Housing Upkeep and Public Good Provision in Residential Neighborhoods

Tammy Leonard

Department of Economics

University of Dallas

1845 East Northgate Drive

Irving, TX 75062-4736

Tel: 972-721-4110; TLeonard@udallas.edu

December 13, 2017

Abstract

Neighborhood condition is a public good in part provided by neighborhood residents' private property maintenance. Considering neighborhood condition as an impure public good provides a theoretical basis for understanding how the level of neighborhood quality may affect residents' home maintenance decisions. Empirical results in a low-income neighborhood, where formulating public policy to improve neighborhoods is of significant concern, indicate a positive substitution effect. When neighborhoods improve, residents respond by increasing exterior home upkeep. This result is robust to both changes in the neighborhood condition generated by other neighbors' increase in maintenance and exogenous public investment in the neighborhood.

Keywords: Public Goods, Neighborhoods, Joint Products

JEL Codes: H41, R23, D12

Acknowledgements: This work was supported by funding from the National Science Foundation (NSF/SES-0827350).

1 Introduction

Neighborhood condition affects the well-being of neighborhood residents. When neighborhoods improve many improved outcomes become more likely— property values increase (Dubin, 1992), neighborhoods become more aesthetically pleasing (Leonard et al., 2010), socializing among residents increases (Sampson, 2003), neighborhood children often benefit from improved stability (Schaefer-McDaniel, 2009), individuals engage in more outdoor physical activity (Saelens et al., 2003; Sallis and Glanz, 2006) and communities benefit from increased tax revenue. Likewise, the opposite can be said of neighborhoods in decay. Neighborhood condition is a public good whose provision is in some ways unique from other public goods considered in urban settings: exterior property maintenance or upkeep contributed by individual homeowners plays a significant role in the provision of neighborhood condition.

In this paper, residential property upkeep is examined as a source of contributions to neighborhood condition and the degree to which the contributions change with changes in the overall level of neighborhood condition is estimated. In doing so, I first develop a theoretical motivation for the study by framing neighborhood condition as an impure public good (Sandler and Culyer, 1982). This extension of the impure public goods model illustrates that the nature of the supply technology used to aggregate homeowners’ contributions to neighborhood condition is important. For example, is it the least maintained house on the block that brings down the neighborhood, or is neighborhood condition based more on the average house on the block? Secondly, complementarities in the public and private goods generated by home maintenance are critically important for understanding how neighborhood residents’ maintenance decisions should be expected to change in the face of changes in neighborhood condition. Rich longitudinal data detailing the quality and condition of parcels in a low-income residential neighborhood from 2009 through 2012 is used to understand how changes in condition impact individual property upkeep. Empirical results indicate a positive substitution effect. When neighborhoods improve, residents respond by increasing home maintenance. This result is robust to both changes in the neighborhood condition generated by other neighbors’ increase in maintenance and exogenous public investment in the neighborhood.

This paper aligns the literature examining social interactions within residential neighborhoods

with public economic theories regarding public good provision. For example, it has been posited that neighborhood social interactions can be motivated from two perspectives: a psychological motivation to "keep up" with ones neighbors, and financial incentives that come from improved property values (Ioannides and Zabel, 2008). Extension of the impure public goods model to the case of neighborhood condition gives theoretical grounding to both of these perspectives.

Additionally, this work is most relevant for the case of neighborhoods where homeowners associations or restrictive covenants are lacking. It is in these neighborhoods where home maintenance is most crucial. In particular, this work informs the extent to which a wide range of private, public or legal interventions on the housing stock might augment the housing maintenance behaviors of existing neighborhood residents. I argue that these issues are most crucial in low-income neighborhoods where the consequences of neighborhood decline are most severe. Hence, the empirical application focuses on such a neighborhood.

2 Background

2.1 Neighborhoods and Public Policy

The evolution of public policies impacting housing has increasingly suggested an important role for neighborhood context in influencing outcomes of neighborhood residents (Ioannides and Zabel, 2008). For example, the "Moving to Opportunity" (MTO) program by its design asserts that policy makers believe neighborhoods might matter, and despite lacking a complete understanding of how they matter, the conclusion that neighborhoods do matter for many outcomes remains intact (Sanbonmatsu et al., 2006; Katz et al., 1999; Clark, 2008). Apart from policy interventions such as MTO which exogenously change neighborhood conditions, most often households are affected by endogenous changes in neighborhood conditions. Thus a clearer understanding of how neighborhoods change is paramount to urban public policy (Jargowsky, 1997; Kawachi et al., 2003).

The condition and quality of residential neighborhoods has received elevated attention in the wake of housing market shocks such as occurred during the great recession. Several authors have documented neighborhood price declines associated with proximity to foreclosed properties (e.g.

Lin et al. (2009); Kingsley et al. (2009); Leonard and Murdoch (2009); Harding et al. (2009)) and there is considerable public concern about homeowner’s behavioral response to marked declines in neighborhood condition. Do homeowners eventually “give up” or do they stay and “make-up the difference”—attempting to compensate for the degradation of neighborhood condition posed by absent homeowners or vacant properties? Furthermore, is their scope for policy to step-in and stymie the deterioration of neighborhood condition? If so, most initiatives would hope to step-in in just the right way. Organizations such as Habitat for Humanity, for example, often aim to invest in neighborhoods in such a way as to improve the neighborhood condition trajectory, but then allow private investments by neighborhood residents (e.g. home maintenance) to continue that trajectory. Mixed-income development in which public and private housing developments coexist rely on residents’ in-kind response to public investments in the neighborhood for long-term neighborhood stability (Novack, 2014). However, relatively little is known about the economic efficiency of neighborhood revitalization efforts.

The public finance implications of the relationship between maintenance decisions and neighborhood condition are especially substantive for the case of low-income neighborhoods with the potential to suffer from significant quality degradation. Neighborhood decline jeopardizes the welfare of neighborhood residents contributing to the propagation of social problems that often impose high costs for society—such as crime (Sampson et al., 1997), and poor academic achievement for children (Caughy et al., 2013). Further, neighborhood decline reduces the property tax base used to fund programs to combat these problems. An increased understanding of the relationship between neighborhood condition and individual maintenance decisions may point to interventions that can stymie neighborhood decline before the deterioration process has fully taken hold.

2.2 Home Maintenance

Underlying the concern over dynamics of neighborhood condition, is a general intuition that neighborhood residents consider the overall level of neighborhood condition or the expected trajectory of neighborhood condition when making maintenance decisions. However, much of the economic literature considers only the individual aspects of the maintenance decision. Within

this literature, there are mixed results. Harding et al. (2000) finds that homeowners at higher risk of default as measured by higher loan-to-value ratios, spend less on home maintenance. However, Leonard (2013) found that during the housing market downturn of the great recession, many homeowner's increased their home maintenance expenditures, despite the fact that loan-to-value ratios had increased. Ioannides (2002) presents a possible explanation for the divergence in results. He finds that individuals invest more in maintenance activities when their neighbors also do. Additionally, Galster (1987) illuminates the complexities of the household's neighborhood investment decision.

The literature supports two motivations for individuals to contribute to their neighborhood's condition through property maintenance. First, there are tangible private benefits from doing so. Since individuals gain significant private utility from home maintenance, then private motivations may in fact be a large driver as suggested by the urban economics literature (Harding et al., 2000, 2007). However, neighborhoods are jointly utilized, and considerations for the maintenance decisions of others in the neighborhood and the overall quality of the extant neighborhood condition are also potential factors which influence household's home upkeep decisions (Ioannides, 2002; Ioannides and Zabel, 2008). In this respect, neighborhood condition may be considered as a public good (or bad).

Public good provision is generally characterized by free-riding whereby individuals contribute sub-optimally, depending instead on the contributions of others (Cornes and Sandler, 1996). However, viewed as an impure public good, home maintenance decisions may not be plagued by free-riding. The impure public good model provides a rationale whereby a household's maintenance decisions might be positively related to the overall level of public good in the neighborhood (i.e. neighborhood condition). In this case conformity or reciprocity, rather than free-riding, would be a better explanation for home upkeep decisions.

