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ABSTRACT

Using data compiled from concentrated residential urban revitalization programs implemented in Richmond, VA, between 1999 and 2004, we study residential externalities. Specifically, we provide evidence that in neighborhoods targeted by the programs, sites that did not directly benefit from capital improvements nevertheless experienced considerable increases in land value relative to similar sites in a control neighborhood. Within the targeted neighborhoods, increases in land value are consistent with externalities that fall exponentially with distance. In particular, we estimate that housing externalities decrease by half approximately every 990 feet. On average, land prices in neighborhoods targeted for revitalization rose by 2 to 5 percent at an annual rate above those in the control neighborhood. These increases translate into land value gains of between \$2 and \$6 per dollar invested in the program over a six-year period. We provide a simple theory that helps us interpret and estimate these effects.

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1 Introduction

The existence of cities is a manifestation of the presence of agglomeration forces between economic agents. While much has been written about the nature and characteristics of these forces, most studies have focused on agglomeration forces between producers. As a result, virtually all urban theories have these producer-based agglomeration economies at their core.[1] In fact, agglomeration effects can also result from interactions between residents. Specifically, they can take the form of housing externalities whereby improvements made to a particular house can have an effect on the value of nearby houses. To the extent that these effects decline with distance, this form of externalities can lead to the agglomeration of residents and, potentially, the formation of cities. Moreover, because the presence of housing externalities may justify government intervention, in that equilibrium allocations will differ from efficient outcomes, assessing the importance of these externalities in practice is central to urban policy. In this paper, therefore, we study the magnitude and characteristics of housing externalities. We are interested in the effects of housing externalities on average land prices and in how fast these effects decline with distance. These are the key characteristics that lead to agglomeration.

The standard problem in measuring agglomeration effects lies in the circular causation present in all spatial concentrations of economic activity. People and firms locate in a specific area because that area is particularly productive or pleasant to live in, but the area is particularly productive or pleasant to live in because others chose to reside or work at that location. This implies that identifying agglomeration effects in the data requires an exogenous source of variation in the "attractiveness" of a given location. In this paper, we exploit such a source of variation by taking advantage of an urban revitalization program implemented in Richmond, Virginia, between 1999 and 2004: the Neighborhoods-in-Bloom (NiB) program. We describe the program and its associated policies in detail in Section 2. For now, we note that this program represented federally funded housing investments concentrated in a few disadvantaged neighborhoods. We know the location of homes that obtained direct funding, and the amount that was received. We also have information on housing prices and a comprehensive list of housing characteristics before and after the program was implemented. This information allows us, using a hedonic regression, to estimate land prices before and after the policy was implemented. Taking into account city-wide time effects, we can calculate the effects of the program in the various treated neighborhoods. Put another way, we estimate the effects of the policy on land values controlling for investments

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[1] See the theoretical survey in Duranton and Puga (2004) and the empirical survey in Rosenthal and Strange (2004).

in observable housing characteristics. By carrying out this exercise only for houses that were not directly targeted by the Neighborhoods-in-Bloom program, we ensure that the effects we measure are not the valuation of unobservable investments directly associated with its policies.

We estimate changes in land prices, following the Neighborhoods-in-Bloom program, that are consistent with the predictions of a simple theory of housing externalities. We present this theory in Section 3. In particular, increases in the returns to land decline with distance from the impact area. This effect, which we measure nonparametrically in the data, emerges clearly and corresponds to housing externalities that decline by half approximately every 990 feet. The theory also has predictions for the magnitude of the effects induced by the Neighborhoods-in-Bloom policies that are consistent with our measurements. Finally, we use the findings from our estimation exercise to obtain parameter values for our model. This step potentially allows the model to guide the design of urban policies, although we leave this task to future research.

The exercise we have just described does not directly allow us to make statements regarding the total return to land associated with the Neighborhood-in-Bloom program. We are able to assess whether changes in land prices are consistent with housing externalities that decline with distance, and how fast they decline, but additional information is needed to draw conclusions regarding the average increase in land values associated with these external effects. We use time effects at the city level to control for any city-wide changes and, potentially, general equilibrium effects induced by the Neighborhood-in-Bloom policies. That said, as indicated in Section 2, the magnitudes of these policies are generally small enough that they are unlikely to affect land rents in the city as a whole. In order to identify the effects of the revitalization policies that arise by way of housing externalities, one needs to take a stand on the scope of these externalities, and measure increases in land values over and above those at the boundary of a selected neighborhood. This is, in principle, problematic since we have little information regarding the scope of housing externalities, nor do we know whether other non-observables might have affected land values at the boundaries of the neighborhoods under consideration. Fortunately, a key feature of Neighborhoods-in-Bloom offers us an alternative approach.

One of the unique aspects of the study we carry out in this paper relates to the presence of a neighborhood that shares almost identical physical and demographic characteristics as those selected for urban revitalization. Although initially considered by the Neighborhoods-in-Bloom task force, this neighborhood did not ultimately receive funding for reasons that were secondary and non-economic in nature. Hence, we use it as a control with which to contrast our findings for neighborhoods explicitly targeted by the urban renewal program.

Two key results emerge: i) in contrast to the treated neighborhoods, our estimates of changes in land rents in the control neighborhood do not fall with distance as we move away from its centroid. This result is consistent with the idea that one cannot measure changes in land valuations resulting from housing externalities in the absence of an exogenous source of variation in land prices, ii) we compute average land price increases in the control neighborhood and show that they fall significantly short of those measured in the targeted neighborhoods. We then use the findings associated with the control neighborhood to infer increases in land values arising from externalities induced by the revitalization policies. We find land value gains in the targeted neighborhoods that range between \$2 and \$6 per dollar invested in the program over a six-year period.

To the best of our knowledge, there have been only few studies of housing externalities that rely on a policy experiment with individual housing transaction data, and none where the experiment was spatially concentrated to the degree of Neighborhoods-in-Bloom. In Section 5, we compare our findings with other work that exploit parametric approaches to measure the decline in externalities across space. In general, we find housing externalities that decrease somewhat slower with distance. Ioannides (2002) finds important residential neighborhood effects using neighborhood clusters in U.S. cities. These neighborhood effects, which have received some theoretical and empirical attention in the literature, are broader than the housing externalities considered in this paper as they include other forms of social interactions. See for example Benabou (1996) for an insightful theoretical model describing these types of social interactions and their effects. There are several studies, both theoretical and empirical, that have analyzed urban renewal projects. Davis and Whinston (1961), Rothenberg (1967), and Schall (1976) are notable early examples. None, however, include the type of detailed empirical work we perform in this paper. On a theoretical level, Strange (1992) provides an informative discussion of policy in the presence of strong interactions across neighborhoods.[2]

The rest of the paper is organized as follows. Section 2 describes the Neighborhoods-in-Bloom program. Section 3 presents the model and the effects of housing subsidies on equilibrium outcomes. Section 4 discusses our empirical methodology and Section 5 presents our findings. Section 6 offers concluding remarks.

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[2] Durlauf (2004) provides a survey of the literature on neighborhood effects.

2 The Neighborhoods-in-Bloom Urban Revitalization Program

The Neighborhoods-in-Bloom (NiB) program was an outgrowth of the observation by Richmond city officials that during the previous 25 years, investment programs undertaken to revitalize areas within the city had demonstrated only limited success. They noted that the programs had often improved small areas–such as a city block– but in many instances, measurable improvement in the surrounding neighborhoods remained elusive.

In evaluating the features of previous programs, officials noted that investment activity— in most cases using federal funding sources– had often been targeted in a scattered fashion. This approach had the advantage of reaching a large number of city neighborhoods that qualified under federal guidelines, but available funding per area was necessarily limited. The resulting constraints on investment activity led to impacts on home prices in surrounding areas that were difficult to gauge. Because city officials' objective was to visibly raise the values of surrounding homes, an idea developed that investment concentrated in fewer areas might yield more measurable effects. This approach, they reasoned, might lead to a more noticeable revitalization of the city's housing stock than had the previous, more scattered approach.

To carry out this experiment, city officials began to identify potential areas for investment, determine the number of sites to target and source funding. As had historically been the case, the City of Richmond had numerous areas that qualified for revitalization funding through the Department of Housing and Development's (HUD) Community Development Block Grant (CDBG) and Home Investment Partnership (HOME) programs. Additional funding was made available through other federal monies as well as through the non profit Local Initiatives Support Corporation (LISC), a community development corporation (CDC). The CDBG and HOME funding was attractive to the city, in part, because it was outside money. Simply put, these funds come from the federal government, and the resulting investments benefit the city without reducing local spending on consumption or investment that would otherwise occur if the funds were raised through local taxes. Interestingly, LISC funding also has this advantage. Founded by the Ford Foundation, LISC is a national organization headquartered in New York and is funded by nationwide donations. Because of this structure, funds that flow from the organization to Richmond are effectively exogenous as well in that they do not necessarily originate from local sources.

The selection process of investment sites was a multiple step process. Past scattered approaches to investment had been driven in part by political pressures to fund areas within nearly all city council members' districts. Aware that a more concentrated approach would likely fund fewer sites than the number of districts, broad support of a small number of sites was a primary objective. To achieve that support, in mid 1998, Richmond administrators established an internal planning task force composed of the acting city manager, the assistant city manager, and representatives from a variety of city departments associated with housing and economic development. Several members within the group developed indicators of neighborhood conditions and data that served as comparative portraits of the neighborhoods that qualified to receive CDBG or HOME funds. Throughout 1998 and into early 1999, staff from the city's Community Development Department met with community groups to explain and gather feedback on the approach. In particular, city staff and members of the groups also toured the potential sites, and support for both the concept and for a small group of neighborhoods had come together by February 1999. Later that year, the city community development department recommended four broad neighborhoods. These were Church Hill Central, Southern Barton Heights-Highland Park-Southern Tip, Jackson Ward-Carver, and Blackwell. The locations and size of these neighborhoods relative to the city of Richmond are shown in Figure 1.

Table 1A. Demographics of selected neighborhoods

Neighborhood	Total Persons	Housing Units	Percent Non-White	Percent Below Poverty
Church Hill	1505	822	94.8	27.2
Blackwell	1376	651	97.0	35.8
Highland Park-Barton	2763	1227	97.2	26.3
Jackson Ward-Carver	1975	1332	81.7	29.5
Bellemeade	2742	947	90.2	31.6
City of Richmond	197790	92282	61.5	20.3

These four neighborhoods share many common characteristics. All had been selected according to criteria developed by the city's community development staff and had concentrations of vacant structures, substantial poverty, and low home ownership rates. In addition, the capacity of the areas to revitalize absent NiB investment was viewed as low. The neighborhoods also had active nonprofit Community Development Corporations (CDCs) in place. This was an important feature in that funds from the HUD programs are generally disbursed through these organizations which perform new home construction, rehabilitation, and renovations that comprise the vast majority of investment activity in the neighborhoods. Although the selected NiB neighborhoods share many similarities, one important distinction must be made in that Blackwell was subject to an additional urban program, known as HOPE VI, alongside NiB. HOPE VI was a program designed to raze unfit homes, without at the time creating new construction in their place. Tables 1A and 1B provide a summary of basic demographic and housing characteristics of the selected neighborhoods using the 2000 census and our housing data before the start of the program in 1998.

Table 1B. Characteristics of the housing stock in NiB neighborhoods

Neighborhood	Percent Vacant	Percent Owned	Average Plot Acreage	Median Price^a	Price St. Dev.
Church Hill	21.7	35.7	0.07	14,861	29,244
Blackwell	23.2	32.6	0.09	17,368	16,705
Highland Park-Barton	18.3	40.5	0.14	33,223	24,740
Jackson Ward-Carver	31.5	36.0	0.06	37,914	46,548
Bellemeade	10.8	51.4	0.16	33,881	15,643
City of Richmond	8.4	46.1	0.17	74,394	121,539

a : expressed in 2000 constant dollars

As shown in Figure 1, the selected neighborhoods all fall in the eastern part of the city and share a heritage dating to Richmond's origins. The city was founded because of its location at the fall line of the James River, the farthest inland point navigable to ship traffic. Early development began in this area, but as factories emerged, the neighborhoods in the eastern portion of the city gradually fell into disfavor and declined over time. This process led to changes in the demographic makeup of these areas, with higher poverty rates and lower average home prices, as well as higher percentages of crime relative to citywide averages. Aside from their similarities in terms of demographics, homes in the selected neighborhoods, because of their historical ties, also share many elements of style and construction. In particular, homes in all selected areas consist mostly of row houses of similar sizes, many constructed of brick. A slight exception is Blackwell and Highland Park, where some homes are of detached Queen Anne and Victorian styles.

With funding sources in place and neighborhoods identified, NiB began operations in July 1999. Prior to start up, teams were formed comprised of city staffers, community group representatives, and CDC representatives to review neighborhood redevelopment plans, identify precise boundaries of investment, known as "impact areas", and identify specific homes for renovation and sites for new home construction. Once specific home projects within individual impact areas were determined, the CDCs operating in those areas applied for funds to carry out the projects. Nearly all investment activity consisted of acquisition, demolition, rehabilitation, and new construction of housing within NiB impact areas. The work carried out by the various CDCs varied in impact, reflecting in part the comparative strengths of individual organizations, in that specific CDCs had unique relationships with their home neighborhoods and specialized experience in some categories of construction or rehabilitation.

Spending under the NiB program began in 1999 (although a small fraction preceded the official start date of the program) and continued through 2004. Over this period, approximately \$14 million was spent in total. Slightly over \$11 million came through CDBG and HOME programs, smaller federal programs and Commonwealth of Virginia monies. LISC added nearly \$3 million. Around \$1 million came from other sources, with approximately half that amount from undocumented sources. Most of the spending took place in the 1999 through 2001 period, with yearly expenditures trailing off in the later years of the program.

