Housing Externalities

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Using data compiled from concentrated residential urban revitalization programs implemented in Richmond, Virginia, between 1999 and 2004, we study residential externalities. We estimate that housing externalities decrease by half approximately every 1,000 feet. On average, land prices in neighborhoods targeted for revitalization rose by 2–5 percent at an annual rate above those in a control neighborhood. These increases translate into land value gains of between $2 and $6 per dollar invested in the program over a 6-year period. We provide a simple theory that helps us estimate and interpret these effects in terms of the parameters of the model.

I. Introduction

The location of a house is fundamental in determining its price. Accessibility to the workplace and stores is an important determinant since it saves time on commuting. Other key determinants include the quality of surrounding houses, green areas, streets, and other characteristics of

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neighbors. These considerations imply that residential areas involve a variety of nonmarket interactions between residents and their houses that, at any given location, are reflected in the price of land. Put another way, it is the location of a house that gives it access to these nonmarket interactions, which therefore will be reflected in the price of land. Because households cannot affect the intensity of nonmarket interactions through their own decisions, these interactions are external to them. We refer to these nonmarket interactions as housing externalities.

Housing externalities imply that equilibrium allocations will differ from efficient outcomes and hence potentially justify a role for government intervention. As a result, quantifying the magnitude and characteristics of these externalities (e.g., how they decline with distance) is essential in understanding the impact of urban policy. It is also critical in assessing the effects of events such as the large foreclosure wave observed in 2008 and at the beginning of 2009. Specifically, we cannot measure the impact of investing in the beautification of a block of houses, or the abandonment of a house, without understanding the effects of such an event on the value of neighboring land. In this paper, we study the magnitude and characteristics of housing externalities. In particular, we are interested in the effects of housing externalities on average land prices and how fast these effects decline with distance.

The standard problem in measuring spatial externalities 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 spatial externalities 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 program.

We describe the program and its associated policies in detail in Section II. 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 to estimate land prices before and after the policy was implemented using a hedonic regression. Taking into account citywide 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 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 III. 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 1,000 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 Neighborhoods-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 citywide changes and, potentially, general equilibrium effects induced by the Neighborhoods-in-Bloom policies. That said, as indicated in Section II, 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 nonobservables 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 physical and demographic characteristics almost identical to those of neigborhoods 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 noneconomic 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: first, 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. Second, we compute average land price increases in the control neighborhood and show that they fall significantly short of those measured in the targeted neighborhoods. An additional finding that gives us confidence in using the control neighborhood to measure the magnitude of housing externalities is that while land returns in the targeted neighborhoods are elevated near the impact area, they eventually converge to levels that are close to the average land return in the control neighborhood away from the impact area. The theory predicts precisely this outcome. We 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 6-year period.

While much has been written about the nature and characteristics of spatial externalities, most studies have focused on the manifestation of these externalities between producers. As a result, virtually all urban theories have these producer-based spatial externalities (either pecuniary or nonpecuniary) at their core.[1] Much less has been written about spatial externalities among residents. To the best of our knowledge, there have been only a few studies of housing externalities that rely on a policy experiment with individual housing transaction data, and none in which the experiment was spatially concentrated to the degree of Neighborhoods-in-Bloom. In Section V, we compare our findings with other work that exploits parametric approaches to measure the decline in externalities across space. In general, we find housing externalities that decrease somewhat more slowly with distance as compared to these parametric approaches. 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 since 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

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

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 II describes the Neighborhoods-in-Bloom program. Section III presents the model and the effects of housing subsidies on equilibrium outcomes. Section IV discusses our empirical methodology, and Section V presents our findings. Section VI offers concluding remarks. We also include two appendices, A and B, that discuss robustness checks of our empirical findings.

II. 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 the previous, more scattered approach.

To carry out this experiment, city officials began to identify potential areas for investment and to 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 Urban 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 nonprofit Local

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

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 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, Blackwell, Highland Park Southern Tip–South Barton Heights (from here on Highland Park–South Barton Heights), and Jackson Ward–Carver. An additional neighborhood, Bellemeade, was similar in terms of demographics and housing stock but was not ultimately included in the program. For reasons that we explain below, this last neighborhood will also prove useful in our analysis. The locations and size of these neighborhoods relative to the city of Richmond are shown in figure 1.

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 without NiB investment was viewed as

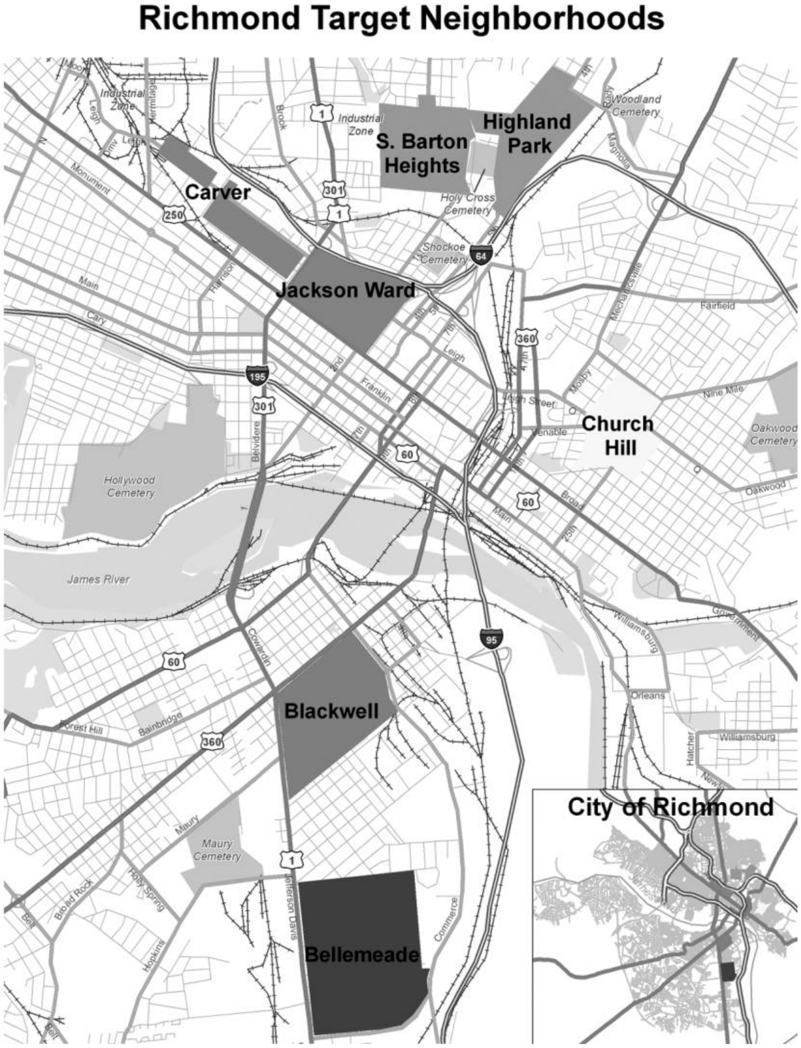

FIG. 1.—Overview of the NiB program, Richmond. Color version available as an online enhancement.

low. The neighborhoods also had active nonprofit 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 constitute the vast majority of investment activity in the neighborhoods. Tables 1 and 2 provide a summary of basic demographic and housing characteristics

TABLE 1
DEMOGRAPHICS OF SELECTED NEIGHBORHOODS

Neighborhood	Total Persons	Housing Units	Percentage Nonwhite	Percentage Below Poverty
Church Hill	1,505	822	94.8	27.2
Blackwell	1,376	651	97.0	35.8
Highland Park–South Barton Heights	2,763	1,227	97.2	26.3
Jackson Ward–Carver	1,975	1,332	81.7	29.5
Bellemeade	2,742	947	90.2	31.6
City of Richmond	197,790	92,282	61.5	20.3

TABLE 2
CHARACTERISTICS OF THE HOUSING STOCK IN NIB NEIGHBORHOODS

Neighborhood	Percentage Vacant	Percentage Owned	Average Plot Acreage	Median Price*	Price Standard Deviation
Church Hill	21.7	35.7	.07	14,861	29,244
Blackwell	23.2	32.6	.09	17,368	16,705
Highland Park–South Barton Heights	18.3	40.5	.14	33,223	24,740
Jackson Ward–Carver	31.5	36.0	.06	37,914	46,548
Bellemeade	10.8	51.4	.16	33,881	15,643
City of Richmond	8.4	46.1	.17	74,394	121,539

* 1993–98 housing price data are expressed in 2000 constant dollars.

of the selected neighborhoods using the 2000 Census and our housing data up to the start of the program in 1998.

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 often consist 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 composed 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 1999–2001 period, with yearly expenditures trailing off in the later years of the program.[3]

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 did not, ultimately, receive funding. Specifically, the neighborhood of Bellemeade lies in the eastern portion of the city, south of the James River (see fig. 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 1 and 2. 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 those 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.[4]

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[3] For more details about the program and another, less detailed, evaluation of the NiB program, see Galster, Tatian, and Accordino (2006).

[4] A question remains as to why there were fewer CDCs in Bellemeade than in the other neighborhoods in the first place, which potentially indicates a lingering selection issue. The results presented in Sec. V, however, suggest that this concern is limited.

III. A Model of Housing Externalities

This section provides a framework that helps one understand and interpret the effects of the urban renewal policies we have just described. More important, it helps underscore the importance of housing externalities in determining the effects of these revitalization policies. We develop a simple model of an open urban neighborhood. The neighborhood is open in the sense that the population, and therefore the size of the neighborhood given constant densities, varies to equate the utility of its residents to the level of utility elsewhere in the city.

The model we present incorporates three key features. First, it incorporates housing externalities using a linear function. That is, housing services experienced by agents depend linearly on the value of their own house, net of land rents, and a weighted average of the value of all other houses, net of land rents, where the weights decrease exponentially with distance. Measuring the rate of decline in these weights is a key target of our estimation in subsequent sections. Second, while all agents live on one unit of land (we impose a constant density), its price, $q(l)$, depends on the location of agents' houses and will reflect the value of location, l. Hence, we will use changes in the price of land induced by the revitalization policy to measure the magnitude and rate of decline in the effects of housing characteristics. Third, agents consume goods and housing services so as to maximize a Cobb-Douglas utility function. Consequently, the fraction of an agent's income spent on housing is a fixed parameter of the model. Davis and Ortalo-Magne (2007) argue forcefully that this is indeed a fitting assumption for the United States using cross-city evidence.