The remainder of this paper is divided into 5 sections. Section 2 describes the model with further implications discussed in Section 3. Section 4 details the data used for the empirical investigation that is described in Section 5. Finally, Section 6 concludes.

3 Theory

3.1 A Model of Impure (Very) Local Public Goods

Some local public goods are provided and utilized within very small geographic areas (e.g. neighborhoods or face blocks)—a much smaller geographic scale than the smallest "typical" jurisdictional boundaries (e.g. school districts, cities, or subdivisions). I refer to these types of public goods as *very* local public goods. Neighborhood condition is an example of such a very local public good. Furthermore, it is provided by activities that jointly produce private and public consumption goods. For instance, mowing ones lawn produces a nice environment for the household to enjoy (the private good) and aesthetic benefits for the neighborhood (the public good).

Previous literature has analyzed joint products in the provision of environmental amenities, the provision of national defense and others (e.g. Posnett and Sandler (1986); Murdoch and Sandler (1984)). Sandler and Culyer (1982) and Cornes and Sandler (1994) show that for the case of joint products, strong Hicksian complementarities in the joint public/private good can generate positive substitution effects. In other words, it is possible to have public good provision increase (decrease) when the level of the public good increases (decreases). Murdoch and Sandler (1984) in fact find evidence for this behavior in the case of military expenditures by NATO member countries.

To investigate the nature of substitution effects in the provision of neighborhood condition, we develop an impure public goods model for the case of very local public goods. In this case, neighborhood condition is provided through individual home upkeep decisions on the part of neighborhood residents. The model implicitly assumes that when neighborhood residents maintain their property, then neighborhood condition is *ceteris paribus* higher (i.e. better).

The theoretical model characterizes the behavior of household i who belongs to a neighborhood community of size I . Each household in the community can undertake upkeep activities q_i which jointly produces neighborhood condition contributions, n_i , and a private good, m_i . Neighborhood condition contributions are aggregated to create N , a public good for members of

the community. The production of n and m are given by

$$n_i = g_i(q_i) \tag{1}$$

and

$$m_i = f_i(q_i) \tag{2}$$

where f and g are concave functions with positive first derivatives. Each household's upkeep activity, q_i , may produce different levels of n_i and m_i ; and the marginal products, f'_i and g'_i may differ across households. The type of upkeep activity will influence the relative amounts of n and m produced. For example, exterior home maintenance activities likely produce a larger proportion of n (the public good) than interior home maintenance activities.

Households take as given the public good contributions produced by neighbors' upkeep activities ($\tilde{N}$). To the extent that the upkeep activities of neighbors increase N , spillover benefits for the household are generated. N , the level of the public good for the neighborhood, is generated from each household's production of n_i through the supply technology given by S :

$$N = S(\tilde{N}, n_i) \tag{3}$$

Recall that each household's production of n_i is given by $g_i(q_i)$. Thus, $\tilde{N}$ is a vector of functions $g_i(q_i)$, one for each $j \neq i$ household in the neighborhood.

An additional activity, x_i , is undertaken that produces exactly one unit of a private good representing "all other goods." Thus, x_i can be taken to represent both the activity and the private good. This private good serves as the numeraire good. The preferences of a representative household in the neighborhood are given by

$$U^i = U^i(x_i, m_i, N) \tag{4}$$

The utility function is assumed to be strictly concave and nonsatiable. Substituting (1) through (3) into (4) gives:

$$U^i = U^i(x_i, f_i(q_i), S(\tilde{N}, g_i(q_i))) \tag{5}$$

The household's preferences can then be represented in activity space:

$$V^i = V^i(x_i, q_i, \tilde{N}) \quad (6)$$

where $\tilde{N}$ is taken as given. The two utility functions, U and V , are related in that they must satisfy the following relationships for each individual:

$$V_x^i = U_x^i \quad (7)$$

$$V_q^i = U_q^i = f'_i U_m^i + g'_i U_N^i \quad (8)$$

$$V_{\tilde{N}}^i = U_{\tilde{N}}^i \quad (9)$$

where partial derivatives are indicated by subscripts (i.e. $\partial U^i / \partial x_i = U_x^i$).

Households face a budget constraint that considers both wage and non-house investment income (Y_i) and housing appreciation income (A_i):

$$Y_i + A_i(N) = x_i + pq_i \quad (10)$$

Households optimally choose between activities x_i and q_i by maximizing (6) subject to (10). Solving for the first order conditions and substituting (7) and (8) yields:

$$p - \frac{\partial A_i}{\partial N} \frac{\partial S}{\partial g_i} g'_i = f'_i MRS_{mx}^i + g'_i MRS_{Nx}^i \quad (11)$$

The left hand side (LHS) of equation (11) may be interpreted as the net marginal cost of additional upkeep activities. The demand for these activities is implicitly defined:

$$q_i = q_i(Y_i + A_i(N), p, N) \quad (12)$$

The empirical section will estimate (12). Of particular policy interest is the income and substitution effects associated with the demand for q_i . In order to explore the substitution and income effects, I follow the approach of Murdoch and Sandler (1984) by examining the dual to

the utility maximization problem– cost minimization. Given, equilibrium values of m_i , N and U_i , the conditional cost function is given by

$$c^i(m_i, N, U^i) = \min_c [c^i(x_i, m_i, N) \geq U^i] \quad (13)$$

$c_i(\cdot)$ is assumed to be twice continuously differentiable. Taking partial derivatives of $c_i(\cdot)$ with respect to m and N yields

$$\frac{\partial c^i(m_i, N, U^i)}{\partial m_i} = -MRS_{mx}^i = -\pi_m^i(m_i, N, U_i) \quad (14)$$

$$\frac{\partial c^i(m_i, N, U^i)}{\partial N} = -MRS_{Nx}^i = -\pi_N^i(m_i, N, U_i) \quad (15)$$

The MRS terms on the right-hand side (RHS) of (11) can now be written in terms of π_m^i and π_N^i . For simplicity, assume a 2-household neighborhood¹ with individual 1 choosing optimal allocations of q_1 and x_1 while taking individual 2's choice of q_2 as given. The first-order condition for individual 1, then becomes

$$p - \frac{\partial A^1}{\partial N} \frac{\partial S}{\partial g_1} g'_1 = f'_1 \pi_m^1(f_1(q_1), S(g_1(q_1), g_2(q_2)), U^1) + g'_1 \pi_N^1(f_1(q_1), S(g_1(q_1), g_2(q_2)), U^1) \quad (16)$$

Holding price constant and then taking the total derivative allows me to solve for the change in q_1 in response to an exogenous change in q_2 :

$$\frac{dq_1}{dq_2} = \left[\frac{\frac{\partial A^1}{\partial N} \frac{\partial^2 S}{\partial g_1 \partial g_2} g'_1 g'_2 + g'_2 (f'_1 \pi_{mN}^1 \frac{\partial S}{\partial g_2} + g'_1 \pi_{NN}^1 \frac{\partial S}{\partial g_2})}{\phi} \right] + \left[\frac{f'_1 \pi_{mu}^1 + g'_1 \pi_{Nu}^1}{\phi} \right] \frac{dU^1}{dq_2} \quad (17)$$

where

$$\phi = - \left[\frac{\partial A^1}{\partial N} \frac{\partial^2 S}{\partial g_1^2} (g'_1)^2 + \begin{pmatrix} f'_1 & g'_1 \end{pmatrix} \begin{bmatrix} \pi_{mm}^1 & \pi_{mN}^1 \frac{\partial S}{\partial g_1} \\ \pi_{Nm}^1 & \pi_{NN}^1 \frac{\partial S}{\partial g_2} \end{bmatrix} \begin{pmatrix} f'_1 \\ g'_1 \end{pmatrix} \right].$$

Since I have assumed that $A_i(\cdot)$ is linear in N , $\partial^2 A / \partial N^2 = 0$.² Except for the terms containing $\partial A^1 / \partial N$, $\partial S / \partial g_2$, and $\partial S^2 / \partial g_1 \partial g_2$ —which appear in both the numerator and denominator of

¹The results are easily transferable to the n-household community.