Finally, one of the unique aspects of the study we carry out in this paper relates to the presence of a neighborhood that was almost included in the NiB program but that did not, ultimately, received funding. Specifically, the neighborhood of Bellemeade lies in the eastern portion of the city, south of the James River (see Figure 1). Its makeup and location are typical of NiB neighborhoods and, according to a former city official closely involved with the NiB selection process, "absolutely matched" the selected neighborhoods in physical and demographic terms. This is in fact also clear from Tables 1A and 1B. The reason that Bellemeade did not make the final cut, he suggests, is that the area did not have active enough CDCs, so that the channel used to direct NiB investment dollars was mostly absent. This distinction, however, makes Bellemeade close to an ideal control neighborhood. In particular, because no NiB investment took place in that neighborhood, and given that its demographics and housings stock closely match that of the selected NiB neighborhoods, it is natural to use Bellemeade as a benchmark in gauging changes in neighborhood land values arising from the NiB program.[3]

3 A Model of Housing Externalities

This section provides a framework that offers insight into the types of urban renewal policies we have just described. More importantly, it helps underscore the importance of housing externalities in determining the effects of these revitalization policies. Consider a neighborhood represented by $\mathcal{N} = [-R, R]$, where R denotes the neighborhood's edge, with density of land

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[3] A question remains as to why there were fewer CDC's in Bellemeade than in the other neighborhoods in the first place, which potentially indicates a lingering selection issue. The results presented in Section 5, however, suggest that this concern is limited.

equal to one. All agents living in the neighborhood work at location 0.[4] We assume that all agents are endowed with one unit of time, and that some of this time is spent commuting to work. Thus, an agent commuting from location $\ell \in \mathcal{N}$ only works $e^{-\tau|\ell|}$ time units, $\tau > 0$. The production technology is linear, and transforms one unit of time into w units of a final good.

Agents' preferences are defined over housing services enjoyed at a given location, denoted by $\widetilde{H}(\ell)$ for an agent living at ℓ, and other types of consumption, $c(\ell)$. The only good in the economy can be allocated to either investment in housing or consumption. All agents live on a lot of size one, which they rent from absentee landlords at rate $q(\ell)$. Housing services at a location are obtained from owning a piece of land and directly improving it, as well as from the amount of housing services produced nearby. The fact that housing services produced at a given location affect housing services enjoyed elsewhere defines a housing externality. Formally, if $H(\ell)$ denotes investments in housing undertaken by an individual living at ℓ, then

$$\widetilde{H}(\ell) = \delta \int_{-R}^{R} e^{-\delta|\ell - s|} H(s) ds + H(\ell). \tag{1}$$

Hence, aside from home improvements they make at a given location, individuals also benefit from having nearby housing owned by others that is well-maintained. In particular, housing services enjoyed at location ℓ reflect in part a weighted average of housing services produced at neighboring sites, with weights that decline with distance at an exponential rate $\delta > 0$.

Agents living at location ℓ spend their income, $we^{-\tau|\ell|}$, on the unit of land they rent at rate $q(\ell)$, housing investments, $H(\ell)$, and consumption, $c(\ell)$. We assume that individuals order consumption baskets according to a Cobb-Douglas utility function. Hence, an agent living at some location ℓ solves

$$\max_{c(\ell),\, H(\ell)} u(c(\ell), \widetilde{H}(\ell)) = c(\ell)^{\alpha} \widetilde{H}(\ell)^{1-\alpha}, \;\; 0 < \alpha < 1, \tag{P$_\ell$}$$

subject to

$$c(\ell) + q(\ell) + H(\ell) = we^{-\tau|\ell|}, \tag{2}$$

and

$$\widetilde{H}(\ell) = \delta \int_{-R}^{R} e^{-\delta|\ell - s|} H(s) ds + H(\ell),$$

where housing services produced at other locations, $H(s)$, are taken as given. The optimality conditions associated with problem (P$_\ell$) imply that

$$(1 - \alpha) c(\ell) = \alpha \widetilde{H}(\ell). \tag{3}$$

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[4] This simplifying assumption ensures symmetry but is otherwise unimportant for the questions we shall be asking.

Substituting this condition into the agent's budget constraint (2), and using the equation describing the externality from housing (1), immediately yields an expression for housing services obtained at ℓ that depends only on prices and housing services produced elsewhere,

$$\widetilde{H}(\ell) = (1-\alpha)\left\{ we^{-\tau|\ell|} - q(\ell) + \delta \int_{-R}^{R} e^{-\delta|\ell-s|} H(s)ds \right\}. \tag{4}$$

3.1 The Neighborhood Equilibrium

There are two key conditions that determine equilibrium allocations in the neighborhood. First, all agents are identical and can choose freely where to live, including in another neighborhood if their utility falls below some reservation utility, $\overline{u}$. In equilibrium, therefore, individuals obtain utility $\overline{u}$ at all locations, which immediately implies that

$$\widetilde{H}(\ell) \equiv \overline{H} = \overline{u}\left(\frac{1-\alpha}{\alpha}\right)^{\alpha}. \tag{5}$$

That is, housing services enjoyed at any location are the same throughout the neighborhood. It follows from Equation (1) that the function describing housing investments at different sites is a fixed point of the following functional equation,

$$H(\ell) = \overline{H} - \delta \int_{-R}^{R} e^{-\delta|\ell-s|} H(s)ds, \quad \ell \in [-R, R]. \tag{6}$$

The second condition needed to determine equilibrium allocations involves a boundary condition for land rents at either edge of the neighborhood, which we denote by $q_R > 0$. From equations (4) and (5), land rents in the neighborhood are given by

$$q(\ell) = we^{-\tau|\ell|} + \delta \int_{-R}^{R} e^{-\delta|\ell-s|} H(s)ds - \frac{1}{1-\alpha}\overline{H}. \tag{7}$$

At the boundary, therefore, we have that R implicitly solves

$$\delta \int_{-R}^{R} e^{-\delta|\ell-s|} H(s)ds = \frac{1}{1-\alpha}\overline{H} + q_R - we^{-\tau R}. \tag{8}$$

To summarize, an equilibrium for the neighborhood is a function describing housing investments at all locations, $H(\ell)$, a function describing land rents, $q(\ell)$, a level of housing services $\overline{H}$, and a boundary for the neighborhood, R, such that equations (5), (6), (7) and (8) are satisfied.

The solid curves in Figure 2A and 2B depict typical equilibrium housing investment allocations, $H(\ell)$, and land rents, $q(\ell)$, respectively.[5] Housing investments are highest near

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[5] The parameter values used in this example are: $\overline{u} = 13.25$, $\delta = 0.001$, $R = 3500$, $A = 1190$, $\sigma = 0.368$, $w = 25$, $\alpha = 0.6$, and $\tau = 0.00001$.

the boundaries of the neighborhood where externalities from housing are lowest. With lower externalities from housing at locations away from the neighborhood center, individuals living at those locations must spend a greater share of their income on direct home improvements in order to obtain the constant level of housing services $\overline{H}$. The fact that housing externalities are lowest near the neighborhood boundaries also implies that land rents are lowest at those locations. On a more practical level, observe in Figure 1 that the highlighted neighborhoods are indeed often bounded by major roads, such as interstates or highways, and other landmarks that effectively reduce externalities from housing potentially located outside those boundaries. The neighborhood of Blackwell, for instance, is bounded by highways to the west, north, and east, as well as by an industrial railway station in part to the south. Similarly, the neighborhood of Jackson Ward-Carver is bounded by Interstate 64 to the north and Highway 250 to the south, and adjoins an industrial zone to the east. Although not bounded by main roads, the land surrounding Highland Park-South Barton Heights is largely free of housing, composed of a large cemetery to the south, warehouses to the west, and vacant grounds to the east and north.

3.2 The Neighborhoods-in-Bloom Program

Consider a federally funded neighborhood revitalization program that aims to increase housing investments at all locations in an area $\mathcal{A} = [-r, r] \subseteq \mathcal{N}$ by some fixed amount $\sigma > 0$. Throughout the paper, we refer to $\mathcal{A}$ as an 'impact area.' Let $H_p(\ell)$ denote the new equilibrium housing investment function that emerges after implementation of the policy. Similarly, let $\widetilde{H}_p(\ell)$ describe housing services enjoyed at location ℓ following the program. Because the reservation utility from living in some other neighborhood is unchanged, and agents can freely move between neighborhoods, housing services are still given by Equation (5) so that $\widetilde{H}_p(\ell) = \overline{H}$. Then, for $\ell \in \mathcal{N} \backslash \mathcal{A}$, $H_p(\ell)$ solves

$$\overline{H} = H_p(\ell) + \delta \int_{-R}^{R} e^{-\delta|\ell-s|} H_p(s)ds + \sigma\delta \int_{-r}^{r} e^{-\delta|\ell-s|}ds, \tag{9}$$

where the last term in (9) captures externalities generated by the program and obtained at a location outside the impact area. For locations $\ell \in \mathcal{A}$ that are directly affected by the revitalization policy, we have that

$$\overline{H} = H_p(\ell) + \delta \int_{-R}^{R} e^{-\delta|\ell-s|} H_p(s)ds + \sigma \left(\delta \int_{-r}^{r} e^{-\delta|\ell-s|}ds + 1 \right), \tag{10}$$

where the last term now reflects the fact that those locations are also the direct recipients of capital improvements σ.

Since $\overline{H}$ remains unchanged following the urban development program, it follows that $H(\ell)_p - H(\ell) < 0$ for all $\ell \in [-R, R]$. To see this, note from equations (6) and (9), and abstracting from the direct subsidy, that for $\ell \in \mathcal{N} \backslash \mathcal{A}$,

$$\begin{aligned} H(\ell)_p - H(\ell) &= -\delta \int_{-R}^{R} e^{-\delta|\ell - s|} \left[H_p(s) - H(s)\right] ds - \sigma\delta \int_{-r}^{r} e^{-\delta|\ell-s|} ds \\ &= \sigma\delta \Big\{ -\int_{-r}^{r} e^{-\delta|\ell-s|} ds + \delta \int_{-R}^{R} e^{-\delta|\ell-j|} \int_{-r}^{r} e^{-\delta|j-s|} ds dj \\ &\quad -\delta^2 \int_{-R}^{R} e^{-\delta|\ell-j|} \int_{-R}^{R} e^{-\delta|j-k|} \int_{-r}^{r} e^{-\delta|k-s|} ds dk dj + \ldots \Big\} \\ &< 0 \end{aligned} \tag{11}$$

since

$$\delta \int_{-R}^{R} e^{-\delta|\ell-s|} ds = \delta \int_{0}^{2R} e^{-\delta s} ds = -\left. e^{-\delta s} \right|_0^{2R} = 1 - e^{-\delta 2R} < 1,$$

so that $\int_{-r}^{r} e^{-\delta|j-s|} ds < 1$ as well. The direct effect of subsidies, of course, only serves to amplify this effect in the impact area. Put another way, Equation (11) implies that investment in housing decreases everywhere in the neighborhood, and this decrease is more pronounced the closer the locations are to the impact area. In this framework, therefore, the neighborhood revitalization program crowds out private investment in housing. The subsidy to home improvements in effect allows agents to enjoy housing services without having to spend on those services themselves. The implied relaxation of their budget constraint leads individuals to bid up the price of land so that, in the new equilibrium, higher land rents, $q_p(\ell)$, prevail throughout the neighborhood.

The difference in land rents created by the implementation of the policy, net of the direct capital improvement σ, is given by

$$q_p(\ell) - q(\ell) = \delta \left[\int_{-R}^{R} e^{-\delta|\ell-s|} \left[H_p(s) - H(s)\right] ds + \sigma \int_{-r}^{r} e^{-\delta|\ell-s|} ds \right] > 0. \tag{12}$$

We have already argued that the first term in square brackets is negative. The second term captures positive externalities generated by the capital improvement policy. In this respect, the size of the exogenous increase in housing investment at each targeted location, σ, and the extent of the impact area, $\mathcal{A}$, have a first order positive effect on land prices. In contrast, because commuting costs, τ, and income, w, affect land rents in the same way in (7), both before and after the introduction of the policy, these features are essentially differenced out and only affect land prices through changes in $H(.)$ in Equation (12). Note that since $q_p(\ell) - q(\ell)$ in (12) is simply the negative of the change in land rents $H_p(\ell) - H(\ell)$ in (11), it immediately follows that $q_p(\ell) - q(\ell) > 0$. Hence, our assumption of Cobb-Douglas preferences with elasticity of substitution equal to one (which implies an unchanged

$\overline{H}$ following the policy) ensures that the implementation of the revitalization program is associated with higher land rents. This choice of preferences stems from empirical work on cities which has found the Cobb-Douglas specification with respect to land and consumption to fit the data well (see Davis and Ortalo-Magne, 2007).

In the end, as a result of the revitalization program, housing investments fall and land prices rise throughout the neighborhood. Agents consume a constant fraction of housing, and now that nearby homes offer additional housing services, they prefer to invest less where they live. The revitalization policy increases the value of location and, therefore, land prices. We summarize these results in the following proposition:

Proposition 1 *Following the positive housing subsidy on a set of locations A, housing investments decrease at all locations, $H(\ell)_p - H(\ell) < 0$ $\forall \ell \in [-R, R]$, and land rents increase at all locations, $q_p(\ell) - q(\ell) > 0$ $\forall \ell \in [-R, R]$.*

The new equilibrium land rents, $q_p(\ell)$, are described by the dashed curve in Figure 2B. As we have just argued, these new land rents are everywhere higher in the neighborhood, and especially when close to the impact area. Figure 2C shows the percentage or log difference between post-policy and pre-policy land rents on either side of the center of the impact area, net of the direct capital improvements brought about by the renewal program. This difference, therefore, reflects only the propagation of housing externalities across space induced by the federal housing investment increase.