In the model we develop, a housing subsidy will be capitalized in land rents. It will increase land rents not only at locations with targeted houses but also at all other locations in the neighborhood. A subsidy that improves a particular house increases housing services enjoyed by its residents and, through housing externalities, housing services enjoyed by neighboring residents as well. This increase in housing services implies a change in the proportion of housing services to other goods consumed, so that agents adjust optimally by reducing their own expenditure in housing services. In other words, a subsidy implies additional wealth for residents of targeted houses and, through housing externalities, for other residents as well, which they then spend according to the fixed shares implied by their Cobb-Douglas utility. Therefore, living in or around a subsidized house allows agents to spend relatively less on housing and more on other consumption goods. This process leads to a bidding up of land rents throughout the neighborhood, which, by making land more expensive, counteracts the initial rise in wealth. Ultimately, this keeps absolute amounts of expenditures on consumption goods and utility constant but reduces expenditures on housing services. In the end, both the subsidy and its amplification through housing externalities are capitalized in land rents. The increase in land rents is larger in areas that are close to targeted houses since residents at those locations can reduce their purchases of housing services to a greater degree without reducing their actual consumption of these services. In this model, therefore, public subsidies crowd out private investments in houses and increase land rents.

The results we have just characterized follow from the three main assumptions outlined above. A modification of the model that makes housing investments complementary to the value of other houses may partially or completely eliminate the crowding-out effect we have just described. Most important, however, this change would not eliminate the capitalization of the subsidy in land rents. Similarly, moving away from the Cobb-Douglas preference specification would imply that as housing services become cheaper (either because of the direct subsidy or because of externalities), agents change the fraction of income they spend on housing, which could increase or reduce the crowding-out effect depending on their elasticity of substitution. Still, the capitalization of subsidies in land rents would remain. Because our aim is to measure the magnitude, and rate of decline with distance, of housing externalities capitalized in land rents, we proceed with a simple model that includes a positive crowding-out effect. We will also show in Section V that this simple model captures the shape of the housing externality quite well. We now turn to the actual model.

Consider a neighborhood represented by $\mathcal{N} = [-R, R]$, where R denotes the neighborhood's edge, with density of land equal to one. All agents living in the neighborhood are endowed with one unit of time. The production technology is linear and transforms one unit of time into w units of a final good. We assume that all agents commute outside the neighborhood to work and that the neighborhood is small relative to the city as a whole so that agents face the same commuting costs. In that sense, we interpret w as a wage net of commuting.

Agents' preferences are defined over housing services enjoyed at a given location, denoted by $\tilde{H}(l)$ for an agent living at l, and other types of consumption, $c(l)$. The only good in the economy can be allocated to either investment in housing or consumption. All agents live on a lot of size 1, which they rent from absentee landlords at rate $q(l)$. 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 $H(l)$ denotes investments in housing undertaken by an individual living at l, then

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

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 $\delta > 0$.[5]

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

$$\max_{c(l),H(l)} u(c(l), \tilde{H}(l)) = c(l)^{\alpha}\tilde{H}(l)^{1-\alpha}, \quad 0 < \alpha < 1, \tag{2}$$

subject to

$$c(l) + q(l) + H(l) = w, \tag{3}$$

and

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

where housing services produced at other locations, $H(s)$, are taken as given. The optimality conditions associated with problem (2) imply that

$$(1-\alpha)c(l) = \alpha\tilde{H}(l). \tag{4}$$

Substituting this condition into the agent's budget constraint (3) and using the equation describing the externality from housing (1) imme-

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[5] The specification in eq. (1) scales the externality by its rate of decline with distance, δ. This renders the aggregate externality received by a given house over an infinite interval independent of its rate of decline. One could choose an alternative normalization and govern the level of the externality with a different parameter, which would make fitting the model to the data somewhat easier. However, given the good fit between the model and the estimated land rent changes we obtain below, we abstract from this additional complication.

diately yields an expression for housing services obtained at l that depends only on prices and housing services enjoyed elsewhere,

$$\tilde{H}(l) = (1-\alpha)\left[w - q(l) + \delta\int_{-R}^{R} e^{-\delta|l-s|}H(s)ds\right]. \tag{5}$$

A. *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, $\bar{u}$. In equilibrium, therefore, individuals obtain utility $\bar{u}$ at all locations, which immediately implies that

$$\tilde{H}(l) \equiv \overline{H} = \bar{u}\left(\frac{1-\alpha}{\alpha}\right)^{\alpha}. \tag{6}$$

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:

$$H(l) = \overline{H} - \delta\int_{-R}^{R} e^{-\delta|l-s|}H(s)ds, \quad l \in [-R, R]. \tag{7}$$

Note that the operator defined by the right-hand side of (7) is a contraction,[6] and so a solution to (7) for any R exists and is unique by the contraction mapping theorem.

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 (5) and (6), land rents in the neighborhood are given by

$$q(l) = w + \delta\int_{-R}^{R} e^{-\delta|l-s|}H(s)ds - \frac{1}{1-\alpha}\overline{H}. \tag{8}$$

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

$$\delta\int_{-R}^{R} e^{-\delta|R-s|}H(s)ds = \frac{1}{1-\alpha}\overline{H} + q_R - w. \tag{9}$$

In summary, an equilibrium for the neighborhood is a function de-

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[6] It satisfies Blackwell's sufficient conditions for a contraction of monotonicity and discounting, since $\delta\int_{-R}^{R} e^{-\delta|l-s|}ds < 1$ as we show in the next subsection (see Stokey, Lucas, and Prescott 1989, 54).

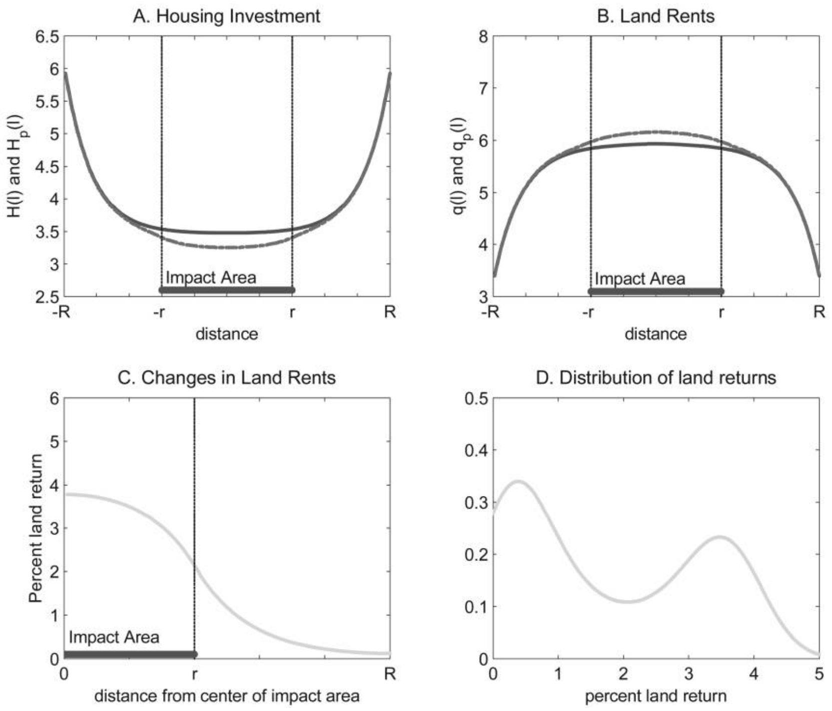

FIG. 2.—A model of housing externalities

scribing housing investments at all locations, $H(l)$, a function describing land rents, $q(l)$, a level of housing services, $\overline{H}$, and a boundary for the neighborhood, R, such that equations (6), (7), (8), and (9) are satisfied.

The solid curves in figure 2*A* and *B* depict typical equilibrium housing investment allocations, $H(l)$, and land rents, $q(l)$, respectively.[7] Housing investments are highest near 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

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[7] The parameter values used in this example are $\bar{u} = 13.25$, $\delta = 0.001$, $R = 3{,}500$, $A = 1{,}190$, $\sigma = 0.368$, $w = 25$, and $\alpha = 0.6$.

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.

B. 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 $H_p(l)$ denote the new equilibrium housing investment function that emerges after implementation of the policy. Similarly, let $\tilde{H}_p(l)$ 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 (6) so that $\tilde{H}_p(l) = \overline{H}$. Then, for $l \in \mathcal{N} \backslash \mathcal{A}$, $H_p(l)$ solves

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

where the last term in (10) captures externalities generated by the program and obtained at a location outside the impact area. For locations $l \in \mathcal{A}$ that are directly affected by the revitalization policy, we have that

$$H_p(l) = \overline{H} - \delta \int_{-R}^{R} e^{-\delta|l-s|} H_p(s) ds - \sigma\left(\delta \int_{-r}^{r} e^{-\delta|l-s|} ds + 1\right), \tag{11}$$

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 $H_p(l) - H(l) < 0$ for all $l \in [-R, R]$. To see this, note from equations (7) and (10), and abstracting from the direct subsidy, that for $l \in \mathcal{N}\backslash\mathcal{A}$,

$$\begin{aligned} H_p(l) - H(l) &= -\delta \int_{-R}^{R} e^{-\delta|l-s|}[H_p(s) - H(s)]ds - \sigma\delta \int_{-r}^{r} e^{-\delta|l-s|}ds \\ &= \sigma\delta\biggl(-\int_{-r}^{r} e^{-\delta|l-s|}ds + \delta \int_{-R}^{R} e^{-\delta|l-j|} \int_{-r}^{r} e^{-\delta|j-s|}dsdj \\ &\quad - \delta^2 \int_{-R}^{R} e^{-\delta|l-j|} \int_{-R}^{R} e^{-\delta|j-k|} \int_{-r}^{r} e^{-\delta|k-s|}dsdkdj + \cdots\biggr) \\ &< 0 \end{aligned} \tag{12}$$

since

$$\delta \int_{-R}^{R} e^{-\delta|l-s|}ds = \delta \int_{0}^{2R} e^{-\delta s}ds = -e^{-\delta s}\Big|_{0}^{2R} = 1 - e^{-\delta 2R} < 1,$$

so that $\int_{-r}^{r} e^{-\delta|j-s|}ds < 1$ as well. Alternatively, $H_p(l)$ is the fixed point of an operator, defined by the right-hand side of (10) and (11), that maps functions $H(\cdot)$ into uniformly strictly smaller functions than those defined by the operator on the right-hand side of (7). Hence, the contraction mapping theorem and its corollaries (see Stokey et al. 1989, 50–52) imply that $H_p(l) - H(l) < 0$ for all l.