²There is little reason to believe that $\partial^2 A / \partial N^2$ should be large enough to influence the results that follow. Full results that account for a non-zero value for $\partial^2 A / \partial N^2$ are available from the author upon request.

(17)—the results are similar to those of the standard impure public goods model as described by Murdoch and Sandler (1984) and Cornes and Sandler (1994). However, these additional terms have important implications when determining the sign of the substitution effect for the case of neighborhood condition provision.

The denominator, ϕ , is positive. Previous work has established that the second term in ϕ is negative (Cornes & Sandler, 1984), and home upkeep activities may be assumed to produce decreasing returns, $(\partial^2 S / \partial g_1^2 < 0)$, which renders the first term negative as well. The negative sign which proceeds both terms in ϕ then indicates that the denominator for (17) is greater than zero.

The comparative statics for the model take the sign of the numerator. The term in the first set of square brackets in (17) is the substitution effect: holding utility constant, how does individual 1 alter their choice of q_1 when q_2 changes. The term in the second set of square brackets, is the income effect. It has been established, that the income effect is positive (e.g. Murdoch and Sandler, 1984; Cornes and Sandler, 1994, and others).

Three terms comprise the substitution effect: one containing $\partial^2 S / \partial g_1 \partial g_2$, one containing π_{mN} , and one containing π_{NN} . First, π_{NN} is less than zero (Cornes & Sandler, 1984). The signs associated with the remaining terms, however, are less clear. The marginal willingness to pay for m_i when N increases, holding utility constant is given by π_{mN} . If Hicksian complementarities exist between the joint products produced by upkeep activities then the π_{mN} term is positive; otherwise it is negative. Additionally, the terms containing π_{mN} and π_{NN} are weighted by the marginal increase in S produced by a change in $g_2(q_2)$. $\partial S / \partial g_2$ will be constant for some supply technologies, such as an average supply function, but will depend upon g_2 's place in the distribution of home upkeep for other technologies, such as weaker link or weakest link.

The sign of the term containing $\partial^2 S / \partial g_1 \partial g_2$ will also be determined by the public good supply technology. If complementarities exist in the supply technology such that an individual's exterior property upkeep is more valuable if ones neighbors also maintain their homes' exterior, then $\partial^2 S / \partial g_1 \partial g_2$ is positive and zero or negative otherwise. The sign of the substitution effect for the provision of impure public goods within residential neighborhoods depends both upon the degree of complementarities between the public and private joint products produced by upkeep activities and the public good supply technology. The importance of the public good supply

technology in determining the direction of the substitution effect is unique to the case of very local neighborhood public goods. It comes from the inclusion of house appreciation wealth in the impure public goods model applied to the case of neighborhood condition. In other words, the supply technology matters for public good provision because households benefit financially (through home appreciation wealth) from improvements to neighborhood condition.

3.2 Model Implications

3.2.1 Social Interactions and Social Preferences

The impure public goods model implies interactions among neighborhood residents which are closely related to the endogenous effects studied in the social interactions literature (e.g., Manski (1993); Brock and Durlauf (2007); Lee (2007); Ioannides and Zabel (2008); Ioannides and Topa (2010)). As an example, in work complementary to the analysis here, Ioannides (2002) considers the relationship between maintenance expenditures and average neighborhood maintenance expenditures. Average neighborhood maintenance expenditures of neighborhood residents are in some cases poorly correlated with the supply of local neighborhood condition. A key policy concern is what happens when a healthy neighborhood suffers significant signs of decline often associated with vacant properties and absent homeowners. The average maintenance expenditures of neighborhood residents may deviate substantially from neighborhood condition in the presence of vacant properties. The impure public goods model makes clear the importance of the public good supply technology. Further, the impure public good model is useful for informing how and why social interactions might impact the supply of home maintenance. Social interactions may be important to the extent that they give rise to complementarities in the private/public joint products.

3.2.2 Public Good Supply Technology

Table 1 presents mathematical descriptions of 4 common supply technologies—or aggregation functions that describe the process through which the public good is created average, weaker link, weakest link, and best shot. The average supply technology averages over all contributors; $\partial S/\partial g_j$ is constant and $\partial^2 S/\partial g_j \partial g_k = 0$. Therefore, for an average supply technology, the

substitution effect will depend entirely on the degree of complementarities between the public and private joint products produced by upkeep activities and will be indifferent to distributional changes in neighborhood upkeep. The best shot and weakest link supply technologies produce levels of the public good that are equal to the highest and lowest contribution levels, respectively. For best shot or weakest link supply technologies, $\partial S/\partial g_j$ varies depending upon the place of g_j in the distribution of neighborhood home upkeep, but $\partial^2 S/\partial g_j \partial g_k = 0$. The weaker link supply technology produces a level of the public good that is equal to the geometric mean of contribution levels. Weaker link differs from weakest link in that all contribution levels matter, but lower contribution levels have a greater influence on the overall level of public good produced. A weaker link supply technology produces $\partial S/\partial g_j > 0$ and $\partial^2 S/\partial g_1 \partial g_2 > 0$, for $N > 0$. These terms vary in proportion to N/g_j and $N/g_j g_k$, respectively. Thus, a marginal increase by lower contributors will have larger impacts. The likelihood of positive substitution effects for a weaker link technology is increased among residents who contribute the least amount of home upkeep.

3.2.3 Neighborhood Heterogeneity

The impure public goods model does not differentiate across different types of neighborhoods, but neighborhood social environments might create variation in the complementarities associated with the joint products produced by upkeep activities. Therefore, substitution effects in home upkeep decisions might vary across different neighborhood types. For example, in “typical” neighborhoods, enjoyment of the private aspects of neighborhood condition contributions (e.g. a well maintained home, a nice lawn, pretty flowers) may be enhanced by the public aspects of neighborhood condition contributions (e.g. an aesthetically pleasing neighborhood). In this case there would be complementarities between the public and private joint products. On the other hand, complementarities between the public and private joint products may be very low in some neighborhoods with high levels of physical and social disorder (Sampson and Raudenbush, 2004). Some neighborhood levels of insecurity and distrust may be so high, that complementarities between the private and public joint products are not observed. In the empirical sections that follow, I examine data from a very low-income neighborhood where social disorder and distrust are generally considered a problem (Leonard et al., 2010); and where complementarities in the public and private joint products are likely to be at reduced levels.

3.3 Hypothesis

The impure public goods model allows for the possibility of positive or negative substitution effects in neighborhood condition contributions. The extant literature suggests that neighborhood social interactions are likely to produce complementarities in the public and private joint products, thus yielding positive substitution effects. We will test this hypothesis. We will also assess how the test of this hypothesis varies depending upon the supply technology assumed for the aggregation of neighborhood condition contributions.

4 Empirical Study Design

4.1 Data

To empirically test the implications of the impure public goods model applied to the case of neighborhood condition, I use observational and household survey data collected as part of a longitudinal study to examine the effects of 3 new light rail stations in a low-income (median household income=\$30,512), minority (70% African American, 30% Hispanic) neighborhood, the Fair Park neighborhood.