Given that externalities fall exponentially with distance in this model, increases in land value in Figure 2C will generally mimic a diffusion process as they level out with distance from the impact area. The rise in land rents is more pronounced over the impact area because a typical location in that area is mainly surrounded by other locations that received funding for capital improvements. Hence, a location in $\mathcal{A}$ benefits from externalities generated by many similarly affected locations nearby. Note, in particular, the steep drop off in land returns once we move outside the impact region. At locations near the boundary, differences in land rents become mostly flat near zero in Figure 2C. This effect arises because any one location near the boundary, contrary to a location in $\mathcal{A}$, is mainly surrounded by other locations that did not benefit from the revitalization program. External effects from the policy, therefore, are negligible at those locations. Because externalities generate a two-tier effect on land rents across space, changes in land rents produced by the revitalization program will generally be characterized by a bimodal distribution. This is shown in Figure 2D. Keep in mind, from Equation (12), that this bimodal aspect of land returns arises independently of the direct effect related to capital improvements in $\mathcal{A}$.

4 The Empirical Framework

This section sets up an empirical framework whose aim is to help us identify the extent to which the effects of the NiB programs, in practice, propagated to non-targeted sites. We are also interested in whether we can establish empirically that these external effects decline with distance in a way suggested by Figure 2C. If so, we also wish to a gauge how far the effects of NiB programs were able to extend in this case.

We denote a location in the city of Richmond by $\ell = (x, y) \in \mathcal{R}^2$, where x and y are Cartesian coordinates. Let p represent the (log) price of a home per square foot of land in the city of Richmond. Our analysis begins with the following semiparametric hedonic price equation,

$$p = \mathbf{Z}\boldsymbol{\beta} + q(\ell) + \varepsilon, \tag{13}$$

where $\mathbf{Z}$ is a $k-$element vector of conditioning housing attributes such that $cov(\mathbf{Z}|\ell) = \Sigma_{z|\ell}$, $q(\ell)$ is the component of home prices directly related to location, and ε is a random variable such that $E(\varepsilon|\ell, \mathbf{Z}) = 0$ and $var(\varepsilon|\ell, \mathbf{Z}) = \sigma_\varepsilon^2$. While this semi-log specification is standard in the analysis of real estate data, we differ somewhat in that we try to remain flexible with respect to the form of $q(\ell)$. In particular, we do not assume that $q(\ell)$ lies in given parametric family.[6]

We are interested in assessing the effects of NiB policies on the component of prices related to location, $q(\ell)$, in the various targeted neighborhoods described previously. This suggests estimating Equation (13) both before and after the NiB policies come into effect. Because our concern is with assessing the extent of residential externalities, we omit observations on homes that directly benefited from NiB funding in our estimation. Although our model predicts that the types of renewal programs considered here generally crowd out of private investment, it is conceivable that these programs induced a reshuffling of heterogenous populations across neighborhoods, consistent with gentrification, that is not captured in our framework. In particular, a higher income household that decided to relocate to an impact area and further invested in home improvements would have very likely used some NiB funding (since the program aimed to precisely subsidize this type of investment). As such, simply subtracting public home improvements at that location would overstate the external effect of the policy on land prices. Because we have no way of measuring any additional private spending on home improvements at locations that received NiB funding, a

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[6] The assumption of separability between Z and $q(\ell)$ is made for computational simplicity, and abstracts from a potential complementarity between location and housing attributes. See Ho (1995), and Anglin and Gencay (1996), for alternative applications of the semiparametric hedonic pricing model to the real estate market.

conservative strategy is to omit the observation altogether.

Some key questions that the analysis will attempt to uncover are: i) How did the price of land change in each of the neighborhoods in Figure 1, say from $q(\ell)$ to $q_p(\ell)$, at sites not directly targeted by the NiB revitalization projects? ii) Can we relate this change to some notion of distance from a focal point in a given impact area? In particular, do the findings related to the neighborhoods targeted for revitalization indicate external effects that dissipate with distance? Conversely, given the absence of an impact area in the control neighborhood of Bellemeade, are land price changes in that neighborhood more uniform across space?

4.1 Data Description

Our dataset stems from two sources. First, the city of Richmond collected records of all properties that benefited from NiB funding between 1999 and 2004. These records include the geo-coded location of those properties as well as the amount and type of funds that it received. Second, we also obtain from the city of Richmond a geo-coded listing of all properties sold between 1993 and 2004 that includes information on condition and age, construction descriptors (e.g. exterior materials, type of heating, etc.), and various dimensional attributes (e.g. lot size, size of living area, etc.). Since the NiB revitalization programs specifically targeted residential properties, we remove from our sample all non-residential properties, mainly commercial buildings. We also delete listings that were likely incorrectly recorded, including homes listed as being built before 1800 and homes whose living area is recorded as less than 250 square feet. Because all of our data is geo-coded, we are able to cross-check our two datasets and remove any property that directly benefited from NiB funding. In this sense, we aim to measure only the external effects associated with the NiB programs. In all, we have $44,412$ sales observations.

Descriptive statistics of the housing characteristics for all years are reported in Table 2. These characteristics include the furnished square footage of a house, the number of years since the house was first built, its plot acreage, and the number of bathrooms available (with half baths counting as one half). We also include binary variables that indicate whether the house has central air conditioning, whether its exterior is brick or vinyl, and whether it is heated using gas or hot water. The city of Richmond also assigns condition grades to each house, which we capture using binary variables to indicate whether a house was assessed in good condition, poor condition, or very poor condition. Finally, we include among our conditioning variables, $\mathbf{Z}$, a set of time dummies that capture secular city-wide increases in home prices driven by aggregate factors such as city population growth or interest rates changes.

Table 2. Data Summary

Variable	Mean	St. dev.	Min.	Max.
Sales Price^a	74394	121539	11	8946680
Air Conditioning	0.5716	0.4949	0	1
Brick Exterior	0.4611	0.4985	0	1
Vinyl Exterior	0.0404	0.1970	0	1
Gas Heating	0.1267	0.3326	0	1
Hot Water Heating	0.2167	0.4120	0	1
Square Footage	1664.9	1190.3	319	63233
Age (in years)	63.78	26.46	0	205
Acreage	0.2337	0.3506	0.012	37.67
Good Condition	0.1789	0.3833	0	1
Poor Condition	0.0196	0.1385	0	1
Very Poor Condition	0.0137	0.1162	0	1
No. Bathrooms	1.546	1.245	0	1

a : Expressed in constant 2000 dollars.

4.2 Estimation of the Parametric Effects

In order to estimate the non-parametric component of Equation (13), $q(\ell)$, we must first address the estimation of the parametric effects, $\boldsymbol{\beta}$. Let n denote the number of observations on home prices and k the number of variables in $\mathbf{Z}$. A popular approach, pioneered by Robinson (1988), proceeds in two steps. In the first step, non-parametric (kernel) estimates of $E(p|\ell)$ and $E(\mathbf{Z}|\ell)$ are constructed. Since Equation (13) implies that

$$p - E(p|\ell) = [\mathbf{Z} - E(\mathbf{Z}|\ell)]\boldsymbol{\beta} + \varepsilon, \tag{14}$$

the second step involves replacing the conditional means in (14) by these non-parametric functions and estimating $\boldsymbol{\beta}$ by least squares. Robinson (1988) shows that estimates of $\boldsymbol{\beta}$ obtained in this way are $\sqrt{n}$ consistent. Because of the size of our dataset, and given that separate non-parametric regressions are required for each housing attribute in $\mathbf{Z}$, this method proves onerous in our case. To circumvent this problem, Yatchew (1997, 2001) proposes a differencing approach that we adopt in this paper.

The basic idea behind Yatchew's (1997, 2001) estimation strategy is to re-order the data, $(p_1, \mathbf{Z}_1, \ell_1)$, $(p_2, \mathbf{Z}_2, \ell_2)$, ... , $(p_n, \mathbf{Z}_n, \ell_n)$ so that the ℓ's are close, in which case differencing tends to remove the non-parametric effects. In particular, first-differencing of (13) gives

$$p_i - p_{i-1} = (\mathbf{Z}_i - \mathbf{Z}_{i-1})\boldsymbol{\beta} + q(\ell_i) - q(\ell_{i-1}) + \varepsilon_i - \varepsilon_{i-1}. \tag{15}$$

Assuming that a Lipschitz condition holds for q, $|q(\ell_a) - q(\ell_b)| \leq L||\ell_a - \ell_b||$, the difference in non-parametric component in (15) vanishes asymptotically.[7] Yatchew (1997) shows that the OLS estimator of $\boldsymbol{\beta}$ using the differenced data (i.e. the projection of $p_i - p_{i-1}$ on $\mathbf{Z}_i - \mathbf{Z}_{i-1}$) is also $\sqrt{n}$ consistent. This estimator of $\boldsymbol{\beta}$, however, achieves only 2/3 efficiency relative to the one produced by Robinson's method. This can be improved dramatically by way of higher-order differencing. Specifically, define $\mathbf{\Delta p}$ to be the $(n-m) \times 1$ vector whose elements are $[\mathbf{\Delta p}]_i = \sum_{s=0}^{m} d_s p_{i-s}$, $\mathbf{\Delta Z}$ to be the $(n-m) \times k$ matrix with entries $[\mathbf{\Delta Z}]_{ij} = \sum_{s=0}^{m} d_s Z_{i-s,j}$, and similarly for $\mathbf{\Delta}\boldsymbol{\varepsilon}$. The d_s's denote constant differencing weights and m governs the order of differencing. We thus estimate a more general version of Equation (15),

$$\mathbf{\Delta p} = \mathbf{\Delta Z}\boldsymbol{\beta} + \sum_{s=0}^{m} d_s q(\ell_{i-s}) + \mathbf{\Delta}\boldsymbol{\varepsilon}, \; i = m+1, ..., n, \tag{16}$$

where the following two conditions are imposed on the differencing coefficients, $d_0, ..., d_m$:

$$\sum_{s=0}^{m} d_s = 0 \text{ and } \sum_{s=0}^{m} d_s^2 = 1. \tag{17}$$

The first condition ensures that differencing removes the non-parametric effect in (13) as the sample size increases and the re-ordered ℓ's become "close". The second condition is a normalization restriction that implies that the transformed residual in (16) has variance σ_{ε}^2. When the differencing weights are chosen optimally, the difference estimator, $\boldsymbol{\beta}_{\Delta}$, obtained by regressing $\mathbf{\Delta p}$ on $\mathbf{\Delta Z}$ approaches asymptotic efficiency by selecting m sufficiently large.[8]

We use $m = 10$ which produces coefficient estimates that are approximately 95 percent efficient when using optimal differencing weights. Note that, as a practical matter, the initial re-ordering of the ℓ's is not unambiguous here since $\ell \in \mathcal{R}^2$. We re-order locations using a path created by a Hamiltonian nearest neighbor algorithm and, for our dataset, this yields a mean distance between locations, $1/n \sum ||\ell_i - \ell_{i-1}|$, that is 24 to 28 times smaller than that obtained by simply re-ordering locations according to their x or y coordinate (i.e. the wrap-around method)[9].

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[7] Suppose that locations constitute a uniform grid on the unit square (the re-scaling is without loss of generality). Each point may then be thought of as residing in an area of $1/n$, and the distance between re-odered adjacent observations, $||\ell_i - \ell_{i-1}||$, is $1/\sqrt{n}$.

[8] Optimal differencing weights, $d_0, ..., d_m$, solve min $\delta = \sum_{k=1}^{m} (\sum_s d_s d_{s+k})^2$ subject to the constraints in (17). See Yatchew (1997).

[9] The starting point when using the nearest neighbor approach is arbitrary but has little implications for our results.

4.3 Non-Parametric Kernel Estimation of $q(\ell)$

Denote by Y the price of a home "purged" of its contribution from housing characteristics, where Y is obtained using first stage estimates, $Y = p - \mathbf{Z}\widehat{\boldsymbol{\beta}}_\Delta$, and construct the data (Y_1, ℓ_1), (Y_2, ℓ_2),...,(Y_n, ℓ_n). Because $\widehat{\boldsymbol{\beta}}_\Delta$ is a consistent estimator of $\boldsymbol{\beta}$, standard kernel estimation methods applied to purged home prices yield consistent estimates of $q(\ell)$.

The *Nadaraya-Watson* kernel estimator of q at location ℓ_j is given by

$$q(\ell_j) = n^{-1} \sum_{i=1}^{n} W_{hi}(\ell_j) Y_i. \tag{18}$$

In other words, the component of home prices directly related to location, ℓ_j, is a weighted-average of the Y's in our data sample. The weight $W_{hi}(\ell_j)$ attached to each price Y_i is given by

$$W_{hi}(\ell_j) = \frac{K_h(\ell_j - \ell_i)}{n^{-1} \sum_{i=1}^{n} K_h(\ell_j - \ell_i)}, \tag{19}$$

where

$$K_h(u) = h^{-1} K(\frac{u}{h}),$$

and $K(\psi)$ is a symmetric real function such that $\int |K(\psi)| d\psi < \infty$ and $\int K(\psi) d\psi = 1$. Thus, we may choose to attach greater weight to observations on prices of homes located near ℓ_j rather than far away by suitable choice of the function K. In particular, as in much of the literature, our estimation is carried out using the Epanechnikov kernel. The distance between location ℓ_j and some other location ℓ_i in the city is simply measured as a Euclidean distance in feet. An implication of the Epanechnikov kernel is that prices of homes located more than a distance of h feet from ℓ_j will receive a zero weight in the estimation of $q(\ell_j)$. In that sense, the bandwidth h has a very natural interpretation in this case.[10]

The NiB programs were first implemented in 1999 and nearly phased out by 2004. Consequently, we estimate Equation (13) over two subsamples, $1993 - 1998$, the period prior to NiB coming into effect, and $1999 - 2004$, the post revitalization period for which we have data. The first and second subsamples contain 18102 and 26310 observations respectively. Ultimately, we wish to capture increases in the price of land at different locations between 1998 and 2004. Hence, we set the base year for the time dummies in $\mathbf{Z}$ as the last year in each subsample period. All prices are measured in 2000 constant dollars, and we estimate land prices using observations over the entire city of Richmond.

