Valuing Land in Detroit Using the Option Value Approach

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Introduction

In 2010, the flaws in the property tax system in Detroit came to light when properties in lower-value neighborhoods, with an average sale price of $1,700, were taxed based on an assessment of $41,000—representing an overassessment of up to 30 times the actual sale price (Hodge et al., 2017). Through time, tax overassessment has been covered by multiple studies and media reports[1], providing evidence of a broken property tax system and the need to compensate affected homeowners. Additionally, current discussions aim to find a sustainable solution through property tax reform. Among the recommendations, Sands & Skidmore (2015) noted that it is possible under current statutes to implement a citywide land-based special assessment tax that could improve the efficiency of the overall property tax system. A land value tax or a split-rate tax applies a higher tax rate on land than on improvements,[2] and it is intended to foster growth and urban renewal. The rationale behind a split-rate tax is to lower the relative cost of capital versus land, thereby attracting more investments and fostering growth. The split-rate tax model has been adopted in over 30 jurisdictions globally (Dye & England, 2010), including Pennsylvania and Hawaii, with beneficial outcomes such as increased downtown job opportunities (Hartzok, 1997), more efficient use of urban infrastructure, a rise in the capital/land ratio aiding in combating urban sprawl (Banzhaf & Lavery, 2010), increment in the number of business establishments (Hanson, 2021), and an expanded tax base (Yang & Hawley, 2021). This idea merits discussion, especially in light of

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[1] See, for example, the studies and media coverage by Coalition for Property Tax Justice (https://www.illegalforeclosures.org/research)

[2] If taxes only apply to land value, then the tax regime moves from a split rate tax to a land value tax. In the literature, both terms are interchangeable because it is assumed that a land value tax comprises a tax combination with greatest emphasis on land value.

recent challenges with high property tax delinquency and erosion of the tax base in Detroit (Skidmore & Sands, 2012).

However, there are challenges that must be resolved in order to implement a split-rate tax. First, changes to the institutional framework may be needed to implement split-rate or land value taxation because most states would require new statutory authority (Sands & Skidmore, 2015). Second, and most relevant to this study, practitioners must be able to provide accurate and timely assessment of land value separate from improvements (Dye & England, 2010). The contribution of this study is to evaluate a simple method using Option Value (OV) theory, and to provide predicted land values based on this indicator. The call option model of land value indicates that land ownership gives the owner the right without obligation to develop or redevelop the property. Hence, there is an underlying decision to either develop the property and incur construction costs now or delay development to some point in the future (Titman (1985), Capozza & Helsley (1989)) Consequently, the value of a property is the sum of use value (the value of the land and existing structures in current use) and the option value, which is a function of the unrealized development potential of the parcel.

In this paper we present two sets of findings. First, we report empirical evidence for the existence of option value in Detroit property transactions. Using information from the Zillow ZTRAX database and constructing different intensity variables to compare predictions from theory, we estimate hedonic regression models of residential property value that include a measure of option value as an explanatory variable. We contribute to the current literature with a new way of measuring option value through an intensity measure that uses the relative volume of the property built through building footprint information. Results indicate that option value increases with property depreciation, as theory predicts. Having 100 percent option value increases sales prices by 18 percent, in our more conservative estimates. Second, we use these findings to calculate land values, and provide a simple and straightforward method to accomplish this. Results indicate that excluding option value from predicted land values under-estimates values, especially for higher priced properties.

In recent years, researchers have worked to develop approaches that allow land to be estimated separately from improvements. The approaches to measure land values include the residual land valuation approach, where the land value is equal to the sale price minus the replacement cost of the depreciated structure (Davis & Heathcote (2007), (Davis & Palumbo (2008). This method is computationally easy to implement, but it is demanding in terms of the information needed to calculate land values, particularly regarding the information need on replacement costs. Researchers have also used vacant lot sales to calculate land values (Dye & Mcmillen, 2007). The main idea in this approach is that the lack of improvements creates an opportunity to measure the transaction price as the value of the land. Hodge et al. (2015) implemented this approach in Detroit where they found that land values were high near the central business district (CBD) of the city and in the periphery, compared to land value in between. They were also able to generate a land value gradient for the entire city. The disadvantages of this approach are that the vacant lot sales are relatively few in comparison to the total number of transactions, and usually the spatial distribution of this type of lot is not random across the city.

Hybrid methods or methods that are generalizations of the aforementioned approaches have also been developed. Of relevance to the present work has been the visualization of the decision to redevelop a property as an action similar to the call option in the option pricing framework. Clapp

& Salavei (2010), Clapp, Salavei, et al. (2012), Clapp et al. (2021) contribute to the literature by: 1) theoretically justifying the inclusion of option value in traditional hedonic pricing models (Rosen, 1974); 2) proposing empirical functional forms for measuring option value; and 3) offer different variables that capture option value and empirical evidence through studies using data in cities in the United States as well as in Germany. In this work, the redevelopment option value is separated from the value of the property in its current use. This approach particularly relevant and useful for our work. In recent years, these authors have developed a land valuation method including the option value implicitly by relying on the assumption of irreversibility in the decision to redevelop. However, a drawback of these approaches is that these models also require information regarding the replacement cost.