Neighborhood condition data was recorded by independent neighborhood observers who coded the condition of every single family residential parcel (hereafter SFR's) in the neighborhood at 3 time points: 2009, 2010 and 2012. Detailed data collection procedures are reported in the literature (Leonard et al., 2011). SFR characteristics included the overall structural condition of each SFR parcel as well as the presence of several undesirable exterior features: peeling paint, poor lawn maintenance, poor fence structure, trash in the yard, and non-functioning vehicles in the yard or driveway. In total there were 4100 SFR parcels with repeat observations from 2009-2012. Data inter-rater reliability averaged 91% indicating a high degree of accuracy across observations, as well as good temporal stability of the measures. A summary of these parcel condition data is provided in Table 2. The first 2 columns of Table 2 report the mean for each variable in 2009 and 2012, respectively. The most frequently reported undesirable feature was peeling paint, and it was reported for 37% (2009) and 49% (2012) of the properties. Other undesirable features were recorded for 10-5% of the properties. The last 2 columns of Table 2

examine the fraction of properties which “improved” (i.e. an undesirable feature was present in 2009 but not in 2012) and properties which “worsened” (i.e. an undesirable feature was present in 2012 but not in 2009). In all cases we see a split between improving and worsening conditions. For example, 17% (28%) of properties improved (worsened) in terms of peeling paint from 2009 to 2012; and 7.9% (8.3%) of properties improved (worsened) in terms of lawn maintenance from 2009 to 2012.

To create a measure of property upkeep, each of the SFR characteristics described in Table 2 were represented by a binary variable where 1 indicates the presence of the undesirable feature. Factor analysis with a promax rotation was used to create a composite factor representing each property’s level of upkeep (hereafter, *SFR Upkeep*). Table 3 presents a list of the characteristics recorded for each SFR property and their factor loadings. After calculating the factor, factor scores were rescaled so that all values were greater than 0 and higher factor scores represent more property upkeep.³ Each parcel in the neighbor was assigned a value for *SFR Upkeep* equal to the rescaled factor score. *SFR Upkeep* represents a composite measure of neighborhood upkeep activities. It may be interpreted as a weighted average of the absence of undesirable property features, where weights were determined via factor analysis.

Self-reported survey data was also collected as part of the same longitudinal study. This data was used to control for characteristics of the household occupying the property. Survey data was collected in 2009, immediately after the first round of neighborhood data was collected, and in 2012, immediately preceding the last round of neighborhood observational data collection. Survey data was matched with the corresponding neighborhood observational data to provide time-consistent characterizations of the households occupying each housing unit.

While the data comes from a single residential neighborhood in Dallas, TX (the Fair Park neighborhood); we will examine *within* neighborhood variation. Within this single residential neighborhood, we will consider how neighborhood condition varies across smaller local neighborhoods (i.e. neighborhoods defined by quarter mile buffers). Thus, in the sections that follow we use the term “neighborhood” to refer to these more local neighborhoods within the larger Fair Park neighborhood.

³The original factors scores were rescaled according to the following formula: $\text{rescaled factor} = 4 - \text{original factor}$.

4.2 Difference-in-Difference Strategy

A difference-in-difference (DID) approach was used to understand how neighborhood public good contributions change in response to a change in neighborhood condition. (12) provides information on the determinants of q_i that should be included in the model. The sample is very low-income and income data is missing for a large portion of the sample. Therefore unemployment status is used as a measure of income. Likewise, data on housing equity is unavailable, so home ownership status is used to indicate residents who will benefit from gains in home appreciation. Despite the great recession, the local housing market was relatively stable during the period of our data (Edelman, 2008). Several demographic characteristics (age, health status, marital status, and race) are included to account for differences in prices associated with investment in neighborhood condition. For example, home maintenance is likely less expensive for a healthy, young homeowner because they are more capable of investing 'sweat equity' than an older homeowner of poor health.

Including these covariates (X), the following regression model for each housing unit (i) will be estimated:

$$q_{it} = \beta_0 + \beta_1 X_{i,t} + \delta_0 T_{2012,t} + \delta_1 \Delta S(\tilde{N})_i + \delta_2 (T_{2012,t} * \Delta S(\tilde{N})_i) + \epsilon_{it} \quad (18)$$

T_{2012} indicates observations recorded in 2012, and $\Delta S(\tilde{N})$ is the change in neighborhood condition from 2009 to 2012, where positive values indicate an improved neighborhood. The independent variable, q_{it} , is *SFR Upkeep* where q_{it} is observed at 2 time points (2009 and 2012) for each housing unit. (18) was estimated using ordinary least squares regression with clustered standard errors for each i . The difference-in-difference estimator for individual's response to a change in the level of neighborhood condition is given by $\delta_2 * \Delta S(\tilde{N})_i$. This approach is a slight modification of the standard DID approach in that the 'treatment' variable, $\Delta S(\tilde{N})_i$ is a continuous measure of change in neighborhood. Therefore, the control condition is neighborhoods which did not change from 2009 to 2012. The model can also be estimated considering a binary treatment variable. In this case, $\Delta S(\tilde{N})_i$ takes on a value of 1 for neighborhoods whose level of the very local public good increased from 2009-2012 and 0 otherwise. For all cases, the sign of $\hat{\delta}_2$ indicates the direction of the substitution effect.

4.3 Change in Neighborhood Condition, $\Delta S(\tilde{N})$

The change in neighborhood condition, $\Delta S(\tilde{N})$, represents the treatment effect in the DID approach. Several different methods were used for assessing change in neighborhood conditions, $\Delta S(\tilde{N})$. First, neighborhood condition was assessed using *SFR Upkeep* and aggregating according to each of the different supply technologies' aggregation functions (see Table 1). This method relied on aggregating the same measures as those used for the dependent variable, and may present an endogeneity problem. However, change in neighborhood condition was measured using the over 8,000 SFR parcel observations, while q_i is neighborhood contributions of only a small (less than 6%) subset of the SFR contribution measures. Therefore, the degree to which $\Delta S(\tilde{N})$ and ϵ covary is minimal. The concern for endogeneity is further reduced when considering the weakest link technology as only the neighborhood contribution for the lowest contributing parcel is included in $\Delta S(\tilde{N})$. It is likely that in many instances, this parcel is vacant or owned by an absentee homeowner, excluding them from the set of q_i used for the dependent variable. Nevertheless, we also use a strictly exogenous proxy measure for neighborhood change to investigate the impact of any such endogeneity problems. Our additional proxy measure of change in neighborhood condition is based on distance to the nearest new light rail station. The light rail stations opened in 2009, just after the neighborhood parcel data was collected and represent a significant investment in the local neighborhood. Proximity to the new light rail stations is considered as an alternative treatment effect.

4.3.1 Neighborhood Condition based on *SFR Upkeep*

The first set of measures for neighborhood condition are constructed by aggregating *SFR Upkeep* for all SFR parcels within a $\frac{1}{4}$ mile buffer. Buffers were drawn around each residential parcel in the analysis sample and the neighborhood condition, $S(\tilde{N})_X$, variables were calculated considering 4 different neighborhood public good supply technologies, and excluding the neighborhood condition contributions of the house in question. Average ($S(\tilde{N})_{Average}$), weaker link ($S(\tilde{N})_{weaker}$), best shot ($S(\tilde{N})_{best}$), and weakest link ($S(\tilde{N})_{weakest}$) supply technologies were calculated according to the aggregation functions in Table 1. The average supply technology was used instead of a summation technology to normalize for the density of SFR properties in the

neighborhood buffer. Average and summation technologies will be perfectly correlated after controlling for housing density. Weaker link is defined as the geometric mean of contributions while weakest link and best shot are equal to the lowest and highest contributions in the neighborhood, respectively. While I wished to examine best shot as a potential neighborhood public good supply technology, 98.97% of the neighborhoods examined showed no change in neighborhood condition when using this supply technology. Therefore it was excluded from the analysis.

Figure 1 displays the distribution of neighborhood condition in 2009 and 2012 considering each different public good supply technology. Shifts in the distribution of neighborhood condition are different depending upon the supply technology assumed. For the average supply technology (panels (a) and (b)), neighborhood condition shows a shift towards a more bi-modal distribution in 2012. However, when considering the weaker link supply technology (panels (c) and (d)), neighborhood condition was somewhat normally distributed in 2009, but exhibits a considerable shift to the left (worse condition) in 2012. Neighborhood condition as measured by the weakest link supply technology (panels (e) and (f)) exhibits little discernible change pattern from 2009 to 2012, but we note that almost all values at both time points are below the average neighborhood condition of 4. Since weakest link represents the upkeep level of the lowest contributor in each neighborhood, this means that almost all neighborhoods have at least one person whose home upkeep is below the neighborhood average in both time periods.