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[10] In practice, the estimation of $q(\ell)$ is affected to a greater degree by the choice of bandwidth rather than the choice of kernel. See diNardo and Tobias (2001) for a detailed discussion. In this case, the bandwith is chosen by means of Cross-Validation. Hence, we select h so that it solves $\min_h CV(h) = n^{-1} \sum_{j=1}^{n} [Y_j - \widetilde{q}_h(\ell_j)]^2$, where $\widetilde{q}_h(\ell_j) = n^{-1} \sum_{i \neq j}^{n} W_{hi}(\ell_j) Y_i$.

5 Empirical results

This section reviews our findings. We present estimates of the semiparametric hedonic price regression (13) and illustrate what they imply for city-wide land prices prior to the implementation of NiB. This allows us to compute changes in land values for the neighborhoods targeted for revitalization and describe how these changes vary as we move away from the impact area. We then compare our findings for the targeted neighborhoods with those in our control neighborhood. This comparison lets us compute the total effect of the NiB program relative to a benchmark where no such public investment took place. Finally, we use this evidence to calibrate the model of housing externalities presented in Section 3.

Table 3 presents estimates of the parametric components of Equation (13). Virtually all housing characteristics in Table 3 are statistically significant at the 5 percent critical level, and the large majority of these attributes is significant at the 1 percent level in both samples. In addition, both specifications achieve a surprisingly good fit for cross-sectional data.[11]

Coefficients associated with the sale date are significant over and above prices being measured in constant dollars. In the post 1998 period, in particular, our findings suggest a considerable real run up in home prices in the city of Richmond (as with many other U.S. cities over the same time period). We estimate separate semiparametric hedonic price specifications over the pre and post 1998 period to account for possible changes to the valuation of housing attributes triggered by the implementation of the revitalization policy or any other city policy or shock. The housing coefficients shown in Table 1, however, tend to be relatively similar across subsamples. Alternative estimates that hold the coefficients on housing attributes constant across subperiods have immaterial implications for the results we present below.

Of central interest are the nonparametric estimates of land prices, $q(\ell)$, in both the targeted neighborhoods and the control neighborhood.[12] Prior to the start of the NiB project, we estimate land prices that in 1998 averaged \$5.97 per square foot in the neighborhood of Church Hill, \$6.38 in Highland Park-South Barton Heights, and \$5.17 in Blackwell. In contrast, we estimate higher land prices for the city as a whole, with a mean of \$8.29 per square foot, and land prices that are as high as \$100 per square foot in the more affluent parts of Richmond. The large majority of these highly priced sites form part of a historical district known as the Fan located in the center of Richmond. Because the neighborhood of Jackson Ward-Carver adjoins the Fan district, the local averaging implied by kernel estimation gives

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[11] It can be shown that $s_{\Delta}^2 = \frac{1}{n}\sum_{i=1}^{n}(\mathbf{\Delta p}_i - \mathbf{\Delta Z}_i\widehat{\boldsymbol{\beta}}_{\Delta})^2 \rightarrow^P \sigma_{\varepsilon}^2$. Hence, we compute R^2 as $1 - s_{\Delta}^2/s_p^2$.

[12] Land prices are estimated on a grid containing the coordinates of home sales in our pre-policy sample. Using the grid corresponding to post-policy home sales instead does not change our findings.

land prices that have a mean of $12 per square foot in that neighborhood. In contrast, estimated land prices in the control neighborhood of Bellemeade fall well within the range of the other three NiB neighborhoods, with a slightly lower mean at $4.71 per square foot.

Table 3. Estimates of the parametric effects on home prices

	1993-1998 Period			1999-2004 Period	
Variable	Coeff.	*t*-statistics		Coeff.	*t*-statistics
1993	-0.059	-3.453	1999	-0.428	-30.206
1994	-0.039	-2.381	2000	-0.380	-27.401
1995	-0.048	-2.924	2001	-0.303	-22.513
1996	-0.036	-2.203	2002	-0.232	-17.316
1997	-0.029	-1.874	2003	-0.129	9.718
Air Cond.	0.094	7.752	Air Cond.	0.078	7.900
Brick Exterior	0.152	11.386	Brick Exterior	0.186	16.173
Vinyl Exterior	-0.290	-8.636	Vinyl Exterior	-0.187	8.250
Gas Heating	0.092	5.610	Gas Heating	0.154	10.317
Hot Water Heating	0.101	6.624	Hot Water Heating	0.066	5.210
Sq. Ft.[a]	0.055	6.237	Sq. Ft.	0.027	5.496
Age[b]	-0.007	0.218	Age	0.149	5.972
Acreage	-0.815	-37.652	Acreage	-0.423	-34.920
Good Cond.	0.095	6.524	Good Cond.	0.137	11.087
Poor Cond.	-0.510	-11.864	Poor Cond.	-0.375	12.990
Very Poor Cond.	-0.867	-17.327	Very Poor Cond.	-0.613	-17.449
No. Bathrooms	0.003	0.479	No. Bathrooms	0.010	2.251
No. obs.	18102		26310		
R^2	0.64		R^2	0.68	

a : measured in 1000 sq. ft.; b : measured in 100 years.

A contour map of the price of land per square foot for the city of Richmond before NiB is shown in Figure 4. It is clear from the figure that the NiB neighborhoods are associated with some of the lowest land prices in the entire city.[13] Despite its relatively small area of 60 square miles, Figure 4 suggests considerable variation in land prices throughout Richmond. Because lot sizes are relatively homogenous throughout Richmond at around 0.1 acres, our estimates suggest lot prices that vary from $20,000 in the neighborhoods targeted by NiB to $435,000 in the more well-off districts. Table 4 focuses on the NiB neighborhoods more specifically

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[13] To capture policy effects that potentially extend beyond the areas intially targed by NiB, we present our results for a broader definition of neighborhood described in Section 5.1.

and gives estimated land prices per square foot at different percentiles in comparison to the city as whole.

Table 4. Pre-NiB land price per square foot

Neighborhood	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Church Hill	0.81	1.84	5.21	13.32	21.02
Blackwell	0.76	1.84	3.83	7.04	12.15
Highland Park-Barton	1.29	2.61	5.22	8.05	11.59
Jackson Ward-Carver	2.22	4.85	11.77	21.66	31.36
Bellemeade	1.87	2.89	4.71	6.42	8.13
City of Richmond	3.09	5.11	8.29	14.94	27.40

5.1 The Return to Land in the Neighborhoods Targeted by NiB

To relate our empirical findings to the theory in Section 3 more closely, we now explore several key aspects of the data. First, we explore whether changes in land value in the four selected neighborhoods decrease with distance in a way suggested by Figure 2C? Second, given the absence of an impact area in the control neighborhood of Bellemeade, we ask whether changes in land value in that neighborhood are both lower and more uniform across space.

To answer these questions, there are two aspects of the empirical framework that we must first reconcile with the theory presented in Section 3. First, in contrast to our model, targeted neighborhoods in practice generally have more than one impact area. Second, for ease of presentation, we must tackle the issue of how to present our estimates for $\Delta q(\ell)$, where $\ell \in \mathcal{R}^2$, in terms of distance from a focal point, $\Delta q(d)$, where $d \in \mathcal{R}$, analogously to Figure 2C. By way of example, we use the neighborhood of Blackwell to discuss our approach to both issues, and proceed similarly in the other targeted neighborhoods.

Figure 3 shows the targeted neighborhood of Blackwell, denoted by $\mathcal{N}$. Within $\mathcal{N}$, let $\mathcal{A}_i$ represent the cluster of locations that were the direct recipient of NiB funding. There are 2 such clusters shown in Figure 3, which essentially constitute impact areas. Formally, the partitioning of directly targeted locations into separate clusters satisfies a K-means criterion. Specifically, our partitioning of those locations into 2 disjoint subsets, $\mathcal{A}_1$ and $\mathcal{A}_2$, satisfies $\min_K \sum_{i=1}^{K} \sum_{n \in \mathcal{A}_i} |\ell_n - \mu_i|$, where ℓ_n and μ_i are a location and the geometric centroid of $\mathcal{A}_i$

respectively.[14] We define the funding center of an impact area as a convex combination of the locations that received NiB funding within that cluster. These are shown as c_1 and c_2 in Figure 3. The weights in that combination are given by the relative amounts of NiB funds spent at the different locations. In that sense, this funding center represents a focal point of the revitalization policy in a given impact area.

In general, it is possible that a location in between two impact areas, such as between $\mathcal{A}_1$ and $\mathcal{A}_2$ in Figure 3, benefit from externalities related to both sets of funded locations simultaneously. In that case, for simplicity, we attribute any measured external effect on land values to the closest impact area. Thus, for each location ℓ in $\mathcal{N}$, we compute the distance from ℓ to the center of the closest cluster, $d(\ell) = \min_i\{||\ell - c_i||\}$, where c_i is the center of $\mathcal{A}_i$. We can then rank these distances from smallest to largest. In particular, the variable $d(\ell)$ represents a convenient mapping from $\mathcal{R}^2$ to $\mathcal{R}$ that, despite the existence of several impact areas in a given neighborhood, captures some notion of distance from a central point of the policy experiment. It also allows us to plot land price changes with respect to distance from this focal point, $\Delta q(d)$, and to examine whether changes in land value indeed fall as we move away from the policy experiment (i.e. as d increases). In order to capture any external effects that potentially exist beyond the targeted neighborhoods in Figure 1, we extend each neighborhood to encompass locations such that $d(\ell)$ covers a radius of 3500 feet. In doing so, however, we are careful not to cross natural boundaries such as highways, railroad tracks, industrial zones, etc. that often arise before reaching 3500 feet. In practice, therefore, this radius generally represents the broadest definition of a neighborhood that does not infringe on other neighborhoods with distinctly different demographics or housing characteristics.

Figure 5 illustrates (kernel-smoothed) distributions of estimated land price changes, $\Delta q(\ell)$, in each of the NiB neighborhoods. Recall that $q(\ell)$ is estimated from log prices so that $\Delta q(\ell)$ measures percent changes which we express at an annual rate. The distribution of estimated changes in land value generally depicts positive returns in all four cases, although the spread and mean of these distributions vary. The question is whether, as in Figure 2C, these land price increases become smaller as one moves further away from the impact area.

Figure 6 illustrates the behavior of estimated changes in land prices per square foot with respect to distance from the impact area, $\Delta q(d)$. It is apparent that in all four cases, the returns to land fall as the distance from the policy experiment increases.[15] Externalities

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[14] Although this problem potentially yields multiple solutions, the clusters of funded locations are sufficiently separated in our case that this is not an issue.

[15] The curves shown in each panel of Figure 6 are Nadaraya-Watson kernel estimates computed as described in section 4. The 95 percent confidence bands are based on standard errors at each distance, d, computed

are more pronounced close to the funding center and fall steeply as one moves away from locations in the impact area. In the neighborhood of Church Hill (Figure 6A), most of the returns to land are concentrated around the upper tier, which explains a mode annual return of around 12 percent in Figure 5A. In contrast, in the neighborhood of Blackwell (Figure 6B), most of the returns to land are located near the lower tier so that the mode return in Figure 5B is around 4.5 percent. Both Figures 5 and 6 suggest perceivable differences in the way that each neighborhood was affected by the NiB program, with mean annualized returns that vary from 5.93 percent in Blackwell to 9.71 percent in Church Hill. Thus, we examine more closely below the relationship between the size of the capital improvement program in a particular neighborhood and its overall gain in value from externalities. Recall from Equation (12) that both the size of the impact area and the amount of funding for home improvements have a first-order effect on price changes. It remains that in all four cases, the neighborhoods targeted for revitalization appear to have fared appreciably better than the control neighborhood of Bellemeade whose mean return of 3.88 percent is shown as the flat solid line in Figure 6. Strikingly, observe that land returns in the targeted neighborhoods tend to level out at the control neighborhood mean as the distance from the center of the impact area reaches 2500 to 3500 feet.

Figure 7 shows contour maps of the returns to land in each of the NiB neighborhoods. In each neighborhood, distinct land return 'hills' are clearly visible.[16] Furthermore, the locations we identify as centers of the policy experiment (i.e. the convex combination of funded locations) tend to be situated near the peaks of those 'hills'. In some cases one center tends to dominate; as in Church Hill where the southern policy center is located right at the top of the highest hill in land returns. Given the absence of an impact area in Bellemeade, a key question then is: are changes in land value in the control neighborhood lower and more uniform across locations unlike those shown in Figure 6 and 7?

5.2 Comparisons with the Control Neighborhood of Bellemeade

Figures 8A and 8B illustrate the behavior of changes in land value in the control neighborhood of Bellemeade. Figure 8A shows changes in the return to land as a function of distance from the centroid of the neighborhood (since Bellemeade does not contain an impact area), while Figure 8B illustrates the distribution of returns in that neighborhood. It is clear from the

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as $s(d) = \sqrt{\frac{b_K \sigma_\varepsilon^2}{h\widehat{p}(d)n}}$, where $\widehat{p}(d) = \frac{1}{hn}\sum_{i=1}^{n} K(\frac{d_i - d}{h})$, $b_K = \int K(u)du$, and n is the number of observations in each panel.