Our contribution to the literature is as follows. First, we propose two empirical measures of property structural intensity to calculate the option value in Detroit transactions, and we compare this measure with one already used in the literature. To our knowledge, this is the first paper to present evidence of option value for the city of Detroit and to use a combined three-dimensional intensity variable with neighborhood quality, that capture the potential to redevelopment. Second, using the notion of option value as discussed above, we propose a simple method to measure land values: the use of hedonic models where measures of option value and current land use value are used to estimate the value of land. We include in our results a subsample of teardown properties (McMillen & O’Sullivan, 2013).

The remainder of this paper is organized as follows. Section II presents the theoretical framework. In section III, we present the specifications that identify the option value in hedonic regression models. Section IV provides the sources of data and discusses modifications we made to the original database. In section V, we present empirical evidence of the option value in Detroit using three types of intensity variables and the predicted land values. Finally, section VI concludes.

Real Options and Urban Land Valuation: Literature Review

The concept of real options comes from the finance literature related to asset investment decisions (Geltner et al., 2001). The evaluation of an investment decision involves making calculations regarding the expected net profit that the asset will grant in the future. The real option approach is a method that improves the prediction of the standard net present value (NPV), by including in this evaluation the opportunity cost for a lost option value (McDonald & Siegel, 1986). This option value arises from two important characteristics of an investment: irreversibility and the possibility of delay (Dixit & Pindyck, 1994). Hence, in each investment decision, the investor is holding an option (analogous to the call option), where she has the right but not the obligation to invest (or modify) an asset. The value of this option is embedded in the total value of the asset.

Real options framework were first applied to the context of real estate decision analysis by Titman (1985). In this environment, the figure of the investor is the landowner who owns a property as an asset. In each period, the landowner has the option to develop or modify her asset to another scale, or to do nothing depending on the net benefits perceived from this action. This option is embedded in the total value of the property, which has allowed to identify the real option value from property transactions information. In the following lines we offer a compilation and analysis of the empirical literature. To our knowledge, this is the first attempt to organize the literature in a systematic way, which is in itself a contribution.[3]

Real option theory implies the existence of 1) *development option*, when the landowner of undeveloped (raw) land has the option to develop to an optimal scale and in the optimal time, and 2) *redevelopment option*, when the landowner of a developed land can redevelop the property to a higher and best use (Womack, 2015).[4] Table 1 presents a summary of the empirical papers that study these decisions and identify what percentage of a property's market value is attributable to option value. The table is divided into two sections depending on the type of option being studied.

Quigg (1993) is the first empirical work that calculates the development option of vacant land. She uses the framework proposed by Williams (1991), where optimal date and optimal intensity of a vacant depends on expectation of future rents of the asset, that is not yet built, minus the construction costs. Using improved land transactions, she estimates the non-observable optimal developed property for vacant land (option model price). Additionally, she uses vacant land transaction prices and several parameters to calibrate the model can calculate the intrinsic value. Option value premium is then defined as the division between the difference of option value minus intrinsic value, divided by intrinsic value. Their results indicate that this option premium is equivalent, on average, to 6% of the value of vacant properties.

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[3] Womack (2015) provides a survey paper of the literature on real options and urban land values. However, the author does not delve into the results of the empirical studies, since the main objective is to cover all the literature on these topics, including theoretical research and gentrification. Our section elaborates on the subsection Womack (2015) calls "Redevelopment Option" in his article.

[4] There is a third option, the *abandonment option*, when the owner of either undeveloped or developed land can sell or abandon the property. In this work we do not focus on this option, but it would be interesting to study it in future research.

A very similar study by Grovenstein et al. (2011), but conducted in a different city and time, found that the option value is 6.6% of the total value of the vacant land. Unlike the study by Quigg (1993), Grovenstein et al. (2011) estimates the elasticity cost, one of the parameters that most affects the variation in the results. Both studies rely on construction cost information, something that is not necessarily available in all contexts. Additionally, both studies construct a counterfactual of the vacant property as if it were developed at its optimal scale with data from the already developed properties. This methodological decision, although very creative, can cause bias if the properties developed are inherently different (in unobservable variables) from those that are not yet developed.

Ooi et al. (2006) addresses this issue with a different approach. The authors exploit a natural experiment from Singapore Government Land Sales (GLS), where two types of auctions are held. Private auctions where vacant land is traded without restrictions, and GLS auctions where vacant land is traded but must be developed immediately after purchase. In this sense, this second type of transaction is stripped of any type of option, because development becomes mandatory. Therefore, the difference between both types of transaction should be equal to the value of the option value, *ceteris paribus*. Authors find a 45% option value in vacant properties, and they indicate that the main factor driving this effect is uncertainty of future prices. These results agree with those found by Cunningham (2006), where he estimates that price uncertainty reduces the likelihood of development and increases vacant land prices.