Figure 2 displays histograms of the change in neighborhood condition from 2009 to 2012 for each different supply technology. Higher positive values represent more improved neighborhood condition in 2012 while negative values represent worsened neighborhood condition in 2012. The histograms differ markedly for the different supply technologies. Average (panel (a)) supply technology gives a bi-modal distribution, while weaker link (panel (b)) supply technology shows somewhat of a skewed distribution. The distribution for changes as measured by the weakest link supply technology peaks near 0 (no change), and is fairly symmetric.

Figure 3 presents the geographic distribution of changes in neighborhood condition. Overall, for all three supply technologies there is a general pattern of worsening neighborhood condition on the south-western side of the neighborhood and improving neighborhood condition on the north-eastern side of the neighborhood. A cluster of the most improved neighborhoods is found near the new light rail station located in the eastern residential section of the neighborhood (Hatcher

Station). However, there are noticeable differences between the different supply technologies. For instance, improved neighborhoods are located on all sides of Hatcher Station for the average and weakest link technologies, but only to the north of the station when considering the weaker link technology.

4.3.2 Neighborhood Condition Based on Proximity to New Light Rail Stations

Figure 4 displays the distribution of distance to the nearest commuter light rail station for the sample. Two distance measures were used. The first was distance to the nearest rail station. The second measure was distance to the Hatcher Station. The Hatcher station is the east-most light rail station and is the only neighborhood light rail station that exclusively serves neighborhood residents. The other 2 light rail stations may be used by neighborhood residents, but they were primarily located to serve the State Fair of Texas Fairgrounds—a large complex of museums and historical buildings. Because these two stations are located on the periphery of the fairground complex, they may have had less impact on the residential neighborhood condition.

On average, study participants lived 0.8 miles from the nearest light rail station and 1.02 miles from the Hatcher station. Treatment/control groups are assigned based on 1/4 mile thresholds (e.g. the treatment group lived within 1/4 mile of a light rail station, and the control group lived more than 1/4 mile from a light rail station). A continuous measure of treatment effect was also computed using distance to light rail stations, similar to the continuous treatment measures of change in neighborhood condition. The continuous proximity measure was calculated by subtracting each observations distance to the light rail station from the sample mean. Constructed in this way, properties nearer to a light rail station have a higher value for $\Delta S(\tilde{N})$.

4.4 Summary of Data included in Models

Table 4 provides a complete description of the variables used in the analysis which follows and Table 5 provides summary statistics for the data. In total there were 273 instances where the full data needed for the analysis was available in both 2009 and 2012, giving a total sample size (considering both time points) of 546. As expected, mean neighborhood condition takes on lower values (worse condition) as we move from average to weaker link to weakest link supply

technologies. Mean change in neighborhood condition was near 0 for all supply technologies, but the standard deviation was largest for the weakest link supply technology and smallest for the weaker link technology. The average neighborhood resident was 48 years old. 91% of the households in the sample were African American. 33% of the sample had been unemployed in the past 12 months, and 44% are homeowners. Health status averaged 2.9 on a 5 point scale, indicating average overall health within the sample.

5 Results

5.1 Treatment Effects Based on Neighboring *SFR Upkeep*

Coefficient estimates for (18) in which treatment effects are measured by aggregating over the condition of neighborhood SFR properties are presented in Table 6. All models contain controls for homeownership, age, employment status, health status, marital status, and race/ethnicity. None of these controls have statistically significant coefficient estimates. In particular, our coefficient estimate for unemployment (our proxy measure for income) is insignificant suggesting that we do not observe income effects in the supply of neighborhood upkeep within the Fair Park neighborhood. This is not unsurprising given the fact that there is little variation in income within the neighborhood and when income is available for a household, it is often transitory (i.e. temporary labor).

In each model treatment effects are estimated for a different neighborhood public good aggregation function. There are considerable differences in the estimated response of contributions to changes in neighborhood condition across the three models. Positive substitution effects are estimated for the average and weakest link supply technologies; however the substitution effect is negative when considering the weaker link technology. For an average supply technology a 1 unit improvement in average neighborhood condition is related to a 0.97 improvement in a household's own home upkeep (Table 6, Model 1). For the weakest link technology, a 1 unit improvement in the condition of the worst house in the neighborhood is associated with a 0.26 increase in a household's home upkeep (Table 6, Model 3). However, Model 2 shows a different story: a 1 unit increase in neighborhood condition measured by the weakest link supply technol-

ogy is associated with a .51 unit decrease in own home upkeep (Table 6, Model 2). Model fit is highest for the average supply technology.

The heterogeneity in direction of the substitution effect remains something to be investigated. In the data $\Delta S(\tilde{N})_{weaker}$ has a low level of correlation with $\Delta S(\tilde{N})_{weakest}$ ($\rho = 0.38$) and $\Delta S(\tilde{N})_{average}$ ($\rho = 0.43$). However, $\Delta S(\tilde{N})_{weakest}$ and $\Delta S(\tilde{N})_{average}$ are more highly correlated ($\rho = 0.80$). Because of the low-level of correlation between $\Delta S(\tilde{N})_{weaker}$ and the other measures of neighborhood change, they may be included together in a composite model to understand the relative importance of different operationalizations of neighborhood change and individual home upkeep. Next, (18) is estimated but $\Delta S(\tilde{N})$ is now a vector of different measures of change in neighborhood condition created from assuming different supply technologies. First all measures of change in neighborhood condition are included in a single model, then one of the highly correlated measures is dropped in subsequent models to account for multicollinearity in the average and weakest link technologies. The results are reported in Table 7. Measures of neighborhood condition using weaker link technology are never statistically significant in these models. Furthermore, the results indicate a positive substitution effect. Inclusion of the average supply technology measures in the model produces the best model fit.

5.2 Treatment Effects Based on Proximity to Light Rail Stations

Next, proximity to the nearest light rail station was used to produce proxy measures of change in neighborhood condition. These estimation results are presented in Table 8. In all cases, we estimated positive substitution effects. Individuals living nearer to the light rail stations where significant public investment in the neighborhood were made, were more likely to improve their upkeep of their own housing parcel. All substitution effects were statistically significant except those for Model 3 where the proxy for change in neighborhood condition was measured by a continuous measure of relative distance to the nearest light rail station. Estimated substitution effects for the threshold definitions of the treatment effect at 1/4 mile in models (1) and (2) are statistically indistinguishable. However estimated substitution effects for the proximity definitions in models (3) and (4) are statistically distinct. Positive substitution effects are much stronger considering proximity to the Hatcher Station.

5.3 Robustness Checks

The change in neighborhood condition based on neighboring *SFR Upkeep* was included in the models as a continuous measure of treatment intensity. Robustness checks were conducted in which treatment was represented by a binary variable indicating neighborhoods that had improved in condition from 2009-2012. The results of these model specifications provided substantively similar implications as the estimation results for the continuous version of the model.

Also, the potential selection issue in the data should not be ignored. If the trajectory of neighborhoods is known, individuals who are most willing to contribute may self-select into neighborhoods that are improving. The study from which this data was drawn collected repeat observations from households that were geographically sampled. In each case, one adult from each household completed the survey. Study data can be matched across survey waves so that housing units in which repeat survey takers matched across survey waves are identified. These households may be considered as non-movers. There are also other housing units in the sample which were occupied by the same household during the period of the study, but different adults from the household completed the surveys. In these cases, I was unable to distinguish between movers and non-movers. As a robustness check of the results, the regression models were re-estimated including only the housing units for which I could identify that the same household occupied the property during the entire study period (N=52). The results are substantively similar to the results for the full sample. The primary difference is for the weakest link supply technology, the coefficient estimate is no longer significant because of larger standard errors estimates for the smaller sample size. When distance to the nearest rail station was used to assign treatment, substitution effects remained positive but results were not statistically significant as standard errors were greatly increased, likely due to the much smaller sample size.