[16] The north-eastern end of Blackwell consists mainly of an industrial park with some scattered residences. No sales were recorded in that area over our sample period.

figure that the returns to land are more uniform and lower in Bellemeade than in the NiB neighborhoods. The fact that land returns are more uniform across the control neighborhood is also clear from the contour plot shown in Figure 9. The returns in Bellemeade are also more concentrated around the mean (the solid line in Figure 8A) than those in the neighborhoods in bloom and, in some cases, are even negative.

It seems clear from Figure 6 and Figure 8A that the neighborhoods targeted for revitalization generally performed better than the control neighborhood in terms of changes in land value. On average, land prices increased by 3.88 percent at an annual rate between 1998 and 2004 in Bellemeade. This roughly implies a 24 percent increase over this six-year period. In contrast, mean annual land prices increased by 9.71 percent in Church Hill, 5.93 percent in Blackwell, 6.60 percent in Highland Park-South Barton Heights, and 8.65 percent in the neighborhood of Jackson Ward-Carver. Moreover, Figure 6 indicates that sites near the (funding) center of the impact area experienced returns on land of 12 to 15 percent in each of the NiB neighborhoods. At the upper end, therefore, these returns represent almost a doubling of land prices over the period 1998 to 2004 compared to just a 24 percent increase in Bellemeade. Finally, observe that consistent with the absence of any targeted programs in our control neighborhood, changes in land values in Bellemeade display much less variation than in the NiB neighborhoods.

Given the size of the land returns estimated in the NiB neighborhoods relative to Bellemeade, it is natural to ask whether these external gains may have been driven not only by the revitalization policies put in place but also by simultaneous increases in private investments, potentially associated with a new population moving into the NiB neighborhoods, triggered by the renewal program. Several aspects of the analysis suggest that this consideration plays a limited role in this case.

Under the assumptions maintained in Section 3, recall that the model predicted a crowding out of private investments following the renewal program rather than a corresponding increase in private home improvements. This result stems from agents being able to move freely between neighborhoods but also from the assumption that they are identical (and have Cobb-Douglas preferences). In practice, of course, the revitalization policies may have produced a reshuffling of population across neighborhoods such that higher income households moved into the targeted areas and bid up the price of land. This process, in fact, often precisely describes gentrification. If these higher income households also carried out home improvements, the estimated returns on land shown in Figure 6 overstate the external effects induced by the revitalization policies. However, accounting for a simultaneous increase in income, w, (to reflect a changing population) in addition to public investments, σ, would shift the entire land return gradient, $q_p(\ell) - q(\ell)$, in Figure 2B upwards. Returns to land near the boundary of the neighborhood, R, in Figure 2B would also shift upward if the new population invested in housing outside the impact area.

In contrast to these predictions, what is striking in Figure 6 is that changes in land value in the NiB neighborhoods eventually level out to match the returns estimated in Bellemeade. Recall, in particular, that land returns in the control neighborhood are relatively even around the mean in Figure 8A. Nothing in our estimation procedure is designed to generate or force these results. In addition, this finding suggests that any lingering selection issues associated with the control neighborhood are likely to be minor. Put another way, far enough away from the programs, the targeted neighborhoods tend to behave very much like the control neighborhood.

Finally, there are two other observations that suggest that our results are not driven by simultaneous increases in private investments by way of gentrification. First, anyone moving into a targeted neighborhood after 1998, and privately investing in home improvements, would most likely have taken advantage of the NiB program since the goal of the program was precisely to subsidize that investment. As such, the observation would have been omitted from our sample. Second, the trend in the overall volume of sales in the NiB neighborhoods did not appreciably change before and after the implementation of the NiB program. Any reshuffling of population across neighborhoods, therefore, would have been limited.

5.3 Calibration and the Rate of Decline in Housing Externalities

In order to determine more directly what Figure 6 implies for the speed at which externalities dissipate with distance, we now proceed with a calibration of the model in Section 3 that gives us some sense of the size of the parameter δ. In accordance with CPI weights, we set the share of income spent on housing, $1-\alpha$, to 0.32. Analogously to the rate of interest in a dynamic framework, the level of wages in our model determines the time period tied to the flow of consumption services and housing investments. Thus, we set a daily wage of $w = 80$ which corresponds to ten dollars an hour and would be typical for residents of an NiB neighborhood. We set the radius of each neighborhood, R, to 3500 feet consistent with Figure 6. To calibrate the radius of the impact area, r, we estimate the total size of impact areas in each neighborhood, $\mathcal{A}$, and set $r = \sqrt{(\mathcal{A}/\pi)}$. This yields an impact area radius of 1085 feet in Church Hill, 1190 feet in Blackwell, 1365 feet in Highland Park-South Barton Heights, and 1400 feet in Jackson Ward-Carver. If R is measured in feet, then the parameter σ in Section 3 refers to the amount of spending per foot in the impact area. Note, however, that only some of each neighborhood is composed of residential land. To compute residential area in a given impact region, therefore, we first multiply the number of residential units in the corresponding neighborhood by their mean acreage, which gives us an estimate of total residential acreage in that neighborhood. To obtain residential acreage within an impact area, we then multiply total residential acreage by the ratio of the size of an impact area, πr^2, to total neighborhood area, πR^2. We have available the amount of NiB funds disbursed in each neighborhood. Hence, we can approximate σ in a given neighborhood as

$$\sigma = \frac{\text{Total Funding in Neighborhood}}{\text{No. of Units} \times \text{Mean Unit Acreage} \times \frac{\pi r^2}{\pi R^2}}.$$

However, since the average size of a typical NiB plot in the data is around one tenth of an acre (which correspond to 4356 square feet), and funding took place over a six-year period (or 6 × 365 days), an appropriately scaled value for σ is $\widetilde{\sigma} = \sigma \times (\frac{4356}{6 \times 365})$. This calculation yields NiB spending per unit area of \$6.48 in Church Hill, \$5.61 in Blackwell, \$2.46 in Highland Park-South Barton Heights, and \$5.96 in Jackson Ward-Carver. Finally, because each neighborhood is small relative to the city as a whole, we assume that all residents in a neighborhood face the same commuting costs. Thus, we set $\tau = 0$ and interpret w as a wage net of commuting. This leaves only the parameter $\overline{u}$, which we set to 33. The implied land rent at the edge, q_R, is then around 26 dollars per day per acre, or equivalently 780 dollars a month for a typical lot.

The solid curves in Figure 10 depict land returns predicted from our model in each neighborhood when $\delta = 0.0007$. Given this value of δ, the model does relatively well in replicating the nonparametric estimates from Figure 6, with the exception of Blackwell. Aside from differences in the geography of each NiB neighborhood, the discrepancy in Blackwell likely reflects differences in the effectiveness of CDCs across neighborhoods. As indicated in Section 2, variations across CDCs often result in disparities in the quality of capital improvements, in particular home renovations, generated by a dollar of NiB funding. These disparities, in particular, arise from ties between a given CDC and specific contractors or input suppliers. In addition, recall from Section 2 that Blackwell is unique relative to the other neighborhoods in that, simultaneously with NiB, the Hope VI program in that neighborhood was actively engaged in eradicating housing stock deemed "unfit" but without, at the time, replacing it with new construction. Interestingly, Figure 10 suggests that any differences in the way CDCs operate seem of second order in the other three neighborhoods. In Blackwell, the amount of NiB funding per square foot comes to \$5.61 per square foot. Assuming that this funding translated instead into \$3.10 of effective home improvements relative to the other three neighborhoods (i.e. a ratio of 1 to 1.81), the model would have produced the dotted curve in Figure 10B. Put another way, we think of the negative externalities generated by the simultaneous destruction of housing stock in Blackwell by the HOPE VI program as offsetting the effectiveness of an NiB dollar by about 45 cents. More generally, a value of

0.0007 for δ implies external effects from housing services that fall by half approximately every 990 feet. Note that the model does well in capturing the total magnitude of the effect arising from externalities, namely the difference between land rent returns at the center of the neighborhood and its boundary.

Our findings, therefore, suggests externalities that dissipate somewhat more slowly with distance than estimated in previous work. In particular, Schwartz, Ellen, Voicu, and Schill (2006), using data from a ten-year residential investment program in New York City, find residential externalities lasting out to 2000 feet from a project site, with stronger effects in poor neighborhoods similar to those in this study. Santiago, Galster and Tatian (2001) find effects on house prices at 1000 to 2000 feet from a project site, though the investments in that paper are specific to public housing, not simply housing investment. Ding, Simons and Baku (2000), and Simons, Quercia and Maric (1998), examining CDC investments in Cleveland, find price effects that dissipate between 300 and 500 feet from a project site, though their methodology indicates that distances further than 500 feet were not investigated. In contrast to our investigation, all of these papers estimate house prices (rather than land values) using parametric hedonic regressions rather than the nonparametric approach adopted in this paper.

5.4 Urban Revitalization Programs and Gains in Land Value

This section examines more closely the relationship between the size of the NiB program implemented in a specific neighborhood and its overall gain in land value. In particular, while we have the amount of funding received in each of the concerned neighborhood between 1998 and 2004, we wish to arrive at an estimate of overall land gains over that period for comparison.

Table 5A Neighborhood land values in 1998

Neighborhood	No. of units	Median plot value	Neighborhood value
Jackson Ward	2913	33,338	97,113,594
Highland Park	3471	42,170	146,372,070
Church Hill	2520	21,136	53,262,720
Blackwell	1411	31,081	43,855,291

From the city of Richmond, one can obtain the number of residential units in each of the targeted neighborhoods. These are shown in the first column of Table 5A. Although consistent data on lot sizes for each of these units is unavailable, we can compute the median land value of a lot in each of the neighborhoods from our dataset. In particular, we have lot sizes for homes that have sold in each neighborhood which we can multiply by our estimated price per square foot land, $q(\ell)$, at each corresponding location. Multiplying the number of units in a given neighborhood by its median plot value then gives us an estimate of total neighborhood value in 1998. These are shown in the last column of Table 5A. Note that there are considerable variations in neighborhood values. The median plot value in Highland Park-South Barton Heights, for instance, is roughly twice as expensive as in Church Hill prior to the revitalization policy, with roughly 1.4 times the number of units.

Table 5B Overall land gains and the size of urban revitalization programs

Neighborhood	Excess Return	Neighborhood Gain	NiB Funding	Gain:Funding Ratio
Jackson Ward	4.77	27,793,911	4,127,636	6.73
Highland Park	2.72	23,887,922	4,261,211	5.61
Church Hill	5.84	18,663,257	3,129,187	5.96
Blackwell	2.05	5,394,201	2,533,243	2.13

To compute overall land gains in the targeted neighborhoods, the first column of Table 5B gives the (annualized) mean excess return to land in each neighborhood relative to Bellemeade. Given the value of land shown in Table 5A for each neighborhood, we can readily compute its overall gain between 1998 and 2004. These gains are shown in the second column of Table 5B. The last column in Table 5B then shows the ratio of this overall land gain to the amount of NiB funding received for each neighborhood. Surprisingly, these ratios are quite close in three of the four neighborhoods at about 5.5 to 6. The ratio in Blackwell is considerably lower, however, which explains the difficulty in matching the returns for that neighborhood in the calibration exercise carried out earlier. As indicated previously, variations in CDC's across neighborhoods and the fact that the Hope VI program was in the process of razing unfit homes in Blackwell, without at the time replacing it with new construction, made that neighborhood somewhat unique. In any case, it remains that total increases in land value in each neighborhood (Table 5B, column 2) generally reflect the intensity of the NiB program in that neighborhood (Table 5B, column 3).

At this stage, it is absolutely crucial to recognize that our results, both in terms of theory and the empirical work, depend importantly on the exogeneity of NiB funding. Specifically, it matters critically that NiB expenditures were financed from sources exclusively outside Richmond. One cannot, therefore, expect the ratios of land gains to funding shown in Table 5B to obtain more generally as the size of revitalization programs increases. Broader programs are less likely to be funded solely from external sources. Moreover, when the funds that finance revitalization policies are raised from local taxes, externalities will be positive in the targeted neighborhoods but negative in areas where higher taxes lead to a reduction in housing investments. In practice, this reduction often arises by way of population moving outside the city boundaries to escape the increase in taxes. In that sense, the ratios of gains in land value to funding in Table 5B are best interpreted as upper bounds.

As a final thought experiment, we can compare the results shown in the last column of Table 5B with a more direct implication of the model in Section 3. Specifically, consider the effects generated by \$1 of capital improvements spent at the center of an impact area. If externalities from housing services decline exponentially with distance in the way described in Equation (1), the external effect obtained a distance s away from that location is given by $\delta e^{-\delta s}$. Thus, the aggregate externality obtained within a radius R of where the dollar is spent is given by

$$\rho = \delta \int_0^{2\pi} \int_0^R e^{-\delta s} ds d\theta = 2\pi(1 - e^{-\delta R})), \tag{20}$$

which is bounded between 0 and 2π for given δ and R. When R is 3500 feet, as suggested by Figure 6, and $\delta = 0.0007$, as suggested by our calibration exercise, $\rho = 5.74$. This result coincides well with the magnitudes calculated in Table 5B for the three neighborhoods that were not simultaneously subject to additional housing programs.

6 Concluding Remarks

In this paper we presented and interpreted evidence of housing externalities. Our findings suggest that housing externalities are large, fall by half approximately every 990 feet, and considerably amplify the effects of revitalization programs. The evidence we uncover in this paper can be used, in conjunction with a model of the type we provide, to evaluate and design urban renewal policies. More generally, having estimates of the size and rate of decline of housing externalities is central to the results of any such policy exercise.

