, Owner 2 opts for *I* only if $C^m < 2\alpha Q^m$. Finally, otherwise (i.e., when implementation of redevelopment depends on his choice), Owner 2 opts for *I* only if $C_2^m < (1+\alpha)Q^m - Q^h + C_2^h$ (only if $C_2^m < 2\alpha Q^m - Q^h + C_2^h$).

Table B1: Conditions for Owner 2 to Opt for *I* Given the Relevant Terminal Node Couplet

Node <3> action	NI		
I	terminal node and the relevant conditions	<16> $C_1^h > Q^h - \alpha Q^m$ or $C_2^h > Q^h - (1-\alpha)Q^m$	<17> $C_1^h < Q^h - \alpha Q^m$ and $C_2^h < Q^h - (1-\alpha)Q^m$
	<18> $\max(C_2^h, C_1^h) > Q^h - Q^m$	$2\alpha Q^m > C_2^m$ $2\alpha Q^m > C_2^m$	$(\alpha+1)Q^m - Q^h + C_2^h > C_2^m$ $p^{ml}(C_2^h - Q^h + Q^m - Q^m\alpha) + 2\alpha Q^m > C_2^m$
	<19> $\max(C_2^h, C_1^h) < Q^h - Q^m$	$Q^h + (2\alpha - 1)Q^m - C_2^h > C_2^m$	$\alpha Q^m > C_2^m$ $(p^{ml} - p^m)(C_2^h - Q^h + Q^m) - p^{ml}\alpha Q^m + 2\alpha Q^m > C_2^m$

Node <2> action	NI		
I	terminal node and the relevant conditions	<12> $\max(C_2^h, C_1^h) > Q^h$	<13> $\max(C_2^h, C_1^h) < Q^h$
	<14> $C_1^h > Q^h - (1-\alpha)Q^m$ or $C_2^h > Q^h - \alpha Q^m$	$2\alpha Q^m > C_2^m$ $2\alpha Q^m > C_2^m$	$2\alpha Q^m - Q^h + C_2^h > C_2^m$ $2\alpha Q^m - p^l(Q^h - C_2^h) > C_2^m$

	<15> $C_1^h < Q^h - (1-\alpha)Q^m$ and $C_2^h < Q^h - \alpha Q^m$	$Q^h + \alpha Q^m - C_2^h > C_2^m$	$\alpha Q^m > C_2^m$ $2\alpha Q^m - p^{ml}\alpha Q^m + (p^{ml} - p^l)(Q^h - C_2^h) > C_2^m$

Owner 1's optimal action at node <1>:

- Node <1>
  The backward induction process above leads Owner 1 to essentially choose between two payoffs as she chooses *I* and *NI* at node <1>. Table B2 below lists all possible outcome combinations, and the conditions under which Owner 1 optimally opts for *I*. Shaded cells in the table indicate that no set of model parameters can lead Owner 1 to choose between these two alternative payoffs (given the analysis above). Note that all the conditions listed in Table B2 for Owner 1 to opt for *I* are at least as restrictive as $2Q^m > C_1^m$. In other words, when $2Q^m < C_1^m$, Owner 1's optimal action at node <1> is *NI*. Results further suggest that there is no (non-negative) value of C_1^m under which Owner 1 optimally opts for I without further conditions.

Table B2: Conditions for Owner 1 to Opt for *I* Given the Relevant Terminal Node Couplet

Node <1> action	NI				
	terminal node	<12>	<13>	<14>	<15>
I	<16>	$2\alpha Q^m > C_1^m$ $2\alpha Q^m > C_1^m$	$2\alpha Q^m - Q^h + C_1^h > C_1^m$ $2\alpha Q^m - p^l(Q^h - C_1^h) > C_1^m$	$(4\alpha - 2)Q^m > C_1^m$ $(4\alpha - 2)Q^m > C_1^m$	$(3\alpha - 1)Q^m - Q^h + C_1^h > C_1^m$ $(4 - 2\alpha)Q^m - p^{ml}(Q^h - C_1^h - (1-\alpha)Q^m) < C_1^m$
	<17>	$Q^h + \alpha Q^m - C_1^h > C_1^m$	$\alpha Q^m > C_1^m$ $2\alpha Q^m - p^{ml}\alpha Q^m + (p^{ml} - p^l)(Q^h - C_1^h) > C_1^m$	$Q^h + (3\alpha - 2)Q^m - C_1^h > C_1^m$ $(4\alpha - 2)Q^m + p^{ml}(Q^h - C_1^h - \alpha Q^m) > C_1^m$	$(2\alpha - 1)Q^m > C_1^m$ $(4\alpha - 2)Q^m + p^{ml}(1 - 2\alpha)Q^m > C_1^m$
	<18>	$2Q^m > C_1^m$ $2Q^m > C_1^m$	$2Q^m - Q^h + C_1^h > C_1^m$ $2Q^m - p^l(Q^h - C_1^h) > C_1^m$	$2\alpha Q^m > C_1^m$ $2\alpha Q^m > C_1^m$	$(\alpha + 1)Q^m - Q^h + C_1^h > C_1^m$ $p^{ml}(C_1^h - Q^h + Q^m - Q^m\alpha) + 2\alpha Q^m > C_1^m$

	<19>	$Q^h + Q^m - C_1^h > C_1^m$	$Q^m > C_1^m$ $2Q^m + (p^m - p^l)(Q^h - C_1^h) - Q^m P^m > C_1^m$	$Q^h + (2\alpha - 1)Q^m - C_1^h > C_1^m$	$\alpha Q^m > C_1^m$ $(p^{ml} - p^m)(C_1^h - Q^h + Q^m) - p^{ml}\alpha Q^m + 2\alpha Q^m > C_1^m$