6 Discussion

The theoretical model for neighborhood public goods indicated a potential for positive or negative substitution effects depending upon the complementarities in the public and private joint products generated by a household's upkeep decisions and the neighborhood public good supply technology. Empirical evidence for the direction of substitution effects varied depending upon

the public good supply technology assumed when considering individuals' response to a change in neighborhood condition. For average and weakest link technologies, positive substitution effects are estimated. Households tended to improve the upkeep of their own home when the condition of other homes in the neighborhood also improved. Negative substitution effects were estimated when a weaker link supply technology was assumed, but the results did not hold in models where multiple supply technologies were included. This suggests that weaker link supply technology, at least in the neighborhood examined, may not reflect the conceptualization of neighborhood considered by neighborhood residents when making decisions about exterior property upkeep.

Positive substitution effects are estimated for both the average and weakest link supply technologies, but the coefficient estimates alone are not sufficient to compare the magnitudes of the different estimated substitution effects. In order to make this comparison across supply technologies, the correspondence between a "1 unit change" in average and weakest link supply technologies must be understood. On average there are 274 SFR's within each $\frac{1}{4}$ mile buffer. Therefore, a 1 unit change in the weakest link technology corresponds, on average, to a $\frac{1}{274} \approx 0.0036$ unit change in the average neighborhood condition technology. Thus, the results suggest that the estimated positive substitution effect of changing neighborhood condition through an improvement in upkeep by incremental changes to an average SFR in the neighborhood is much smaller than the estimated effect of changing neighborhood condition through incremental changes to upkeep of the worst SFR in the neighborhood.

It is possible that the estimated positive substitution effects in the models using public good supply technologies to aggregate over individual contributions suffered from endogeneity problems. In this case, some unobserved geographically-varying factor may be causing all neighborhood residents to simultaneously adjust their contribution levels. To further investigate the nature of substitution effects, we considered an alternative measure of change in neighborhood conditions. This measure was based on distance to the new light rail stations that were built in the neighborhood in 2009, just after the first round of neighborhood conditions data were observed. Positive substitution effects remained robust to this alternative model specification, however the magnitude differed depending upon whether treatment was based on proximity to any light rail station or on proximity only to the primary neighborhood light rail station (i.e. Hatcher Station). The marginal effect on private property upkeep of moving closer to any rail

station is 42% less than the marginal effect of moving closer to the Hatcher station. This suggests that the type of neighborhood investment matters. The Hatcher station was perceived locally as an investment for neighborhood residents while other stations were perceived as investments for State Fair of Texas attendees.

While the detailed, objective, neighborhood observational data used for this study allowed for a unique opportunity to understand dynamics of neighborhood change, it also had limitations. First, with regards to external validity, the data came from the low-income Fair Park neighborhood and the dynamics of neighborhood change may not be the same across all types of neighborhoods. When considering public good supply technologies, the measure of neighborhood condition used was based primarily on major dis-amenities associated with features of the home and the surrounding yard space. For other more affluent neighborhoods, changes in neighborhood conditions may work through more subtle features. Additionally, detailed data about changes in the condition of neighborhood public spaces was unavailable. We use proximity to the light rail stations as a proxy for investments in the neighborhood public areas, but this is only one very specific type of neighborhood investment. It is possible that households have negative substitution effects with respect to other types of public neighborhood investments. The substitution effects for upkeep of public spaces are a subject for future research. Finally, precise income and expenditure data was not available, so proxies for these factors were used.

Further work examining the nature of public good supply technologies for the provision of neighborhood condition in different types of neighborhoods is needed to improve upon the external validity of study results. The neighborhood examined is relatively homogenous in terms of demographic and income characteristics. Lack of heterogeneity in these features, may be a reason why the weaker link supply technology performed poorly in explaining public good contributions. Cornes (1993) notes that Nash equilibrium associated with weaker-link and weakest-link technologies differ substantially from those associated with average technologies when income and preference heterogeneity is greater. The nature of the neighborhood public good supply technology is critically important for better understanding of the private motivations for contributing to neighborhood public goods. For example, Ioannides and Zabel (2008) mentions that financial motives for home maintenance rely on a “critical mass” of contributions of ones neighbors before the investments are adequately capitalized into home values. Determination of this “critical

mass” is closely aligned with determining the relevant supply technology.

The results provide some policy-relevant insights, particularly for low-income neighborhoods that are often most susceptible to adverse shocks to neighborhood condition. Households tended to respond in kind to changes in neighborhood condition. The results also indicate that the response is stronger when change in neighborhood condition is associated with change in the worst property in the neighborhood. In the context of adverse housing market shocks and neglected neighborhoods—the lowest contributor is often an ‘absent’ contributor, or a vacant or abandoned property. The results suggest that policy efforts to discourage absentee homeowners and/or reclaim abandoned properties are fruitful and produce externalities in terms of increased contributions of other neighboring residents. Additionally, being closer to the new light rail stations resulted in increases in individual home upkeep. The positive substitution effect was strongest when considering proximity to Hatcher station—the light rail station in which public investment was designed explicitly for the service of local neighborhood residents. This relationship between public investment in neighborhoods and individual property upkeep is encouraging and should be further examined across other neighborhood settings and other types of public investment. In particular, an important policy question regarding the catalyst for neighborhood decay (or renewal) remains. Identifying the root cause of cycles of neighborhood change is beyond the scope of this paper, but the empirical results do suggest some promising areas for future research. For example, both factors which affect individual home upkeep *and* public neighborhood investments are candidate mechanisms for neighborhood change. Further, work is needed examining these same issues in a variety of neighborhoods.

Finally, framing the problem of neighborhood condition in terms of the impure public goods model highlighted the role of social interactions and the public good supply technology in understanding how individuals make contribution decisions. This integration of urban and public economic conceptualizations of neighborhood condition is an important area for future research.

Acknowledgements: This study was funded by the National Science Foundation (NSF/SES-0827350).

References

- Brock, W. A. and S. N. Durlauf (2007, 9). Identification of binary choice models with social interactions. Journal of Econometrics 140(1), 52–75.
- Caughy, M. O., T. Leonard, K. Beron, and J. Murdoch (2013). Defining neighborhood boundaries in studies of spatial dependence in child behavior problems. International journal of health geographics 12(1), 1–12.
- Clark, W. A. (2008). Reexamining the moving to opportunity study and its contribution to changing the distribution of poverty and ethnic concentration. Demography 45(3), 515–535.
- Cornes, R. (1993, Feb.). Dyke maintenance and other stories: Some neglected types of public goods. The Quarterly Journal of Economics 108(1), 259–271.
- Cornes, R. and T. Sandler (1994, 7). The comparative static properties of the impure public good model. Journal of Public Economics 54(3), 403–421.
- Cornes, R. and T. Sandler (1996). The theory of externalities, public goods, and club goods. Cambridge University Press.
- Dubin, R. A. (1992, 9). Spatial autocorrelation and neighborhood quality. Regional Science and Urban Economics 22(3), 433–452.
- Edelman, R. (2008, 2). Dallas housing market: Nation’s most stable. Dallas Business Journal February 10, 2008.
- Galster, G. C. (1987). Homeowners and neighborhood reinvestment. Duke University Press.
- Harding, J., T. J. Miceli, and C. Sirmans (2000). Do owners take better care of their housing than renters? Real Estate Economics 28(4), 663–681.
- Harding, J. P., E. Rosenblatt, and V. W. Yao (2009). The contagion effect of foreclosed properties. Journal of Urban Economics 66(3), 164–178.
- Harding, J. P., S. S. Rosenthal, and C. Sirmans (2007). Depreciation of housing capital, maintenance, and house price inflation: Estimates from a repeat sales model. Journal of urban Economics 61(2), 193–217.