To recall the intuition provided at the beginning of the section, as a result of housing externalities, the revitalization policy allows everyone in the neighborhood to enjoy more housing services given their initial expenditures. This effect may be interpreted as an increase in household wealth stemming from location, but this increase ends up fully capitalized in land rents. In other words, the additional wealth is entirely spent supporting the new value of locations so that agents, while benefiting from housing externalities, still receive the citywide level of utility. The result is a reduction in housing services purchased throughout the neighborhood ($H_p(l) - H(l) < 0$) but unchanged consumption of housing services, $\overline{H}$.

The direct effect of subsidies, of course, serves only to amplify this effect in the impact area. Put another way, equation (12) 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, $q_p(l)$, 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

$$q_p(l) - q(l) = \delta\left\{\int_{-R}^{R} e^{-\delta|l-s|}[H_p(s) - H(s)]ds + \sigma\int_{-r}^{r} e^{-\delta|l-s|}ds\right\} > 0. \quad (13)$$

We have already argued that the term in 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 income, w, affects land rents in the same way before and after the introduction of the policy (see eq. [8]), this feature is essentially differenced out and affects land prices only through changes in $H(\cdot)$ in equation (13). Note that since $q_p(l) - q(l)$ in (13) is simply the negative of the change in housing investments, $H_p(l) - H(l)$, in (12), it immediately follows that $q_p(l) - q(l) > 0$. Therefore, our assumption of Cobb-Douglas preferences with elasticity of substitution equal to one (which implies an unchanged $\overline{H}$ following the policy) and the linearity of (1) ensure that the implementation of the revitalization program is associated with higher land rents. As we argued above, this choice of preferences with respect to land and consumption is consistent with empirical work on cities. As usual, landowners ultimately end up the final beneficiaries of the subsidy and its amplification by way of housing externalities.[8]

The functional form governing how housing services enjoyed at one location are affected by housing services produced elsewhere in (1) is simple and matches well with our empirical findings (see fig. 10 below).

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[8] The assumption that residents do not own land is motivated by the fact that most residents in the targeted neighborhoods do not own their houses (see table 2). The main difference between our model and a model with ownership resides in income effects associated with increases in land prices. With absentee landlords, the increase in land rents implied by the policy benefits these absentee landlords directly. In a model in which all residents own the land on which they live, the increase in land rents will be compensated by an increase in their income (i.e., they would pay the land rents to themselves). This additional income (relative to the model with absentee landlords) will then be used to consume more goods and purchase more housing services in the shares implied by our Cobb-Douglas preference specification. The extra investment in housing will be amplified by way of externalities and further increase land prices. The fixed point of this problem results in the policy implying additional consumption and no substitution of housing investments. Hence, the final result is a larger increase in land rents and consumption in the neighborhood. Of course, such a model would yield very similar (although amplified) effects of housing subsidies, since it implies no crowding-out of private housing investments.

Other functional forms that incorporate complementarities between housing values would imply different effects from the revitalization policy on housing investments but a similar capitalization of subsidies in land rents. To the degree that these complementarities lead to additional increases in housing investments, controlling for changes in housing characteristics when estimating changes in land rents becomes more important. We address this concern in our empirical implementation below by estimating hedonic models that consider housing characteristics before and after the policy. Any remaining unobserved changes in housing characteristics potentially introduce an upward bias in our estimates of the magnitude of housing externalities.

In the end, as a result of the revitalization program, housing investments fall and land prices rise throughout the neighborhood. Agents spend a constant fraction of their income on 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 $\mathcal{A}$, housing investments decrease at all locations, $H_p(l) - H(l) < 0$ for all $l \in [-R, R]$, and land rents increase at all locations, $q_p(l) - q(l) > 0$ for all $l \in [-R, R]$.

The implications of the model we have just proven are illustrated in the numerical example depicted in figure 2. The new equilibrium land rents, $q_p(l)$, are described by the dashed curve in figure 2*B*. As we have just argued, these new land rents are everywhere higher in the neighborhood, and especially when close to the impact area. Figure 2*C* shows the percentage or log difference between postpolicy and prepolicy 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 2*C* 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 2*C*. 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 land rents that decline with distance from the center of the neighborhood, percentage changes in land rents produced by the revitalization program will generally be characterized by a bimodal distribution. This is shown in figure 2*D*. Keep in mind, from equation (13), that this bimodal aspect of land returns arises independently of the direct effect related to capital improvements in $\mathcal{A}$.

IV. 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 nontargeted sites. We are also interested in whether we can establish empirically that these external effects decline with distance in the way suggested by figure 2*C*. 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 $l = (x, y) \in \mathcal{R}^2$, 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:

$$p = \mathbf{Z}\boldsymbol{\beta} + q(l) + \varepsilon, \tag{14}$$

where $\mathbf{Z}$ is a k-element vector of conditioning housing attributes such that $\text{Cov}(\mathbf{Z}|l) = \Sigma_{z|l}$, $q(l)$ is the component of home prices directly related to location, and ε is a random variable such that $E(\varepsilon|l, \mathbf{Z}) = 0$ and $\text{Var}(\varepsilon|l, \mathbf{Z}) = \sigma_\varepsilon^2$. Since $\mathbf{Z}$ is measured in original units (not in logs), equation (14) amounts to a semilog specification that, in levels, implies $P = e^{\mathbf{Z}\boldsymbol{\beta}}Q(l)$, where P and $Q(l)$ denote the house price and land value in dollars at location l, respectively. While this semilog 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 $q(l)$. In particular, we do not assume that $q(l)$ lies in a given parametric family.[9] Our analysis will then focus on log land prices, $q(l)$, rather than on log home prices, p, directly.

We are interested in assessing the effects of NiB policies on the component of prices related to location, $q(l)$, in the various targeted neighborhoods described previously. This suggests estimating equation (14) both before and after the NiB policies come into effect. Because we are

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[9] The assumption of log separability between $\mathbf{Z}$ and $q(l)$ is made for computational simplicity and abstracts from a potential complementarity (beyond the one implied by the semilog specification) between the log of land values 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.

concerned 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 private investment (recall n. 8), it is conceivable that these programs induced a reshuffling of heterogeneous 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 conservative strategy is to omit the observations altogether.

Some key questions that the analysis will attempt to uncover are as follows: (i) How did the price of land change in each of the neighborhoods in figure 1, say from $q(l)$ to $q_p(l)$, 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?

A. *Data Description*

Our data set 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 nonresidential 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 are geo-coded, we are able to cross-check our two data sets and remove any property that directly benefited from NiB funding. In this sense, we aim to measure only the

TABLE 3
DATA SUMMARY

Variable	Mean	Standard Deviation	Minimum	Maximum
Sales price*	97,495	121,539	11	8,946,680
Air conditioning	.5716	.4949	0	1
Exterior:				
Wood and other exterior	.4985	.5001	0	1
Brick exterior	.4611	.4985	0	1
Vinyl exterior	.0404	.1970	0	1
Heating:				
Electric and central warm air	.6566	.4748	0	1
Gas heating	.1267	.3326	0	1
Hot water heating	.2167	.4120	0	1
Square footage	1,664.9	1,190.3	319	63,233
Age (in years)	63.78	26.46	0	205
Acreage	.2337	.3506	.012	37.67
Condition:				
Good condition	.1789	.3833	0	1
Average condition	.7878	.4088	0	1
Poor condition	.0196	.1385	0	1
Very poor condition	.0137	.1162	0	1
Number of bathrooms	1.546	1.245	0	9

* Expressed in constant 2000 dollars.

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 3. 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, its exterior type, and its heating type. 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, average, poor, or very poor condition.[10] Finally, we include among our conditioning variables, $\mathbf{Z}$, a set of time dummies that capture secular citywide increases in home prices driven by aggregate factors such as city population growth or interest rate changes.

B. Estimation of the Parametric Effects

In order to estimate the nonparametric component of equation (14), $q(l)$, we must first address the estimation of the parametric effects, $\boldsymbol{\beta}$.

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[10] Note that one of each of the binary housing characteristics must serve as a benchmark, since not all dummy variables can be included in the hedonic regression. In this case, we choose the most common attribute in each class as the benchmark (see table 4 below).

Let n denote the number of observations on home prices and k the number of variables in **Z**. A popular approach, pioneered by Robinson (1988), proceeds in two steps. In the first step, nonparametric (kernel) estimates of $E(p|l)$ and $E(\mathbf{Z}|l)$ are constructed. Since equation (14) implies that

$$p - E(p|l) = [\mathbf{Z} - E(\mathbf{Z}|l)]\boldsymbol{\beta} + \varepsilon, \tag{15}$$

the second step involves replacing the conditional means in (15) by these nonparametric 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 data set and given that separate nonparametric regressions are required for each housing attribute in **Z**, this method proves onerous in our case. To circumvent this problem, Yatchew (1997) and Yatchew and No (2001) propose a differencing approach that we adopt in this paper.