We estimate that a dollar of home improvement generated between \$2 and \$6 in land value by way of externalities in the neighborhoods of interest. The type of revitalization policies considered here, therefore, appear to have been an excellent investment for the city of Richmond. However, a word of caution is in order. First, as argued earlier, the returns to renewal projects may decrease rapidly with the size of the program. Second, to the extent that the returns computed here include private investment in unobservable housing characteristics, our findings may overstate the effects of the program. Finally, given our findings, a natural question arises: Could a developer have instead privately internalized (a portion of) the external effects associated with the NiB program? In principle, this would have been possible but to capture these externalities, the developer would have had to incur the fixed cost of purchasing (parts of) the neighborhood. The return on total investment, therefore, would have been well within the norm of other standard investment vehicles. For example, abstracting from structures, we estimate that the neighborhood of Jackson Ward-Carver would have cost around \$97 million. Our work then suggests that spending an additional \$4 million in capital improvements yielded about \$28 million from externalities over 6 years. Hence, the return from external effects alone would have come to roughly 4.1 percent at an annual rate. While this represents a reasonable rate of return, it is not one that obviously dominates other investment opportunities given the initial investment of \$97 million. Moreover, obtaining this return involves a degree of community participation that would be difficult for private developers to elicit.

Evidently, the results we obtain in this study are to a degree particular to the NiB program and to the city of Richmond. That said, although the magnitude of housing externalities may vary across settings, the evidence we uncover points to a general feature of residential neighborhoods: The existence of significant housing externalities. In light of this evidence, it would be misleading to omit this feature of residential neighborhoods in standard urban theories used to design urban policy.

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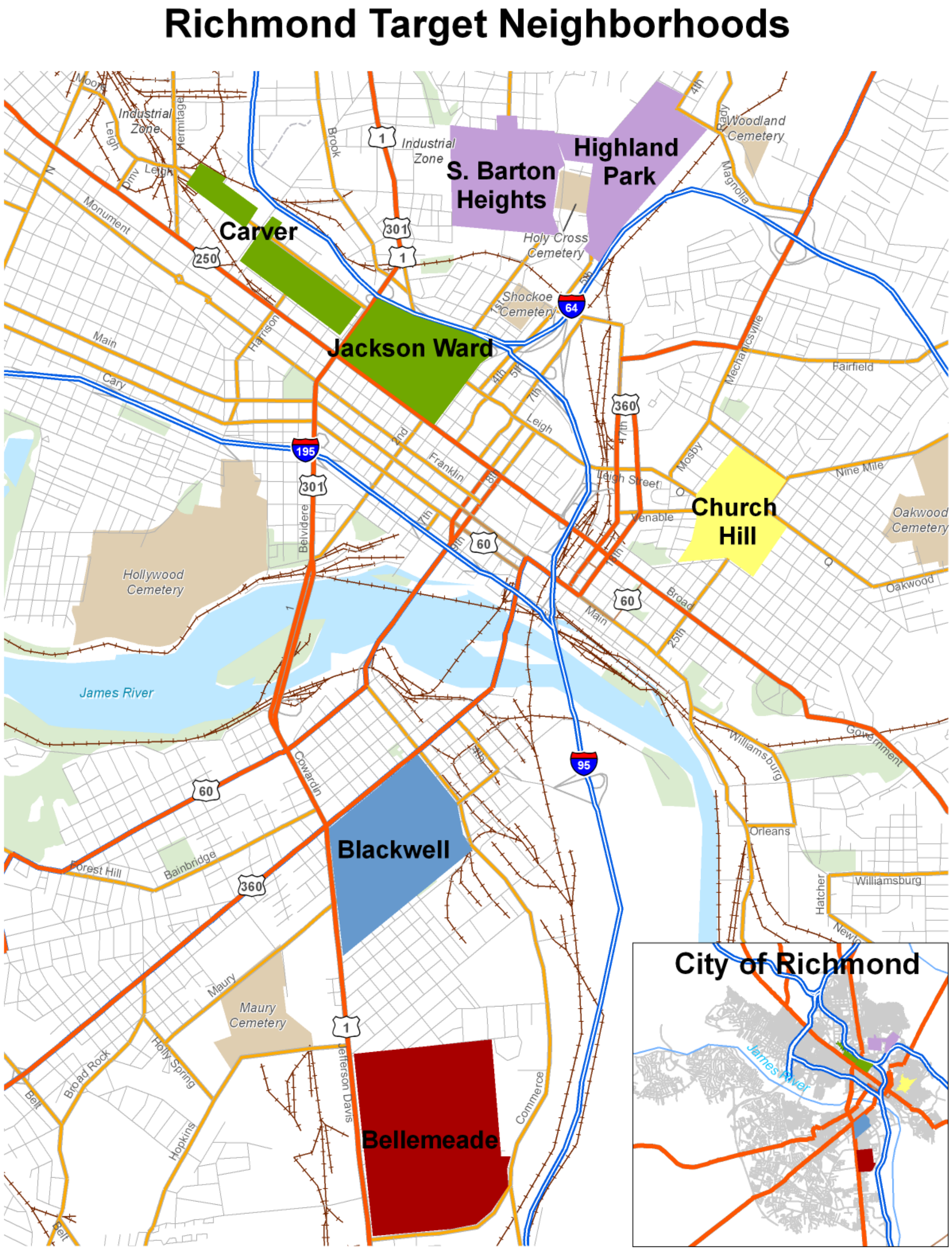