- Ioannides, Y. M. (2002, 3). Residential neighborhood effects. Regional Science and Urban Economics 32(2), 145–165.
- Ioannides, Y. M. and G. Topa (2010). Neighborhood effects: Accomplishments and looking beyond them. Journal of regional science 50(1), 343–362.
- Ioannides, Y. M. and J. E. Zabel (2008). Interactions, neighborhood selection and housing demand. Journal of Urban Economics 63(1), 229–252.
- Jargowsky, P. (1997). Poverty and Place: Ghettos, Barrios, and the American City. New York: Russell Sage Foundation.
- Katz, L., J. Kling, and J. Liebman (1999). Moving to opportunity in boston: Early impacts of a housing mobility program. mimeographed, Princeton University.
- Kawachi, I., L. F. Berkman, et al. (2003). Neighborhoods and health. Oxford University Press New York.
- Kingsley, G., R. Smith, and D. Price (2009). The impacts of foreclosures on families and communities.
- Lee (2007, 10). Identification and estimation of econometric models with group interactions, contextual factors and fixed effects. Journal of Econometrics 140(2), 333–374.
- Leonard, T., R. T. Croson, and A. de Oliveira (2010). Social capital and public goods. Journal of Socio-Economics 39(4), 474–481.
- Leonard, T. and J. Murdoch (2009). The neighborhood effects of foreclosure. Journal of Geographical Systems 11(4), 317–332.
- Leonard, T. C. (2013). The impact of housing market conditions on residential property upkeep. Housing Studies 28(1), 33–56.
- Leonard, T. C., M. Caughy, J. Mays, and J. C. Murdoch (2010). Systematic neighborhood observations at high spatial resolution.

- Leonard, T. C. M., M. O. Caughy, J. K. Mays, and J. C. Murdoch (2011). Systematic neighborhood observations at high spatial resolution: Methodology and assessment of potential benefits. PLoS ONE 6(6), e20225.
- Lin, Z., E. Rosenblatt, and V. Yao (2009). Spillover effects of foreclosures on neighborhood property values. The Journal of Real Estate Finance and Economics 38(4), 387–407–407.
- Manski, C. F. (1993, Jul.). Identification of endogenous social effects: The reflection problem. The Review of Economic Studies 60(3), 531–542.
- Murdoch, J. C. and T. Sandler (1984, November). Complementarity, free riding, and the military expenditures of nato allies. Journal of Public Economics 25(1-2), 83–101.
- Novack, S. (2014, February 4, 2014). An experiment in low-income housing in rapidly gentrifying san francisco.
- Posnett, J. and T. Sandler (1986, April 1). Joint supply and the finance of charitable activity. Public Finance Review 14(2), 209–222.
- Saelens, B. E., J. F. SALLIS, and L. Frank (2003). Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Annals of behavioral medicine 25(2), 80.
- Sallis, J. F. and K. Glanz (2006, Spring). The role of built environments in physical activity, eating, and obesity in childhood. The Future of Children 16(1, Childhood Obesity), 89–108.
- Sampson, R. J. (2003). The neighborhood context of well-being. Perspectives in Biology and Medicine 46(3), S53.
- Sampson, R. J. and S. W. Raudenbush (2004). Seeing disorder: Neighborhood stigma and the social construction of broken windows. Social Psychology Quarterly 67(4), 319–342.
- Sampson, R. J., S. W. Raudenbush, and F. Earls (1997). Neighborhoods and violent crime: A multilevel study of collective efficacy. Science 277(5328), 918–924.

- Sanbonmatsu, L., J. R. Kling, G. J. Duncan, and J. Brooks-Gunn (2006). Neighborhoods and academic achievement results from the moving to opportunity experiment. Journal of Human Resources 41(4), 649–691.
- Sandler, T. and A. J. Culyer (1982, 11). Joint products and multijurisdictional spillovers. Quarterly Journal of Economics 97(4), 707–716. M3: Article.
- Schaefer-McDaniel, N. (2009, 3). Neighborhood stressors, perceived neighborhood quality, and child mental health in new york city. Health & place 15(1), 148–155.

Table 1: Public Good Supply Technologies

Supply Technology	Aggregation Function	$\frac{\partial S}{\partial g_j}$	$\frac{\partial^2 S}{\partial g_j \partial g_k}$
Average	$\frac{1}{T} \sum_{i=1}^T g_i$	$\frac{1}{T}$	0
Weaker Link	$[\prod_{i=1}^T g_i]^{\frac{1}{T}}$	$\frac{S}{T g_j}$	$\frac{S}{T^2 g_j g_k}$
Weakest Link	$\min(g_1, g_2, \dots, g_T)$	1 if $g_1 = \min(g_i)$ 0 otherwise	0
Best Shot	$\max(g_1, g_2, \dots, g_T)$	1 if $g_1 = \max(g_i)$ 0 otherwise	0

Aggregation functions based on definitions in Cornes (1993).

Table 2: Parcel Characteristics Summary Statistics, N=4100

Variable	2009 Mean	2012 Mean	Fraction Improving	Fraction Worsening
Overall poor condition	0.266 (0.442)	0.193 (0.395)	0.184 (0.388)	0.112 (0.315)
Exterior paint is peeling	0.372 (0.484)	0.487 (0.5)	0.17 (0.375)	0.284 (0.451)
Lawn is poorly maintained	0.097 (0.296)	0.101 (0.302)	0.079 (0.27)	0.083 (0.277)
Fence in disrepair	0.072 (0.259)	0.051 (0.22)	0.064 (0.245)	0.043 (0.203)
Trash in yard	0.052 (0.223)	0.052 (0.222)	0.046 (0.21)	0.046 (0.209)
Broken vehicles in yard/driveway	0.059 (0.236)	0.055 (0.229)	0.053 (0.224)	0.05 (0.217)

Standard Deviations in Parenthesis

Table 3: **Factor Loadings for *SFR Upkeep***

Characteristics	Factor Loading
Poor structural condition	0.14454
Exterior paint is peeling	0.17713
Lawn is poorly maintained	0.26970
Fence is in disrepair	0.22393
Trash is in yard	0.24046
Vehicles needing repair or being repaired are in yard/driveway	0.12477

Table 4: **Variable Descriptions**

Variable Name	Variable Description
q (<i>SFR Upkeep</i>)	Measure of property upkeep; Household's neighborhood public good contribution
$\Delta S(\tilde{N})_X$	<p>Measure of treatment effects. Positive values indicate neighborhoods whose condition improved. X indicates the measure used to calculate the treatment effect (i.e. a public good aggregation function or proximity).</p> <p>$\Delta S(\tilde{N})_{average}$: Treatment based on average public good supply technology</p> <p>$\Delta S(\tilde{N})_{weaker}$: Treatment based on weaker link public good supply technology</p> <p>$\Delta S(\tilde{N})_{weakest}$: Treatment based on weakest link public good supply technology</p> <p>$\Delta S(\tilde{N})_{proximity_any_rail}$: Treatment based on distance (miles) to nearest light rail station</p> <p>$\Delta S(\tilde{N})_{proximity_Hatcher}$: Treatment based on distance (miles) to Hatcher Station</p> <p>$\Delta S(\tilde{N})_{proximity-\frac{1}{4}-any_rail}$: equals 1 if house is within $\frac{1}{4}$ mile of nearest light rail station</p> <p>$\Delta S(\tilde{N})_{proximity-\frac{1}{4}-Hatcher}$: equals 1 if house is within $\frac{1}{4}$ mile of Hatcher Station</p>
T_{2012}	Variable takes a value of 1 for observations recorded in 2012 and 0 for observations recorded in 2009
Own	Household respondent owns their own home
Unemployed	Indicator for household respondents who had been unemployed in the past 12 months
Age	Age of the household respondent
Health Status	Self-reported health status of the household respondent; higher numbers represent poorer health
Married	Household respondent is married or cohabitating
Black	Household respondent is non-hispanic black
Hispanic	Household respondent is Hispanic