The basic idea behind Yatchew (1997) and Yatchew and No's (2001) estimation strategy is to reorder the data, $(p_1, \mathbf{Z}_1, l_1)$, $(p_2, \mathbf{Z}_2, l_2)$, … , $(p_n, \mathbf{Z}_n, l_n)$ so that the l's are close, in which case differencing tends to remove the nonparametric effects. In particular, first-differencing of (14) gives

$$p_i - p_{i-1} = (\mathbf{Z}_i - \mathbf{Z}_{i-1})\boldsymbol{\beta} + q(l_i) - q(l_{i-1}) + \varepsilon_i - \varepsilon_{i-1}. \tag{16}$$

Assuming that a Lipschitz condition holds for q, $|q(l_a) - q(l_b)| \leq L\|l_a - l_b\|$, the difference in nonparametric component in (16) vanishes asymptotically.[11]

Yatchew (1997) shows that the ordinary least squares 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 two-thirds efficiency relative to the one produced by Robinson's method. This can be improved dramatically by way of higher-order differencing. Specifically, define $\boldsymbol{\Delta}\mathbf{p}$ to be the $(n - m) \times 1$ vector whose elements are $[\boldsymbol{\Delta}\mathbf{p}]_i = \sum_{s=0}^{m} d_s p_{i-s}$, $\boldsymbol{\Delta}\mathbf{Z}$ to be the $(n - m) \times k$ matrix with entries $[\boldsymbol{\Delta}\mathbf{Z}]_{ij} = \sum_{s=0}^{m} d_s Z_{i-s,j}$, and similarly for $\boldsymbol{\Delta\varepsilon}$. The d_s's denote constant dif-

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[11] This condition represents a relatively weak smoothness requirement in the context of land prices when the data are ordered by location and the number of observations is large (as in this paper's application). In particular, the key is that the condition applies after the data have been reordered so that when the number of observations is large, adjacent locations in the reordered data will tend to be close. Hence, even in a city like Manhattan, we are unlikely to see land price changes that are arbitrarily large between adjacent locations.

ferencing weights and m governs the order of differencing. We thus estimate a more general version of equation (16),

$$\Delta\mathbf{p} = \Delta\mathbf{Z}\boldsymbol{\beta} + \sum_{s=0}^{m} d_s q(l_{i-s}) + \Delta\boldsymbol{\varepsilon}, \quad i = m+1, \ldots, n, \tag{17}$$

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

$$\sum_{s=0}^{m} d_s = 0 \quad \text{and} \quad \sum_{s=0}^{m} d_s^2 = 1. \tag{18}$$

The first condition ensures that differencing removes the nonparametric effect in (14) as the sample size increases and the reordered l's become "close." The second condition is a normalization restriction that implies that the transformed residual in (17) has variance σ_ε^2. When the differencing weights are chosen optimally, the difference estimator, $\boldsymbol{\beta}_\Delta$, obtained by regressing $\Delta\mathbf{p}$ on $\Delta\mathbf{Z}$ approaches asymptotic efficiency by selecting m sufficiently large.[12]

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 reordering of the l's is not unambiguous here since $l \in \mathcal{R}^2$. We reorder locations using a path created by a Hamiltonian nearest neighbor algorithm, and for our data set, this yields a mean distance between locations, $1/n\sum \|l_i - l_{i-1}\|$, that is 24–28 times smaller than that obtained by simply reordering locations according to their x or y coordinate (i.e., the wraparound method).[13]

C. *Nonparametric Kernel Estimation of q(l)*

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

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

$$q(l_j) = n^{-1}\sum_{i=1}^{n} W_{hi}(l_j)Y_i. \tag{19}$$

In other words, the component of home prices directly related to lo-

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[12] Optimal differencing weights, $d_0, \ldots, d_m$, solve $\min \delta = \sum_{k=1}^{m} (\sum_s d_s d_{s+k})^2$ subject to the constraints in (18). See Yatchew (1997).

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

cation, l_j, is a weighted average of the Y's in our data sample. The weight $W_{hi}(l_j)$ attached to each log price Y_i is given by

$$W_{hi}(l_j) = \frac{K_h(l_j - l_i)}{n^{-1}\sum_{i=1}^{n} K_h(l_j - l_i)}, \tag{20}$$

where

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

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 $q(l_j)$. In that sense, the bandwidth h has a very natural interpretation in this case.[14]

In sum, the log price of a house "purged" of the value of its characteristics gives us a set of residuals that represent, given our specification of housing prices, the value of land at given locations plus an error. Our kernel estimation then smooths out the residuals to recover the value of land at these locations. Because our theory centers on land rents, we assume that the value of land is proportional to land rents. However, since our work focuses on comparisons between a prepolicy and a postpolicy period, the constant of proportionality turns out to be unimportant in this case.

The NiB programs were first implemented in 1999 and nearly phased out by 2004. Consequently, we estimate equation (14) over two subsamples, 1993–98, the period prior to NiB coming into effect, and 1999–2004, the postrevitalization period for which we have data. The first and second subsamples contain 18,102 and 26,310 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 **Z** as the last year in each subsample period. All prices are measured in 2000 constant dollars, and we estimate land prices using

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

observations over the entire city of Richmond. In Appendix A we present findings for the same exercise when we restrict the hedonic coefficients on housing attributes to be the same throughout the entire sample.

V. Empirical Results

This section reviews our findings. We present estimates of the semiparametric hedonic price regression (14) and illustrate what they imply for citywide 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 in which no such public investment took place. Finally, we use this evidence to calibrate the model of housing externalities presented in Section III.

Table 4 presents estimates of the parametric components of equation (14). Virtually all housing characteristics in table 4 are statistically significant at the 5 percent critical level, and the large majority of these attributes are significant at the 1 percent level in both samples. In ad-

TABLE 4
ESTIMATES OF THE PARAMETRIC EFFECTS ON HOME PRICES

	1993–98 PERIOD			1999–2004 PERIOD	
VARIABLE	Coefficient	t-Statistic	VARIABLE	Coefficient	t-Statistic
1993	−.059	−3.453	1999	−.428	−30.206
1994	−.039	−2.381	2000	−.380	−27.401
1995	−.048	−2.924	2001	−.303	−22.513
1996	−.036	−2.203	2002	−.232	−17.316
1997	−.029	−1.874	2003	−.129	−9.718
Air conditioning	.094	7.752	Air conditioning	.078	7.900
Brick exterior	.152	11.386	Brick exterior	.186	16.173
Vinyl exterior	−.290	−8.636	Vinyl exterior	−.187	−8.250
Gas heating	.092	5.610	Gas heating	.154	10.317
Hot water heating	.101	6.624	Hot water heating	.066	5.210
Square footage*	.055	6.237	Square footage	.027	5.496
Age[†]	−.007	−.218	Age	.149	5.972
Acreage	−.815	−37.652	Acreage	−.423	−34.920
Good condition	.095	6.524	Good condition	.137	11.087
Poor condition	−.510	−11.864	Poor condition	−.375	−12.990
Very poor condition	−.867	−17.327	Very poor condition	−.613	−17.449
Number of bathrooms	.003	.479	Number of bathrooms	.010	2.251
Observations	18,102		Observations	26,310	
R^2	.64		R^2	.68	

* Measured in 1,000 square feet.

[†] Measured in 100 years.

dition, both specifications achieve a surprisingly good fit for cross-sectional data.[15]

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). Because our dependent variable measures the (log) price of a home per square foot of land rather than just the home price, the coefficient on "acreage" is negative. We estimate separate semiparametric hedonic price specifications over the pre- and post-1998 periods 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 4, however, tend to be relatively similar across subsamples. In Appendix A we show that alternative estimates that hold the coefficients on housing attributes constant across subperiods have immaterial implications for the results we present below.[16]

From table 4, our semilog specification suggests that having air conditioning increases the value of a house (per square foot of land) by 9 percent in the prepolicy period and by 8 percent in the postpolicy period. Similarly, a brick house is worth 15 percent more in the pre-NiB period and almost 19 percent more in the post-NiB period. In contrast, a vinyl exterior decreases the value of the house by 29 percent in the prepolicy sample and by 19 percent in the postpolicy sample. Both gas heating and hot water heating add to the value of a house, but the relative importance of each attribute switches pre- and post-policy. For a given lot size, an additional 1,000 square feet of living space adds 5.5 percent and 2.7 percent to the value of a house in the pre- and postpolicy periods, respectively. As mentioned earlier, because our dependent variable measures price per square foot of land, the coef-

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[15] It can be shown that

$$s_{\Delta}^2 = \frac{1}{n}\sum_{i=1}^{n} (\mathbf{\Delta p}_i - \mathbf{\Delta Z}_i\hat{\boldsymbol{\beta}}_{\Delta})^2 \xrightarrow{P} \sigma_{\varepsilon}^2.$$

Hence, we compute R^2 as $1 - s_{\Delta}^2/s_p^2$.

[16] As noted by Bailey, Muth, and Nourse (1963) as well as Case and Shiller (1987), any differences in the hedonic coefficients between the pre- and postpolicy periods can reflect, in part, the fact that a different set of houses was sold in the two periods. One way to address this issue is to use only repeat sales in the hedonic regression. In our case, the number of repeat sales, particularly in the targeted neighborhoods, is not sufficient to obtain accurate estimates of the price of housing characteristics and, more important, land prices because of the local averaging in the nonparametric portion of the estimation. Hence, we use all sales in our exercise. To assess the importance of this potential problem, in App. A we repeat the exercise while restricting the hedonic coefficients to be identical pre- and postpolicy. This alternative approach results in almost identical rates of decline and magnitudes of the housing externalities. We conclude that sample selection in the regression of the hedonic coefficients does not appear to be a key driver of our results.

ficients on acreage are negative and imply that the value of a house with 0.1 more acre (the size of a typical NiB lot) decreases in value per unit of land by 8.2 and 4.2 percent in the pre- and postpolicy periods, respectively.

Of more central interest are the nonparametric estimates of land prices, $q(l)$, in both the targeted neighborhoods and the control neighborhood.[17] 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 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.

A contour map of the price of land per square foot for the city of Richmond before NiB is shown in figure 3. It is clear from the figure that the NiB neighborhoods are associated with some of the lowest land prices in the entire city.[18] Despite its relatively small area of 60 square miles, figure 3 suggests considerable variation in land prices throughout Richmond. Because lot sizes are relatively homogeneous throughout Richmond at around 0.1 acre, 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 5 focuses on the NiB neighborhoods more specifically and gives estimated land prices per square foot at different percentiles in comparison to the city as whole.

A. The Return to Land in the Neighborhoods Targeted by NiB

To relate our empirical findings to the theory in Section III 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 2*C*. Second, given the absence of

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[17] Land prices are estimated on a grid containing the coordinates of home sales in our prepolicy sample. Using the grid corresponding to postpolicy home sales instead does not change our findings.

[18] To capture policy effects that potentially extend beyond the areas initially targeted by NiB, we present our results for a broader definition of neighborhood described in Sec. V.A.