Figure 1: Overview of the Neighborhoods-in-Bloom Program, Richmond VA

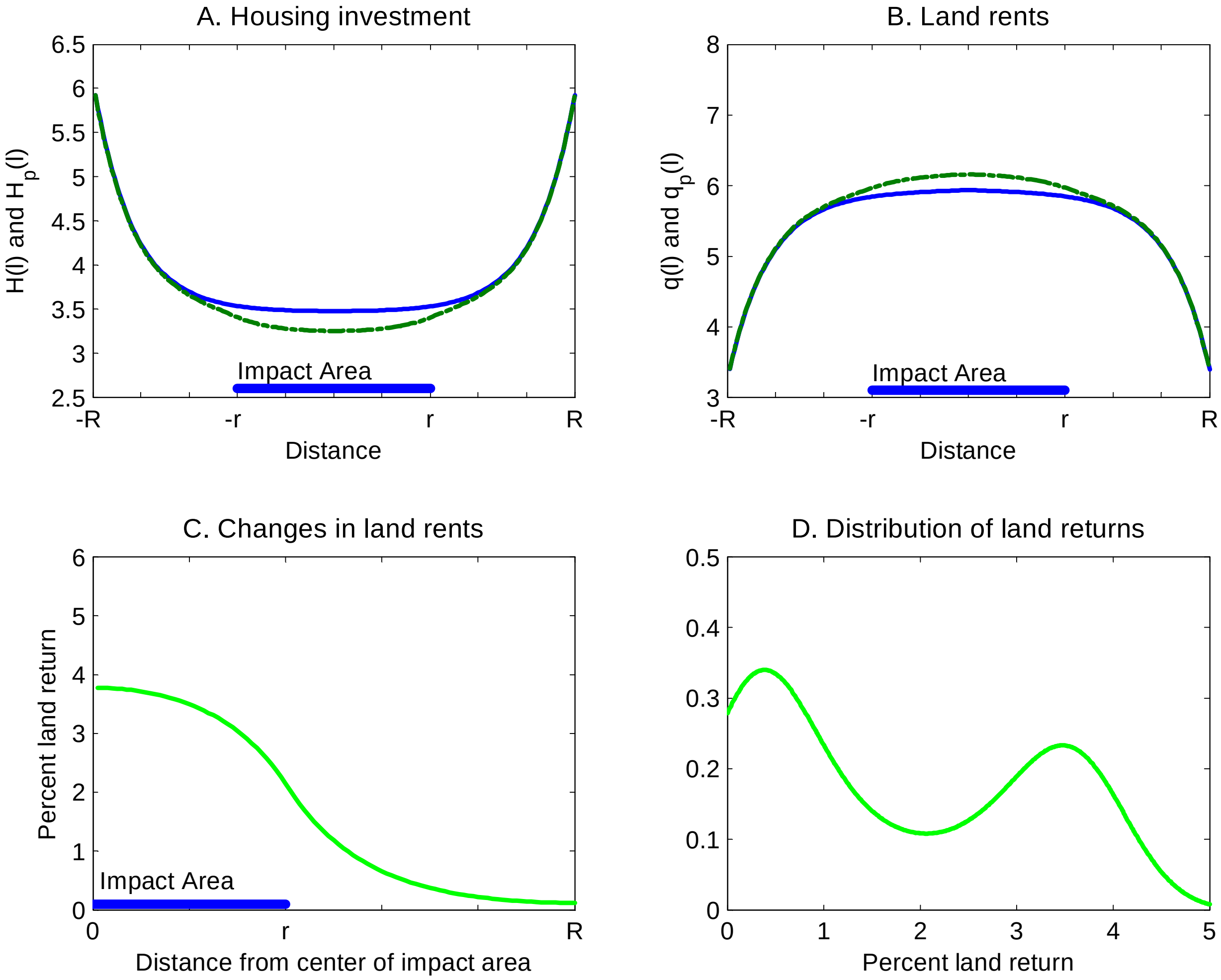


Figure 2: A model of housing externalities

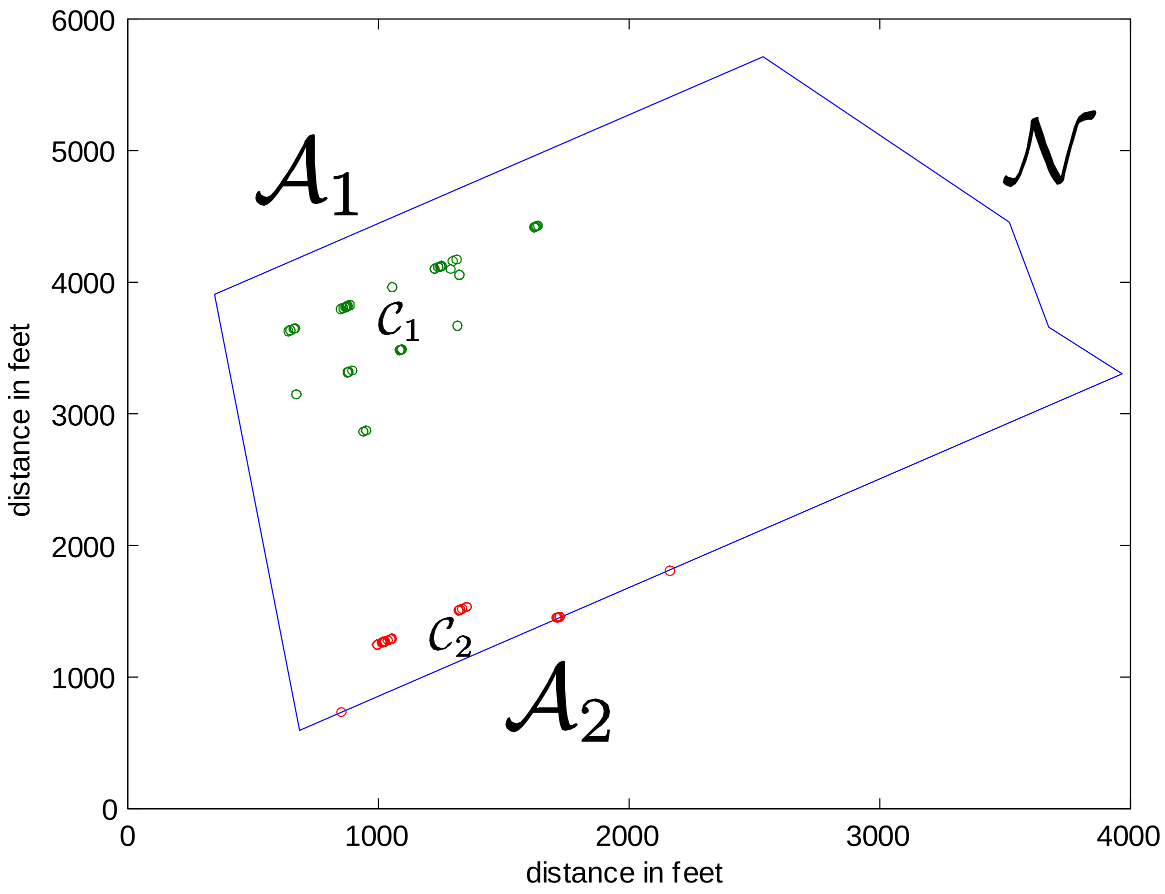


Figure 3: Funding locations and impact areas in Blackwell

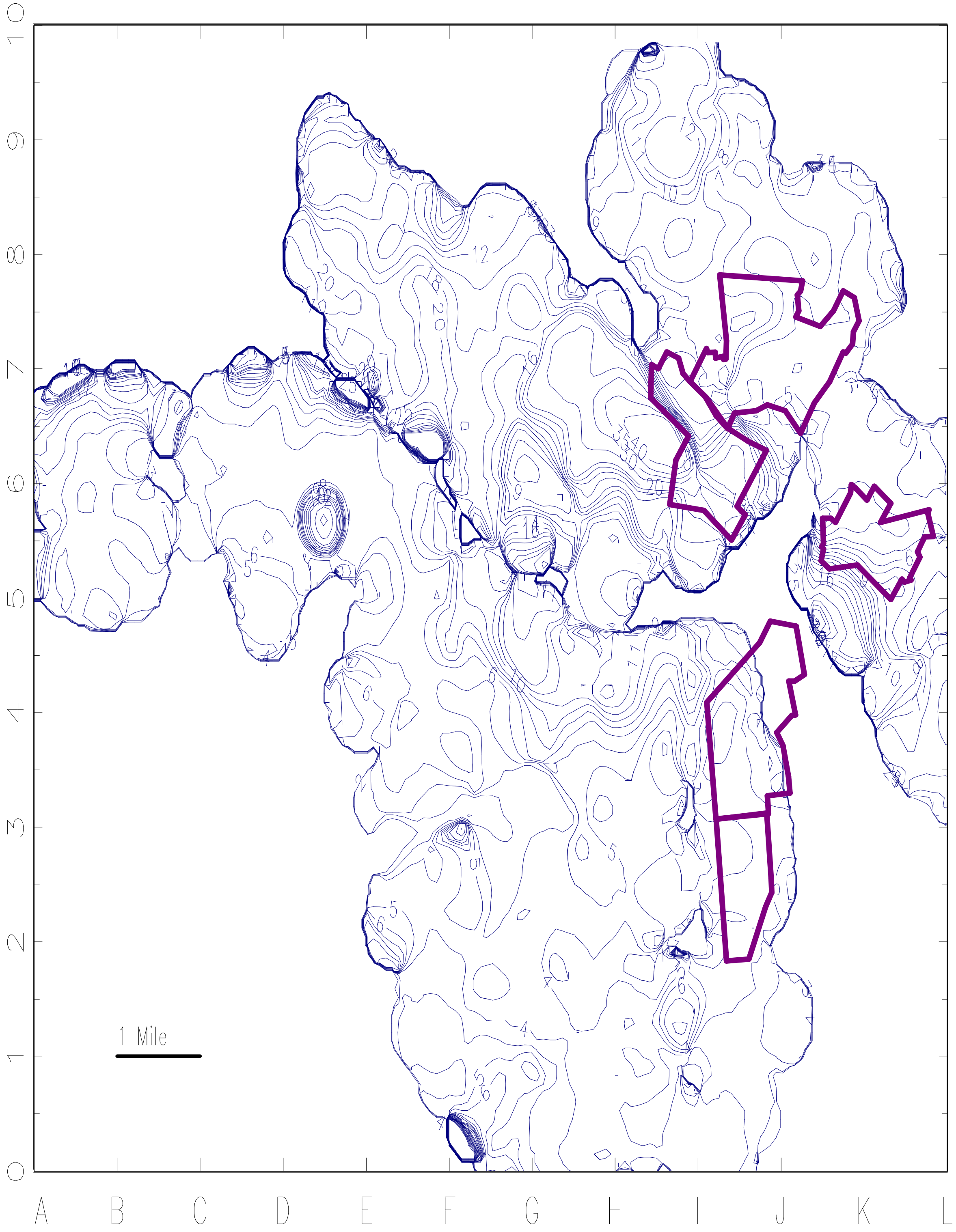
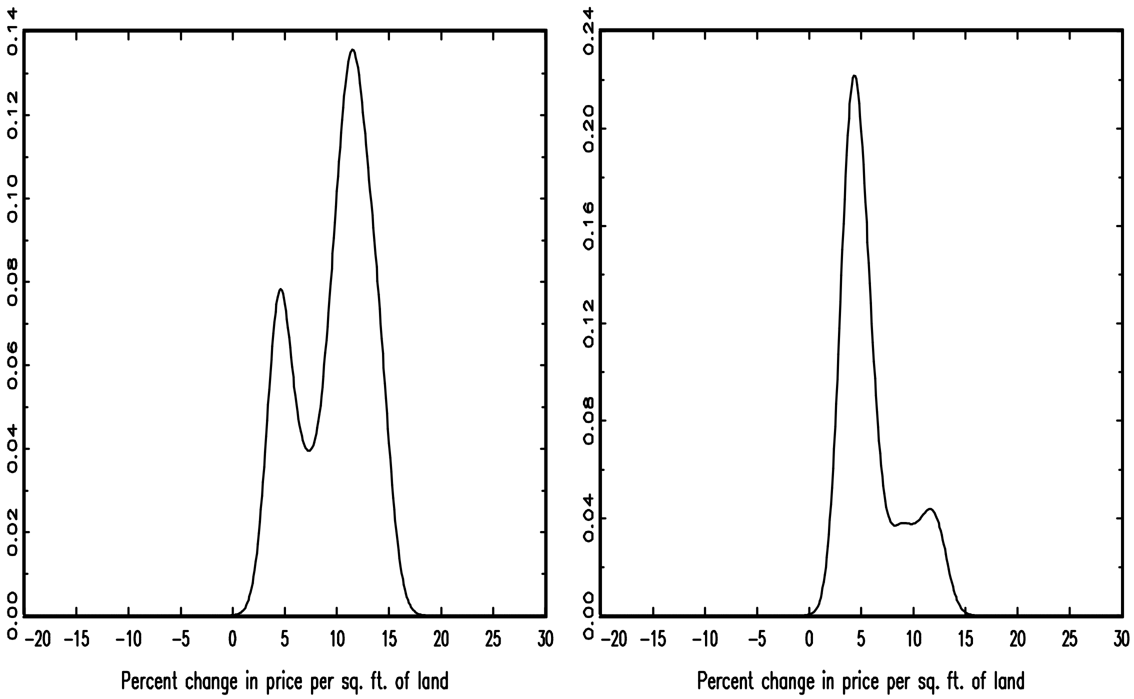
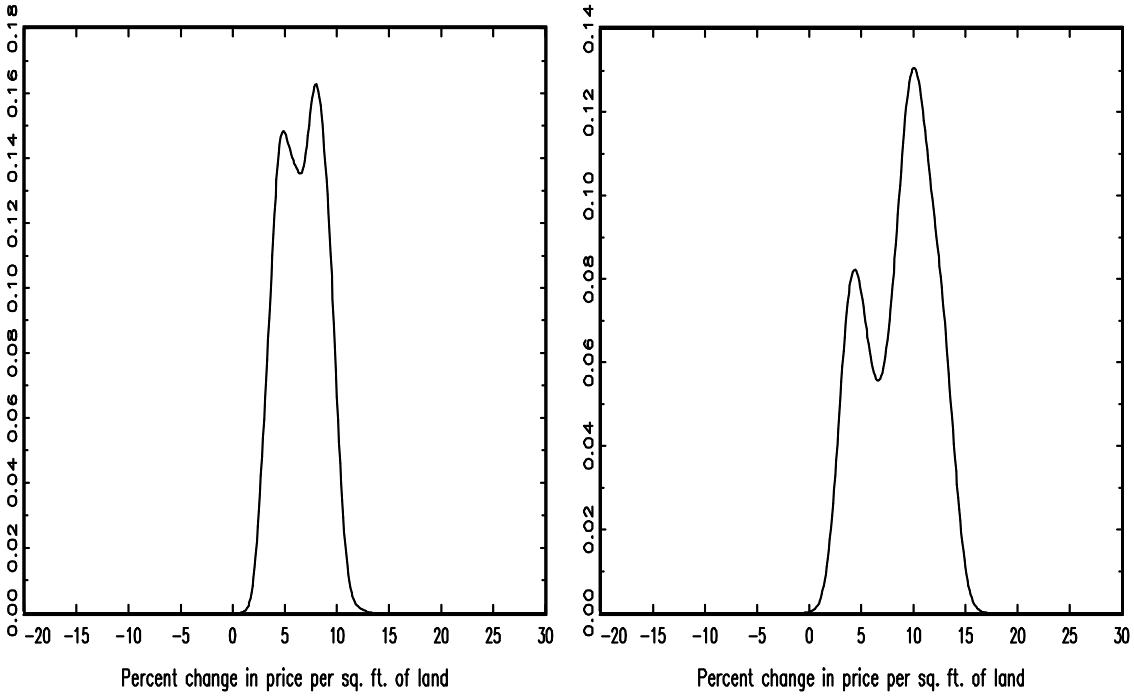


Figure 4: Pre-NiB land prices per square foot in Richmond


A. Church Hill

B. Blackwell


C. Highland Park and South Barton Heights

D. Jackson Ward and Carver

Figure 5: Distribution of changes in land value in the neighborhoods targeted by NiB