Table 5: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
$S(\tilde{N})_{average}$	4.081	0.233	3.474	4.483	546
$S(\tilde{N})_{weaker}$	2.119	0.564	1.015	4.352	546
$S(\tilde{N})_{weakest}$	1.873	0.692	0.742	4.542	546
$\Delta S(\tilde{N})_{average}$	-0.029	0.394	-0.521	0.88	546
$\Delta S(\tilde{N})_{weaker}$	-0.015	0.247	-0.575	1.042	546
$\Delta S(\tilde{N})_{weakest}$	0.013	1.031	-2.988	2.265	546
$\Delta S(\tilde{N})_{proximity_any_rail}$	0.000	0.379	-1.112	0.743	546
$\Delta S(\tilde{N})_{proximity_Hatcher}$	0.000	0.453	-0.950	0.982	546
$\Delta S(\tilde{N})_{proximity-\frac{1}{4}_any_rail}$	0.088	0.283	0	1	546
$\Delta S(\tilde{N})_{proximity-\frac{1}{4}_Hatcher}$	0.084	0.278	0	1	546
Own	0.443	0.497	0	1	546
Unemployed	0.326	0.469	0	1	546
Age	48.256	15.217	18	96	546
Health Status	2.866	1.18	1	5	546
Married	0.419	0.494	0	1	546
Black	0.912	0.283	0	1	546
Hispanic	0.066	0.248	0	1	546

Table 6: **Coefficient Estimates for Difference-in-Difference Models with Treatment Based on the Condition of Neighboring SFR Properties**

Aggregation Function for Calculating $\Delta S(\tilde{N})_X$:	(1) Average Supply Technology	(2) Weaker Link Supply Technology	(3) Weakest Link Supply Technology
$\Delta S(\tilde{N})_X$	-0.549*** (0.0956)	-0.357* (0.147)	-0.154*** (0.0404)
T_{2012}	0.0289 (0.0461)	0.00538 (0.0521)	-0.00370 (0.0492)
$T_{2012} * \Delta S(\tilde{N})_X$	0.968*** (0.103)	-0.513** (0.191)	0.260*** (0.0445)
Own	0.0733 (0.0496)	0.0964+ (0.0507)	0.0718 (0.0509)
Unemployed	-0.0130 (0.0549)	0.00864 (0.0576)	0.00312 (0.0579)
Age	-0.000770 (0.00179)	-0.00104 (0.00180)	-0.000754 (0.00181)
Health Status	-0.0105 (0.0251)	-0.000534 (0.0256)	-0.00764 (0.0253)
Married	-0.00255 (0.0512)	0.0245 (0.0535)	0.0107 (0.0524)
Black	-0.0745 (0.162)	-0.108 (0.148)	-0.115 (0.149)
Hispanic	0.161 (0.170)	0.153 (0.153)	0.133 (0.155)
Constant	4.143*** (0.195)	4.143*** (0.180)	4.182*** (0.181)
Observations	546	546	546
R-squared	0.109	0.029	0.063

Dependent variable for all models is neighborhood condition contributions, q

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, + p<0.10

Table 7: Coefficient Estimates for Difference-in-Difference Models including Multiple Supply Technologies

	(1)	(2)	(3)
T_{2012}	0.0338 (0.0461)	-0.00206 (0.0498)	0.0268 (0.0463)
Change in $S(\tilde{N})_{weaker}$	0.0223 (0.158)	-0.133 (0.159)	0.0291 (0.154)
$T_{2012} * S(\tilde{N})_{weaker}$	0.172 (0.200)	-0.122 (0.209)	0.188 (0.198)
Change in $S(\tilde{N})_{average}$	-0.641*** (0.153)		-0.556*** (0.106)
$T_{2012} * S(\tilde{N})_{average}$	1.214*** (0.187)		1.020*** (0.117)
Change in $S(\tilde{N})_{weakest}$	0.0413 (0.0662)	-0.142** (0.0451)	
$T_{2012} * S(\tilde{N})_{weakest}$	-0.0948 (0.0757)	0.249*** (0.0505)	
Own	0.0776 (0.0493)	0.0742 (0.0507)	0.0750 (0.0494)
Unemployed	-0.0174 (0.0559)	0.00414 (0.0578)	-0.0157 (0.0553)
Age	-0.000820 (0.00178)	-0.000805 (0.00181)	-0.000804 (0.00179)
Health Status	-0.0110 (0.0249)	-0.00763 (0.0255)	-0.0113 (0.0252)
Married	-0.00908 (0.0519)	0.0111 (0.0525)	-0.00805 (0.0516)
Black	-0.0656 (0.166)	-0.120 (0.149)	-0.0770 (0.163)
Hispanic	0.170 (0.173)	0.130 (0.155)	0.158 (0.171)
Constant	4.138*** (0.199)	4.185*** (0.181)	4.153*** (0.196)
Observations	546	546	546
R-squared	0.112	0.064	0.110

Dependent variable for all models is neighborhood condition contributions, q

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, + p<0.10

Table 8: Coefficient Estimates for Difference-in-Difference Models with Treatment Measured by Proximity to Light Rail Stations

Basis for Assigning Treatment:	Discrete $\Delta S(\tilde{N})_{proximity}$ Measures		Continuous $\Delta S(\tilde{N})_{proximity}$ Measures	
	(1) $\leq \frac{1}{4}$ mile of Nearest Station	(2) $\leq \frac{1}{4}$ mile of Hatcher Station	(3) Proximity to Nearest Station	(4) Proximity to Hatcher Station
$\Delta S(\tilde{N})_{proximity}$	-0.229 (0.174)	-0.262 (0.179)	0.0310 (0.136)	-0.266* (0.109)
T	-0.0446 (0.0536)	-0.0447 (0.0533)	-0.00405 (0.0517)	-0.00501 (0.0497)
$T_{2012} * \Delta S(\tilde{N})_{proximity}$	0.450* (0.191)	0.469* (0.198)	0.222 (0.145)	0.531*** (0.118)
Own	0.0991+ (0.0505)	0.0990+ (0.0506)	0.117* (0.0521)	0.0947+ (0.0509)
Age	-0.00114 (0.00183)	-0.00121 (0.00183)	-0.000950 (0.00175)	-0.00128 (0.00179)
Unemployed	0.00897 (0.0595)	0.0118 (0.0596)	-0.00258 (0.0594)	0.0131 (0.0564)
Health Status	0.000119 (0.0256)	0.000650 (0.0257)	-0.00300 (0.0253)	-0.00505 (0.0252)
Married	0.00882 (0.0535)	0.0102 (0.0535)	0.0205 (0.0531)	-0.000799 (0.0528)
Black	-0.104 (0.146)	-0.102 (0.146)	-0.116 (0.152)	-0.0857 (0.156)
Hispanic	0.129 (0.151)	0.132 (0.151)	0.176 (0.154)	0.146 (0.160)
Constant	4.176*** (0.179)	4.175*** (0.179)	4.153*** (0.185)	4.164*** (0.188)
Observations	546	546	546	546
R-squared	0.027	0.028	0.028	0.053

Dependent variable for all models is neighborhood condition contributions, q
For Models (5) and (6), proximity is calculated by subtracting distance to the rail station from the sample average distance to the rail station.

Average distance to the nearest rail station and Hatcher station were 0.8 miles and 1.02 miles, respectively.

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, + p<0.10

(a) Average Supply Technology, 2009 data

(b) Average Supply Technology, 2012 data

(c) Weaker Link Supply Technology, 2009 data

(d) Weaker Link Supply Technology, 2012 data

(e) Weakest Link Supply Technology, 2009 data

(f) Weakest Link Supply Technology, 2012 data

Figure 1: **Distribution of Neighborhood Condition based on *SFR Upkeep***

Figure 2: **Distribution of Changes in Neighborhood Condition based on *SFR Upkeep***

(a) Change in Neighborhood Condition
Average Supply Technology

(b) Change in Neighborhood Condition
Weaker Link Supply Technology

(c) Change in Neighborhood Condition
Weakest Link Supply Technology

Figure 3: Geographic Distribution of Neighborhood Change by Supply Technology

Figure 4: **Distribution of Proximity to New Light Rail Stations**