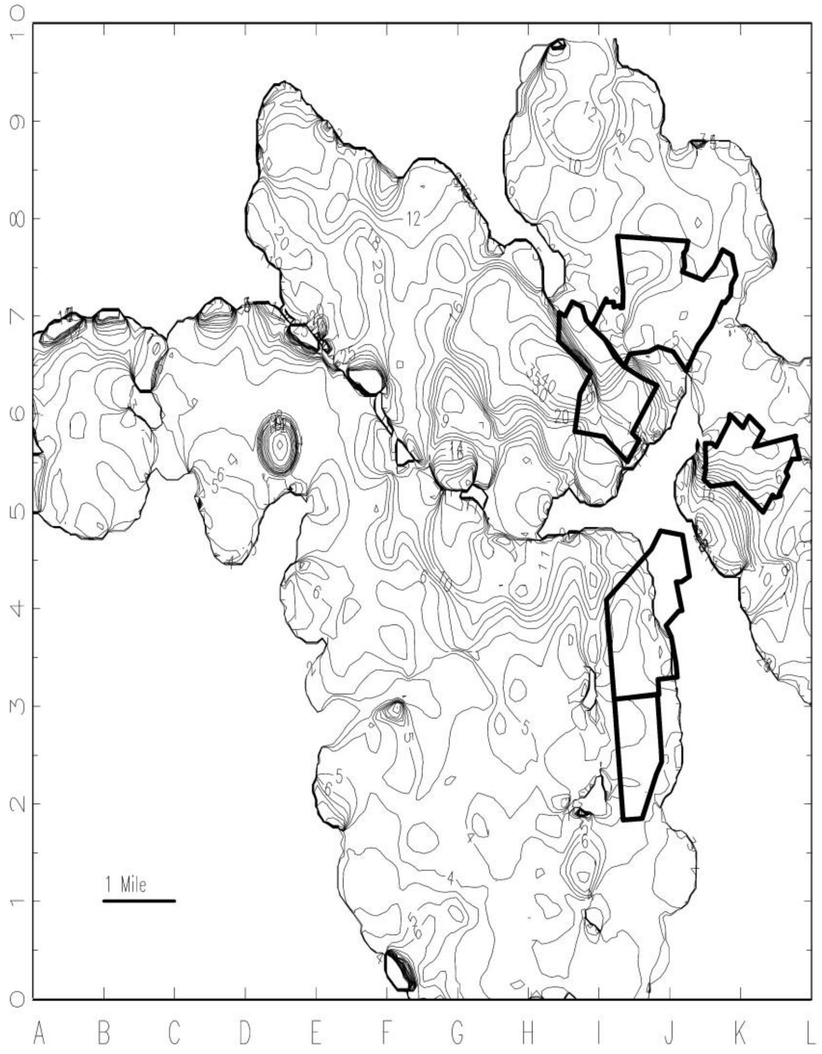

FIG. 3.—Pre-NiB land prices per square foot in Richmond

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 III. First, in contrast to our model, targeted neighborhoods in practice generally have more than one impact area. Second, for ease

TABLE 5

Pre-NiB Land Price per Square Foot

Neighborhood	Percentile 10th	 25th	 50th	 75th	 90th
Church Hill	.81	1.84	5.21	13.32	21.02
Blackwell	.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

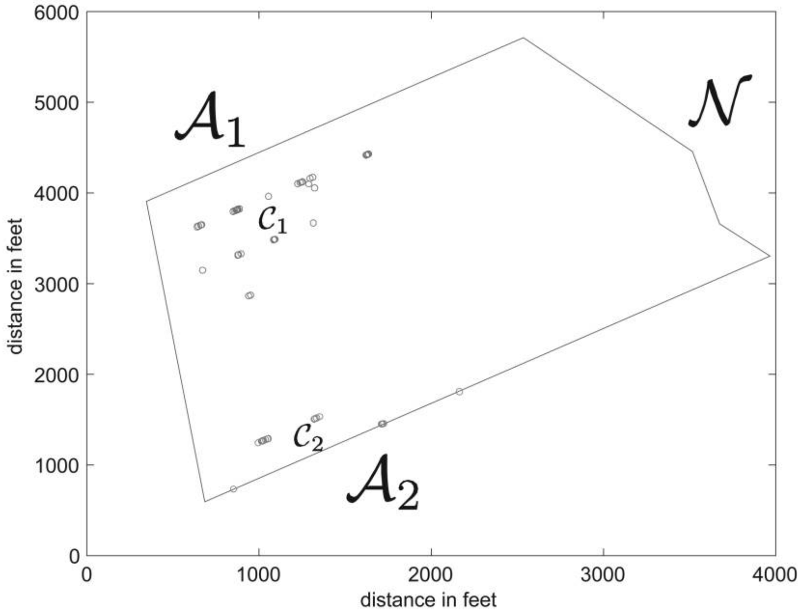

Fig. 4.—Funding locations and impact areas in Blackwell

of presentation, we must tackle the issue of how to present our estimates for $\Delta q(l)$, where $l \in \mathcal{R}^2$, in terms of distance from a focal point, $\Delta q(d)$, where $d \in \mathcal{R}$, analogously to figure 2*C*. 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 4 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 two such clusters shown in figure 4, 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 two disjoint subsets, $\mathcal{A}_1$ and $\mathcal{A}_2$, satisfies $\min \sum_{i=1}^{K} \sum_{n \in \mathcal{A}_i} \|l_n - \mu_i\|$, where $K = 2$ and l_n and μ_i are a location and the geometric centroid of $\mathcal{A}_i$, respectively.[19] 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 4. 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 4, benefits 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, $d(l) = \min_i \{\|l - c_i\|\}$, where c_i is the center of $\mathcal{A}_i$. We can then rank these distances from smallest to largest. In particular, the variable $d(l)$ 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 log 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).[20] 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 $d(l)$ covers a radius of 3,500 feet. In doing so, however, we are careful not to cross natural boundaries such as highways, railroad tracks, industrial zones, and so on that often arise before reaching 3,500 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, $\Delta q(l)$, in each of the NiB neighborhoods. Recall that $q(l)$ is estimated from log prices so that $\Delta q(l)$ measures percentage 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.

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

[20] Appendix B presents an alternative calculation that assesses the results from the standpoint of each location in a neighborhood relative to every funding project location in that neighborhood.

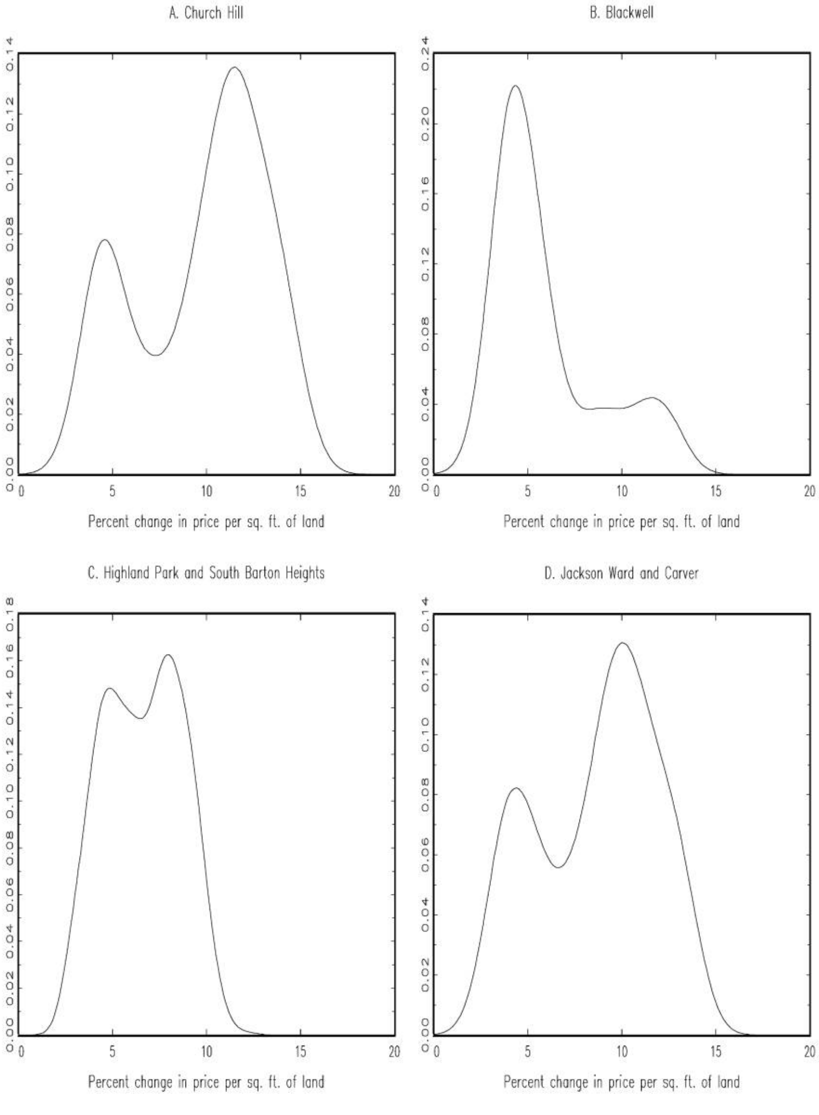

Fig. 5.—Distribution of changes in land value in the neighborhoods targeted by NiB

The question is whether, as in figure 2*C*, 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