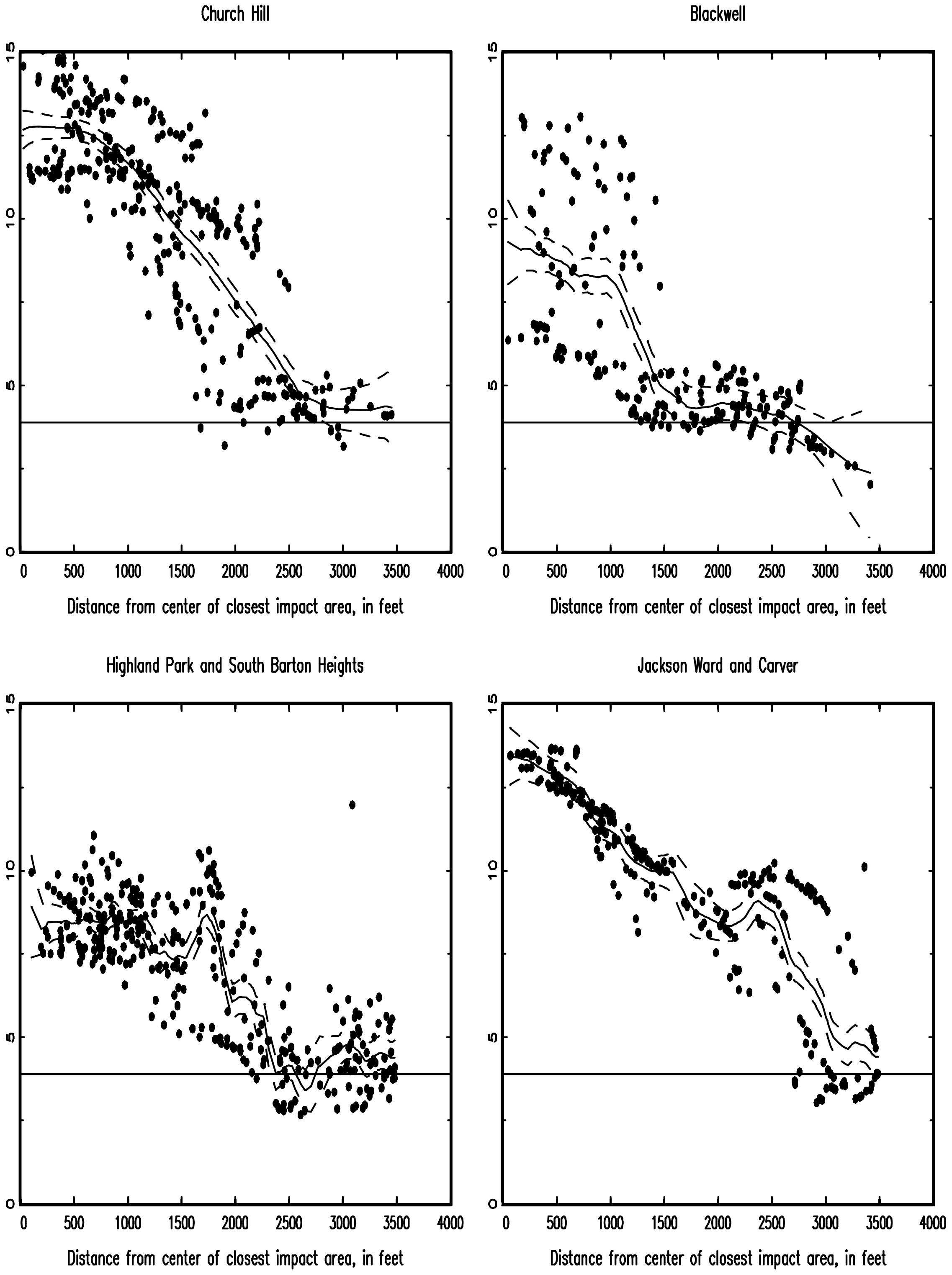


Figure 6: Change in the return to land with distance from the impact area

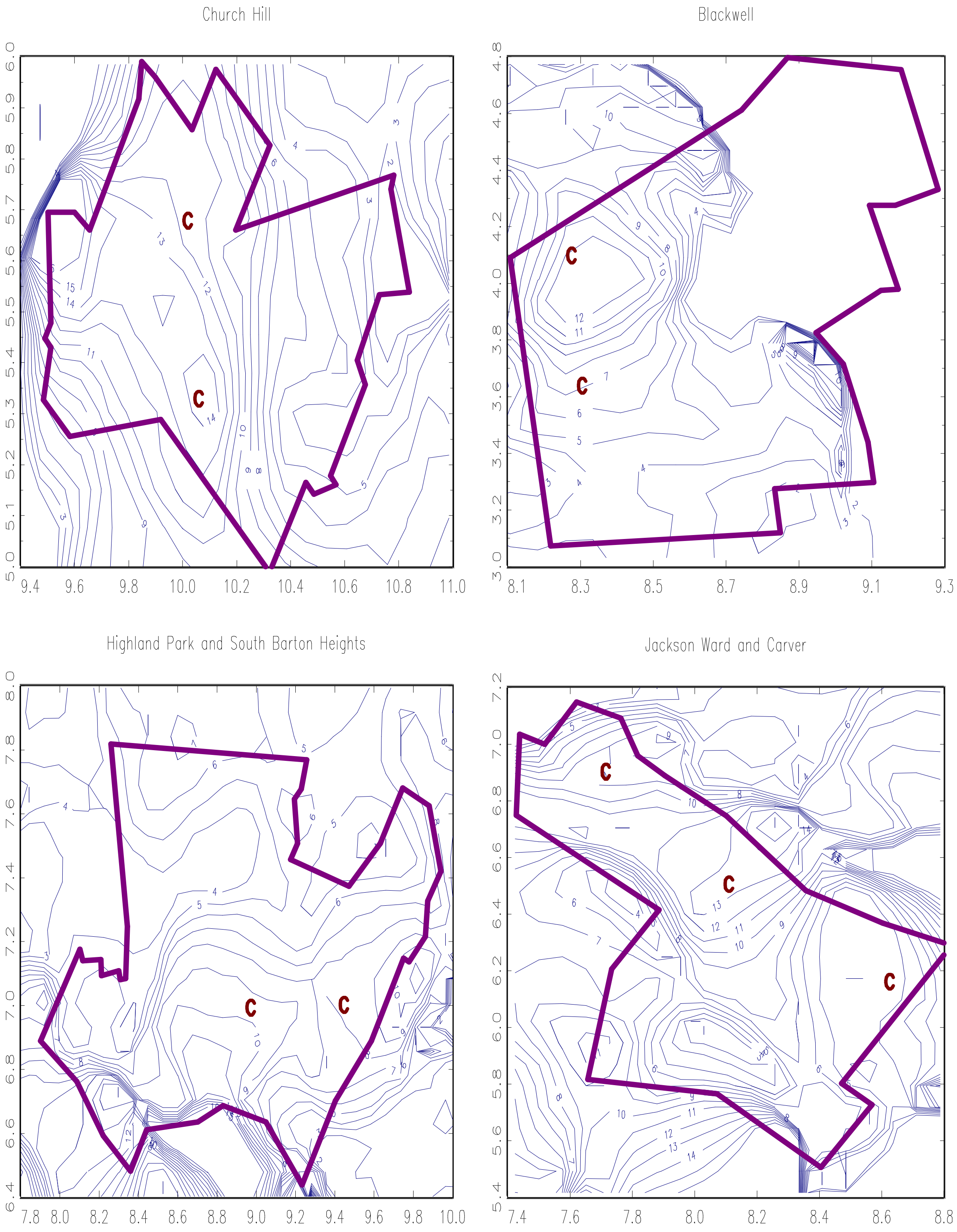
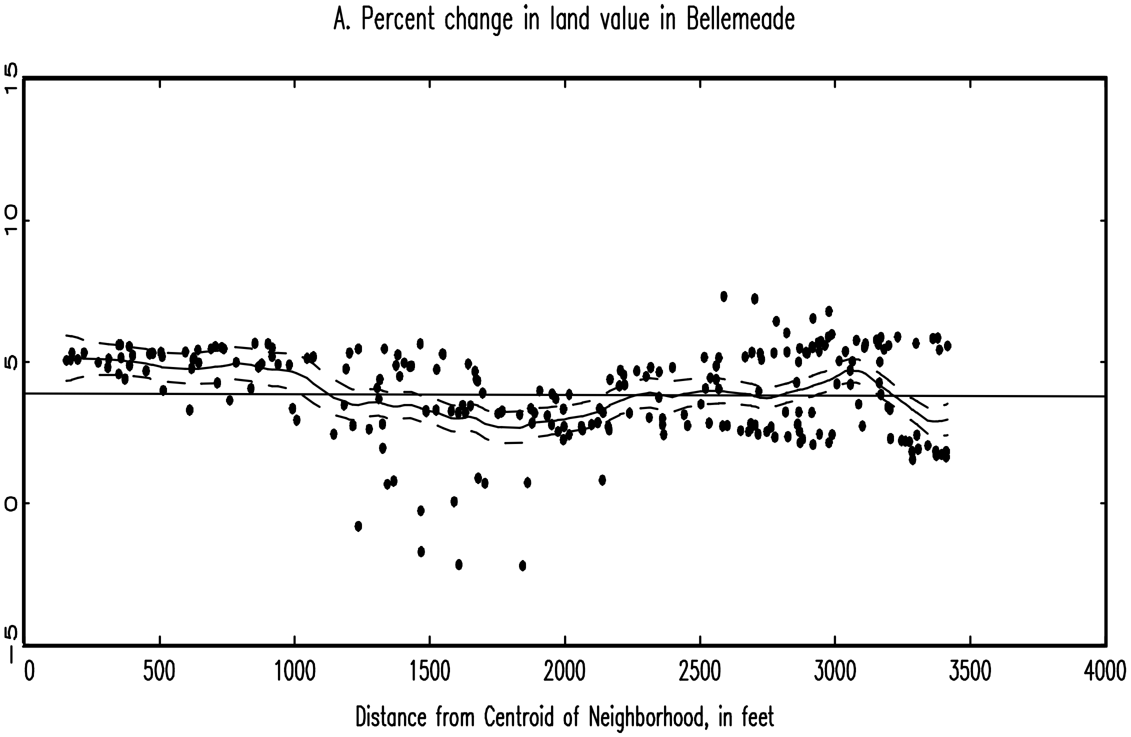


Figure 7: NiB returns to land


A. Percent change in land value in Bellemeade

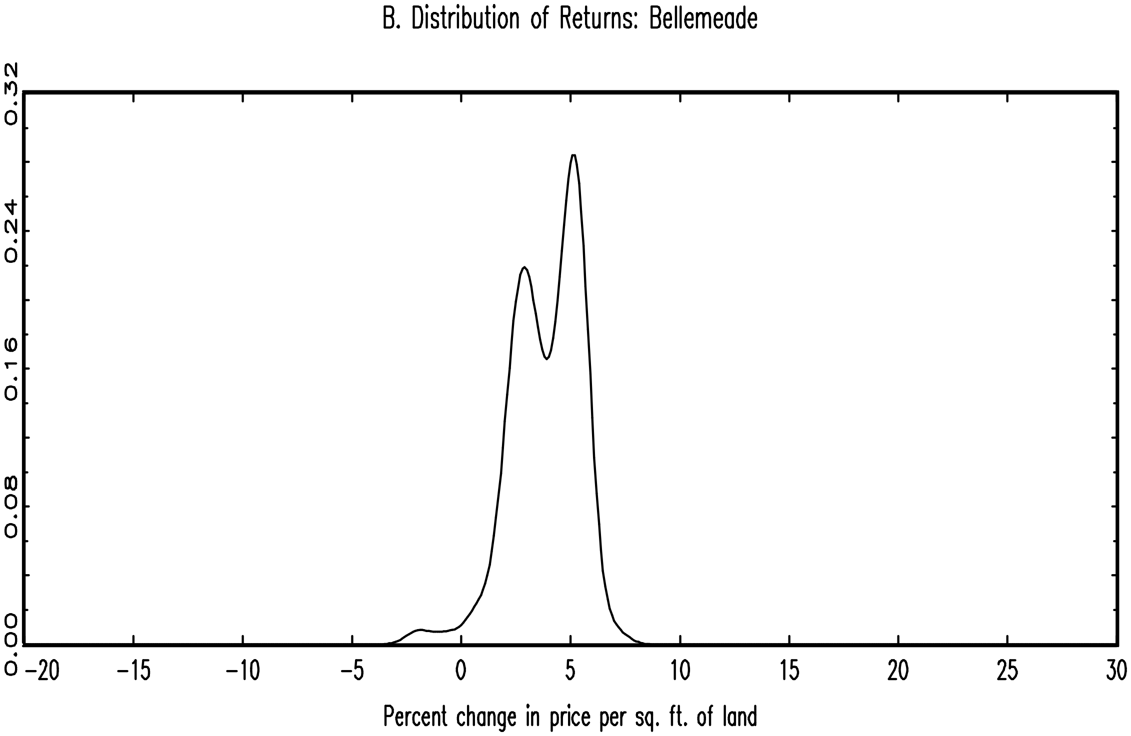

B. Distribution of Returns: Bellemeade

Figure 8: Returns to land in the control neighborhood

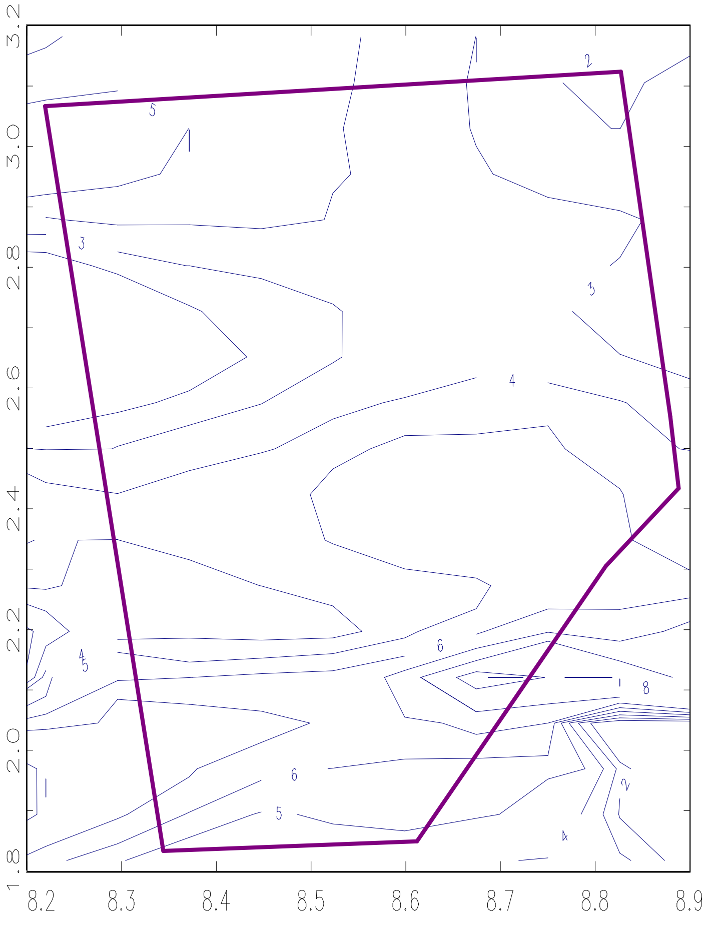
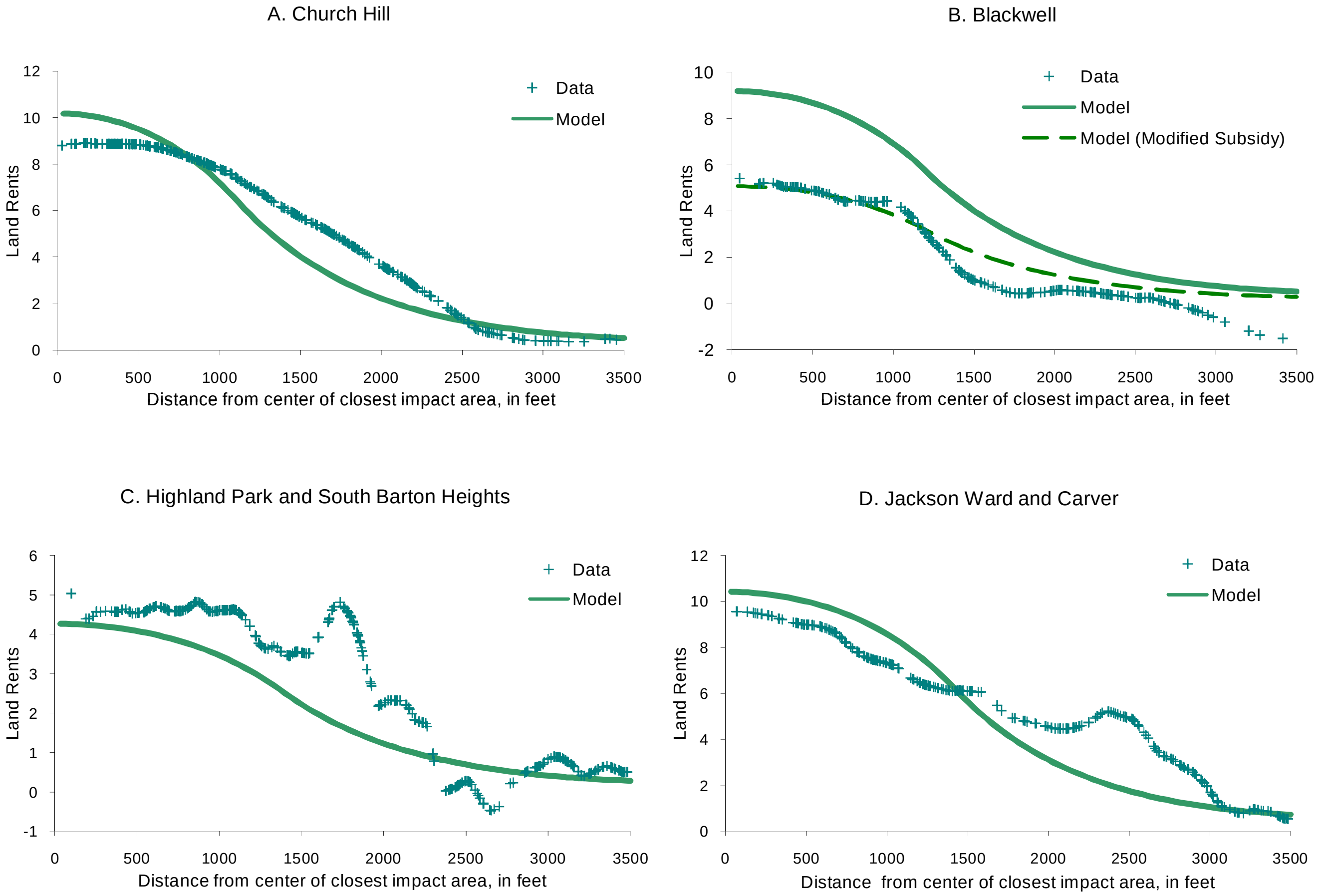


Figure 9: Contour of land price gains in Bellemeade



A. Church Hill

B. Blackwell

C. Highland Park and South Barton Heights

D. Jackson Ward and Carver

Figure 10: Calibrated model and nonparametric estimates of land returns