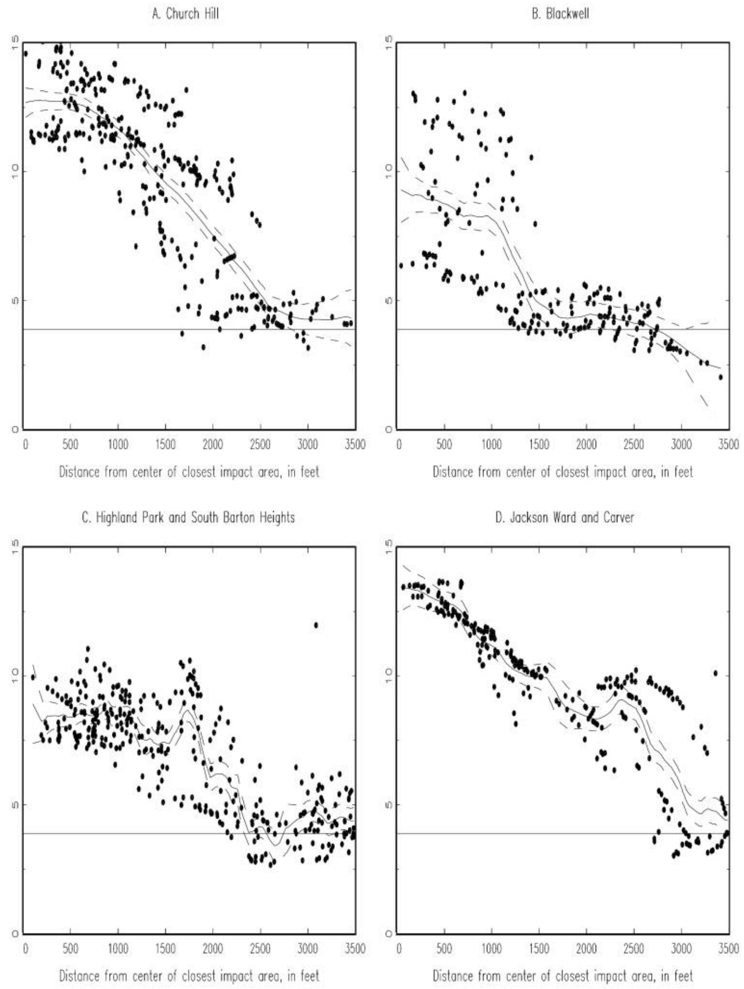

FIG. 6.—Change in the return to land with distance from the impact area

from the policy experiment increases.[21] Externalities 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

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[21] The curves shown in each panel of fig. 6 are Nadaraya-Watson kernel estimates computed as described in Sec. IV. The 95 percent confidence bands are based on standard errors at each distance, d, computed as $s(d) = \sqrt{b_K \sigma_\varepsilon^2 / h\hat{p}(d)n}$, where

$$\hat{p}(d) = \frac{1}{hn}\sum_{i=1}^{n} K\left(\frac{d_i - d}{h}\right),$$

$b_K = \int K(u)\,du$, and n is the number of observations in each panel.

(fig. 6*A*), most of the returns to land are concentrated around the upper tier, which explains a mode annual return of around 12 percent in figure 5*A*. In contrast, in the neighborhood of Blackwell (fig. 6*B*), most of the returns to land are located near the lower tier so that the mode return in figure 5*B* 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 (13) 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 2,500–3,500 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.[22] 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 figures 6 and 7?

B. Comparisons with the Control Neighborhood of Bellemeade

Figure 8 illustrates the behavior of changes in land value in the control neighborhood of Bellemeade. Figure 8*A* 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), and figure 8*B* illustrates the distribution of returns in that neighborhood. It is clear from the 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

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

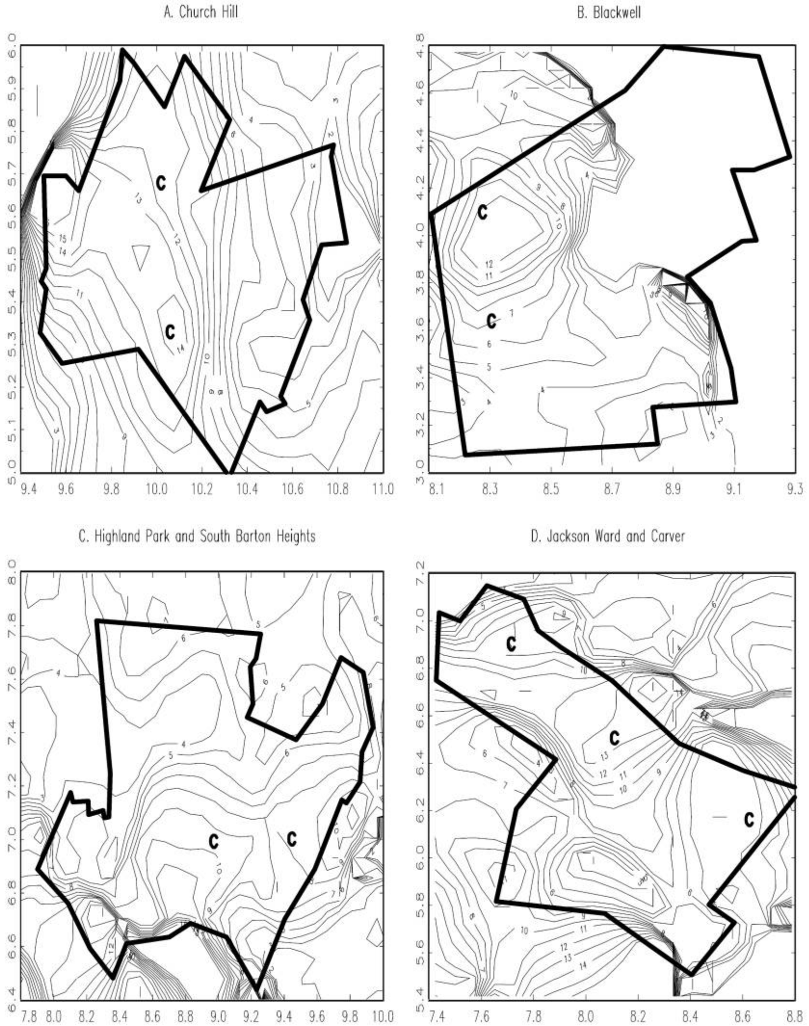
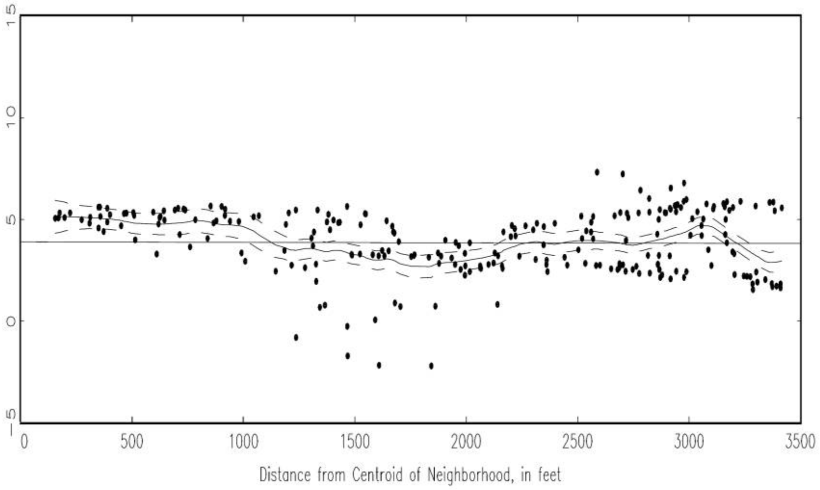


FIG. 7.—NiB returns to land

are also more concentrated around the mean (the solid line in fig. 8*A*) than those in the NiB neighborhoods and, in some cases, are even negative.

It seems clear from figure 6 and figure 8*A* 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

A. Percent change in land value in Bellemeade



B. Distribution of Returns: Bellemeade

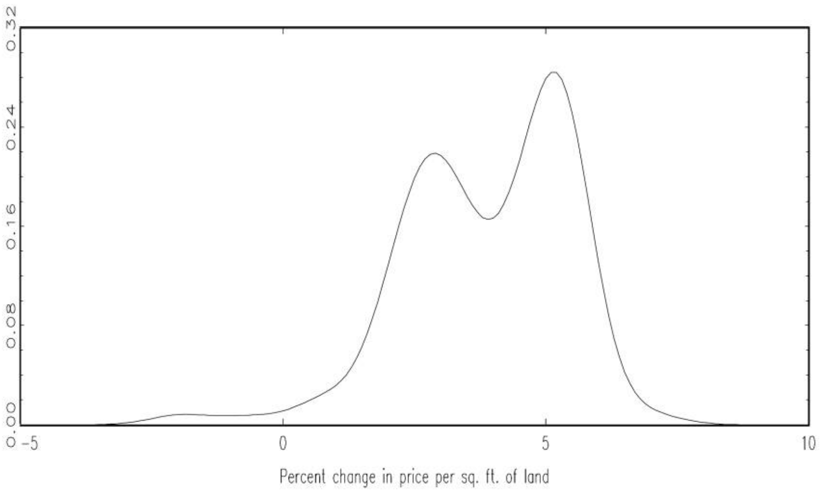


Fig. 8.—Returns to land in the control neighborhood

Bellemeade. This roughly implies a 24 percent increase over this 6-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–

Fig. 9.—Contour of land price gains in Bellemeade

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 1998–2004 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 question the extent to which our results are potentially affected by unobserved housing or neighborhood characteristics that are not taken into account by our empirical framework. One may also 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.

Regarding unobserved housing characteristics, what matters is whether their effects changed over the period under consideration. Recall that the object of interest is $\Delta q(l)$ and not $q(l)$ itself. In that respect, the estimated coefficients associated with observable housing attributes are encouraging in that they tend to be broadly similar across subperiods. A priori, there is little reason to think that this would not be the case for unobservable attributes as well. Still, the characteristics themselves, or other unobserved aspects of the neighborhoods more broadly, could have become more favorable during the postpolicy period and, if so, have increased the measured returns to land. This may bias our estimation of housing externalities upward but will not affect directly the rate of decline of these externalities with distance. There are two other aspects of the NiB neighborhoods, in particular, that merit attention.

First, active CDCs in the targeted neighborhoods could have increased other aspects of their operations (e.g., job training programs or other social services) in conjunction with their participation in the NiB effort. If so, our results compound the effects induced by the revitalization programs with the ramping up of other CDC operations and potentially overstate the increase in land returns stemming from housing externalities. Discussions with city officials directly involved with NiB suggest that other programs were neither enacted nor expanded during the period studied. Hence, although we cannot entirely rule out that minor changes in CDC operations could have had some effects on the land returns we estimate, these effects are likely moderate.

Second, the demand for a plot of land may depend, in principle, not just on what neighboring houses look like but also on who the neighbors are. In that sense, land price changes in the targeted neighborhoods would also reflect any changes in their demographic makeup during the NiB period. City officials also confirm that the NiB neighborhoods experienced virtually no change in the way of demographics over the postpolicy period, which, in fact, remain stable to this day. The demographic figures in table 1 come from the 2000 Census and were helpful because the date happened to correspond to just 1 year after the start of the revitalization programs. Census data, however, are available only at 10-year intervals at this level of detail, and we anticipate that the release of the 2010 Census figures will confirm the relative stability of the demographic structure of the NiB neighborhoods.

As noted above, the most important component of changes in demographics for our results concerns gentrification associated with a new population moving into the NiB neighborhoods and undertaking private investments, potentially driving up land returns over and above those induced by the revitalization policy. Aside from the points we have just discussed, several aspects of the analysis itself suggest that this consideration plays a limited role in this case.

Under the assumptions maintained in Section III, 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 assumptions that they are identical, they have Cobb-Douglas preferences, and externalities enter linearly in housing services. 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, $q_p(l) - q(l)$, in figure 2*B* upward. Returns to land near the boundary of the neighborhood, R, in figure 2*B* 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 8*A*. 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 simply, 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.

C. 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 III that gives us some sense of the size of the parameter δ. In accordance with consumer price index weights, we set the share of income spent on housing, $1 - \alpha$, to 0.32. Analogous 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 \$10 an hour and would be typical for residents of an NiB neighborhood. We set the radius of each neighborhood, R, to 3,500 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 1,085 feet in Church Hill, 1,190 feet in Blackwell, 1,365 feet in Highland Park–South Barton Heights, and 1,400 feet in Jackson Ward–Carver. If R is measured in feet, then the parameter σ in Section III 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

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

However, since the average size of a typical NiB plot in the data is around one-tenth of an acre (which corresponds to 4,356 square feet) and funding took place over a 6-year period (or 6 × 365 days), an appropriately scaled value for σ is $\tilde{\sigma} = \sigma \times [4{,}356/(6 \times 365)]$. This calculation yields NiB spending per square foot for the whole program 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. This leaves only the parameter $\bar{u}$, which we set to 33. The implied land rent at the edge, q_R, is then around \$780 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 notable exception of Blackwell. Generally, a value of 0.0007 for δ implies external effects from housing services that fall by half approximately every 1,000 feet. Note that except for Blackwell, 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.

Aside from differences in the geography of each NiB neighborhood, the discrepancy in Blackwell potentially reflects differences in the effectiveness of CDCs across neighborhoods. As indicated in Section II, 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, Blackwell is somewhat unique among the four neighborhoods in that, simultaneously with NiB, another program known as HOPE VI was actively engaged in eradicating housing stock deemed “unfit” but without, at the time, replacing it with new construction. Thus, some positive effects from the NIB revitalization projects might have been offset by HOPE VI. Of course, as discussed earlier, we cannot entirely rule out that land returns in the other three neighborhoods overstate the effects of housing externalities because of unobserved changes in housing or neighborhood characteristics and that Blackwell, in fact, provides the correct estimate.

Whatever the case in Blackwell, it is clear that a dollar of NiB funding produced less effect in that neighborhood relative to the other three neighborhoods. In Blackwell, NiB funding per square foot comes to \$5.61. 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 : 1.81), the model would have produced the dotted curve in figure 10*B*.

Our findings, therefore, suggest externalities that dissipate somewhat more slowly with distance than estimated in previous work. In particular, Schwartz et al. (2006), using data from a 10-year residential investment program in New York City, find residential externalities lasting out to 2,000 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 1,000–2,000 feet from a project site,

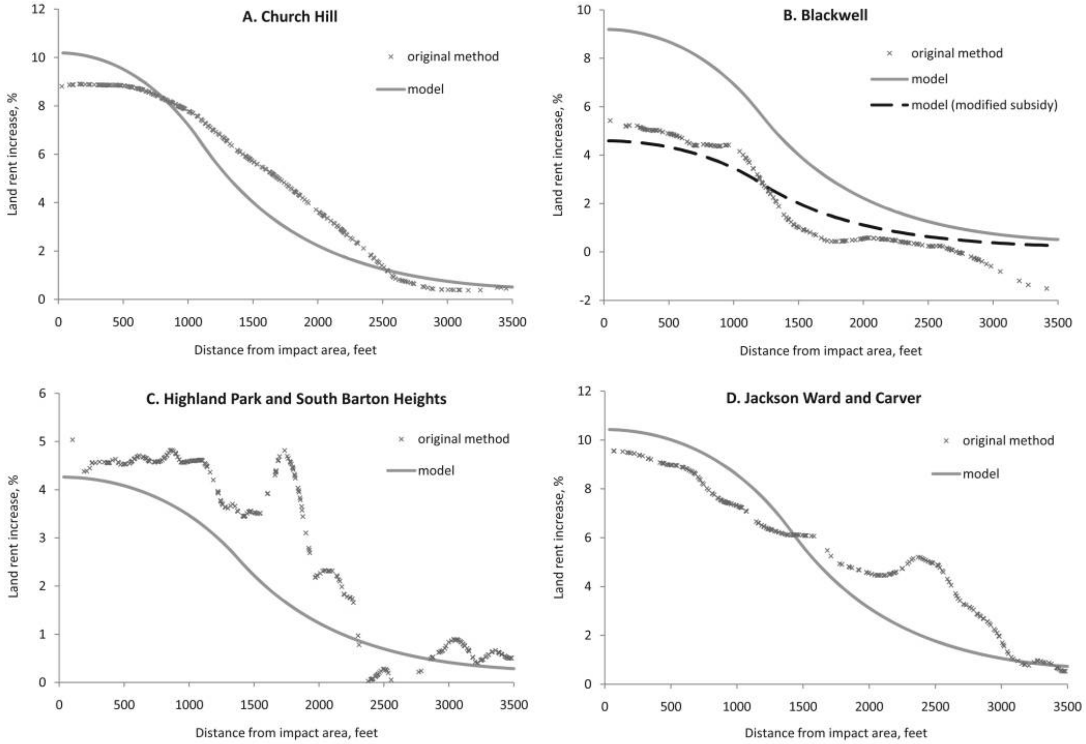


FIG. 10.—Calibrated model and nonparametric estimates of land return

TABLE 6
Neighborhood Land Values in 1998

Neighborhood	Number of Units (1)	Median Plot Value (2)	Neighborhood Value (3)
Jackson Ward	2,913	33,338	97,113,594
Highland Park	3,471	42,170	146,372,070
Church Hill	2,520	21,136	53,262,720
Blackwell	1,411	31,081	43,855,291

though the investments in that paper are specific to public housing, not simply housing investment. Simons, Quercia, and Maric (1998) and Ding, Simons, and Baku (2000), 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.

D. *Urban Revitalization Programs and Gains in Land Value*

This subsection 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 neighborhoods between 1998 and 2004, we wish to arrive at an estimate of overall land gains over that period for comparison.

From the City of Richmond, one can obtain the number of residential units in each of the targeted neighborhoods. These are shown in column 1 of table 6. Although consistent data on lot sizes for each of these units are unavailable, we can compute the median land value of a lot in each of the neighborhoods from our data set. In particular, we have lot sizes for homes that have sold in each neighborhood, which we can multiply by the exponential of our estimated log price per square foot of land, $q(l)$, 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 column 3 of table 6. 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 high as in Church Hill prior to the revitalization policy, with roughly 1.4 times the number of units.

To compute overall land gains in the targeted neighborhoods, column 1 of table 7 gives the (annualized) mean excess return to land in each

TABLE 7

Overall Land Gains and the Size of Urban Revitalization Programs

Neighborhood	Excess Return (1)	Neighborhood Gain (2)	NiB Funding (3)	Gain : Funding Ratio (4)
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

neighborhood relative to Bellemeade. Given the value of land shown in table 6 for each neighborhood, we can readily compute its overall gain between 1998 and 2004. These gains are shown in column 2 of table 7. Column 4 of table 7 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 5.5–6. 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. In any case, it remains that total increases in land value in each neighborhood (table 7, col. 2) generally reflect the intensity of the NiB program in that neighborhood (table 7, col. 3).[23]

At this stage, it is key to recognize that our results, in terms of both 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 7 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 7 are best interpreted as upper bounds.

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[23] In two of the neighborhoods, the estimated distributions of lot value turn out to be skewed to the right so that for the purposes of the calculations in tables 6 and 7, using median plot value likely provides a better approximation of neighborhood value. In Highland Park and Blackwell, average and median plot values are relatively close ($42,091 vs. $42,170 and $31,712 vs. $31,081, respectively). In Jackson Ward and Church Hill, however, average plot value is greater than median plot value ($40,156 vs. $33,338 and $31,446 vs. $21,136, respectively). Hence, to the degree that gain : funding ratios in table 7 potentially overestimate the effects of externalities, using average rather than median plot value only raises these estimates.

As a final thought experiment, we can compare the results shown in column 4 of table 7 with a more direct implication of the model in Section III. 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 circle of radius R around where the dollar is spent is given by

$$\rho = \delta \int_0^{2\pi} \int_0^R e^{-\delta s} ds d\theta = 2\pi(1 - e^{-\delta R}), \tag{21}$$

which is bounded between zero and 2π for given δ and R.[24] When R is 3,500 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 7 for three of the four neighborhoods.

VI. 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 1,000 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, over a 6-year period, 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, appears 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

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[24] To perform this calculation, we have adapted eq. (1) to a two-dimensional space in order to obtain a magnitude directly comparable to the calculations presented in table 7. The model presented in Sec. III is isomorphic to one with two dimensions as long as we restrict our attention to allocations that are symmetric around the center. It is straightfoward to show that such a symmetric equilibrium always exists.

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 $4.1 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 3.8 percent at an annual rate.[25] While this represents a reasonable excess rate of return, it is not one that obviously dominates other investment opportunities given the initial investment of $101.1 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.

Appendix A

Table A1 presents coefficient estimates associated with housing attributes when the coefficients are held constant across prepolicy and postpolicy samples. The estimates are obtained by running the parametric portion of our semiparametric hedonic model on a pooled data sample (instead of two separate data samples as carried out in the main text). We define 2004 to be the base year for all sales so that the coefficients on the time dummies for 1993–97 will now be different. However, note that when properly adjusted for a 1998 base year, these coefficients, as with all other estimates shown in table A1, differ only slightly from those shown in table 4. For example, for 1993, table A1 gives us $-0.640 - (-0.583) = -0.057$ compared to -0.059 reported in table 4. Similarly, for 1994, we have $-0.621 - (-0.583) = -0.038$ compared with -0.039, and so forth. Richmond real housing prices are relatively flat prior to 1998 but increase more significantly after that year. This explains why, in table 4, the coefficients on the 1993–97 time dummies relative to a 1998 base year are small relative to those in years 1999–2003 in the postpolicy sample.

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[25] When 673 percent is used as the rate of return over 6 years (see table 7), an investment of $4.1 million would yield approximately $28 million. Since the original investment to purchase the neighborhood is $97 million, the gross rate of return for a 6-year investment is approximately $(97 + 28)/(97 + 4.1) = 1.23$, which amounts to a net annual rate of return of about 3.8 percent.

TABLE A1
Estimates of the Parametric Effects on Home Prices

	1993–2004 Period	
Variable	Coefficient	*t*-Statistic
1993	−.640	−1.609
1994	−.621	−1.563
1995	−.630	−1.587
1996	−.618	−1.555
1997	−.613	−1.542
1998	−.583	−1.467
1999	−.429	−29.964
2000	−.380	−27.167
2001	−.305	−22.457
2002	−.233	−17.240
2003	−.131	−9.758
Air conditioning	.084	10.918
Brick exterior	.174	19.928
Vinyl exterior	−.221	−11.732
Gas heating	.128	11.590
Hot water heating	.080	8.162
Square footage*	.032	7.348
Age†	.085	4.288
Acreage	−.519	−48.809
Good condition	.118	12.458
Poor condition	−.422	−17.510
Very poor condition	−.704	−24.364
Number of bathrooms	.009	2.336
Observations	44,412	
R^2	.66	

* Measured in 1,000 square feet.
† Measured in 100 years.

As shown in figures A1 and A2, the main effect of imposing constant coefficients across housing attributes is a 2.8 percent upward level effect that is similar across all neighborhoods (mainly by way of citywide time dummies that are now slightly different). However, relative to the control neighborhood of Bellemeade, it is clear that figures A1 and A2 are nearly identical to figures 6 and 8, respectively. The NiB returns tend to converge to those of Bellemeade at about the same distances, land returns tend to be flat across Bellemeade, we continue to miss on the level of Blackwell returns, and so forth. Our conclusions regarding externalities, therefore, remain unchanged.

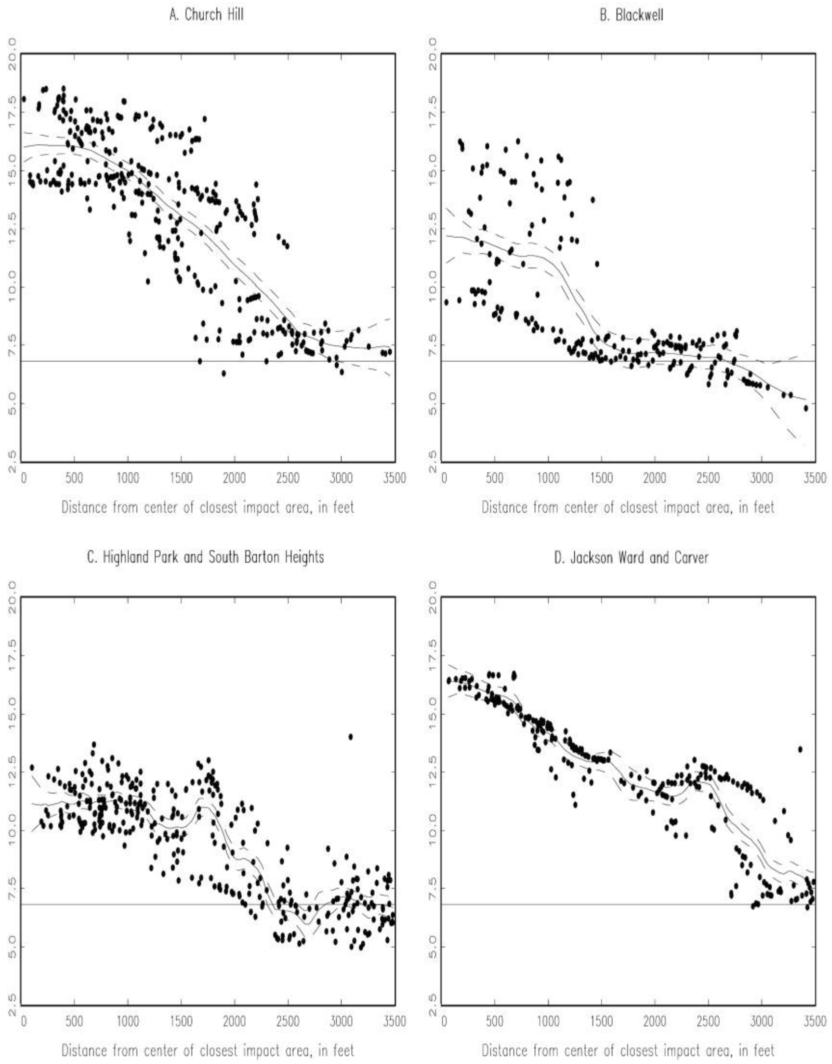

FIG. A1.—Change in the return to land with distance from the impact area with constant pre- and postpolicy hedonic coefficients.

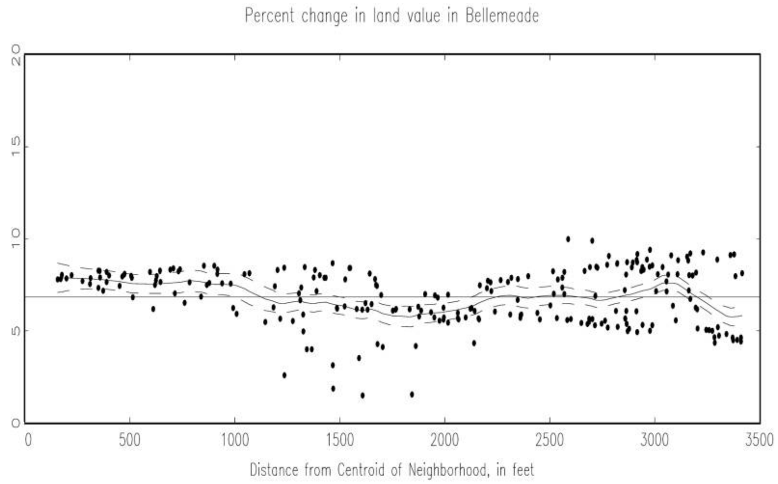

FIG. A2.—Returns to land in the control neighborhood with constant pre- and postpolicy hedonic coefficients.

Appendix B

In the discussion of our findings in Section V.A, we define funding centers within an impact area as the convex combination of locations that received funding within that area using relative funding as weights. We then examine how land price increases change with distance to the closest funding center. This exercise is meant to approximate our theory with a single impact area. Alternatively, one could view the results from the standpoint of every location in a neighborhood. In particular, for every location in a neighborhood, one can compute the distance from that location to every neighborhood funding project location and then examine how price increases change as a function of each location's average distance from the funding projects. One way to take funding investment into account is to weight the distances from a given location to each funding project by relative funds spent on that project. In this way, the (weighted) average distance ensures that distances to more substantially funded projects are given more weight in the analysis.

This alternative exercise in essence flips our original calculations around and will give a different answer because there are multiple impact areas in each neighborhood and locations within an impact area are treated differently under the two distance metrics. In particular, all points in figure 6, and thus the nonparametric curves in figures 6 and 10, will experience a rightward shift (because no location can now be adjacent to every funding project). Key for our purposes is that the rate of decrease in these curves, governed by δ in our theory, should stay approximately the same. Indeed, figure B1 illustrates exactly this point.

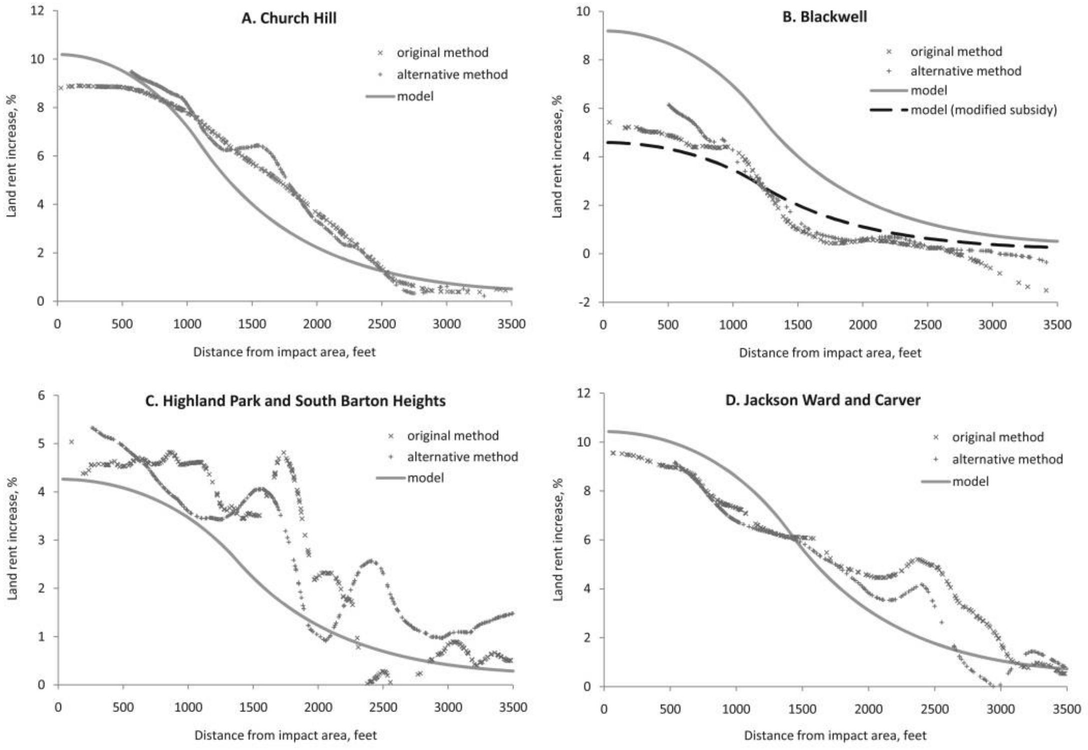

Fig. B1.—Calibrated model and alternative nonparametric estimates of land returns

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