All previous studies focus on the development option, using vacant land. However, recent studies have also focused on expanding the sample of transactions to study the redevelopment option (see second section of Table 1). Pioneers in this area are the work from Clapp & Salavei (2010), Clapp, Salavei, et al. (2012) and Clapp et al. (2013). Our interest rest on the empirical variables to measure the redevelopment option through hedonic pricing models. Clapp & Salavei (2010) conducts a study for Greenwich, Connecticut, where they propose (and test) intensity, a scalar aggregation index for the amount of structure per unit of land, as a proxy variable for the option to redevelop. Intensity moves in the opposite direction to the option value, i.e., the higher the capital intensity of a property, the higher the opportunity cost of modifying or changing the structure to a new optimal level, because demolition costs increase.

The authors propose to measure intensity in three different ways. The first variable is constructed using information from the city assessor and correspond to the ratio between assessed structure value and assessed land value. The second variable is the ratio between the interior square footage and the average interior square footage of nearby new construction. Additionally, they propose a variable that they do not test in the paper, which is the percent of neighboring sales recently torn down or having teardown potential where teardowns are identified by the town assessor. This contribution is essential for our present work, since our first objective is to measure the option to redevelop from a complete sample of property transactions in Detroit.

Two of the three mentioned variables use information from the assessor office. Clapp, Salavei, et al. (2012) also uses the first variable in their study. This kind of information is useful because "[…] it has been shown that assessors add information through careful inspection of the property and the use of hedonic regressions that include numerous location factors… [and they are] able to observe whether the lot is suitable for development and assigns land value accordingly" (p.366, Clapp & Salavei, 2010). However, this may not be the case for Detroit. Skidmore and Sands (2015) present evidence that assessed valuations do not reflect market prices. Further, Hodge, et al. (2017)

shows that properties with lower market values are significantly over assessed. Note, however, that the city underwent a citywide residential reassessment in 2016, which improved the situation. Nevertheless, we do not prioritize assessed value information for our intensity estimators, nor for land value predictions.

Alternatives consist of using a comparison between the current scale of the property, and relatively new and recently sold properties in the neighborhood (as the second variable proposed by Clapp & Salavei (2010)). That is, it is assumed that this last type of property is sold at its high and best use (HBU). Büchler et al. (2020) follows this logic. Their methodology used to estimate redevelopment option in commercial properties consists of a three-steps procedure. First, construction of a continuous variable reflecting option value. Second, a first stage probit, using the continuous variable to instrument a redevelopment variable dummy. Third, second-stage hedonic model. To instrumentalize the redevelopment option, they build three proxies that attempt to measure the difference between a property in its current use versus the same property in its HBU, through the matching with a second sample (not used in the hedonic regression) of recently built properties.

These variables consist of the difference in ratios between Net Operating Income (NOI)[5] and land size, the ratios between structure size and land size, and the comparison between the land use (residential, retail, industrial and office) of the HBU properties and the land use of the property. Munneke & Womack (2020) follow a similar approach, using the ratio of land value to property value, the concentration of teardown activity, and a measured intensity variable such as the floor-

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[5] NOI is a calculation used to determine the profitability of commercial real estate investment (Büchler et al., 2020). Not available for residential properties.

to-area ratio as instruments for the redevelopment option. Both studies propose a key contribution by modeling the redevelop decision first, and then create an index or instrument to be use in the hedonic regression. At the same time both studies require knowing *ex-ante* which properties are effectively those that have the redevelop option.[6]

Let us summarize some empirical considerations when using option value proxies. 1) Development option is usually studied through the separation of the sample, between vacant properties and similar properties with improvements. 2) Redevelopment option is studied from the idea of intensity of the property. 3) Intensity moves in the opposite direction of option value. 4) Usually, the intensity proxy variable enters the hedonic regression in polynomials (to model the curvature of the option value) (Clapp & Salavei (2010), Clapp, Salavei, et al. (2012), Clapp et al. (2013)). 5) Zoning restrictions can also be important when empirically modeling this variable (Clapp et al., 2013). 6) Redevelopment option can have a high degree of spatial clustering (Munneke & Womack, 2020). 6) Finally, the option value varies with the periods of the economic cycle. In periods of expansion, the option value will have a greater weight in the value of the property, while the opposite happens in periods of recession (Clapp et al., 2013). In the next section, we will explain theoretically why this happen.

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[6] In the case of Büchler et al. (2020), this information was within the data from a third-party evaluation. In the case of Munneke & Womack (2020), they divide the sample between teardown and non-teardown property through property characteristics and demolition permit information.

Table 1: Overview of the empirical works analyzing development and redevelopment option in Hedonic Models.

Authors & Year	Key Characteristics	Option Value Variable	Results
Development Option			
Quigg (1993)	<u>Transaction type</u>: unimproved land parcels (vacant lots). <u>Land use type</u>: business, commercial, industrial, low-density residential and high-density residential transactions. <u>Location</u>: City of Seattle. <u>Time</u>: 1976 to 1979. <u>Sample Size:</u> 2,700	$OV\ Premium = \frac{Option\ Model\ Price - Intrinsic\ Value}{Option\ Model\ Price}$	Option Value Premium is calculated as a 6% of the average across all sample observations. For residential properties effect ranges from 1.1% to 11.2%, depending on the year of sale and the density of residential (low or high).
Ooi et al. (2006)	<u>Transaction type</u>: Land transactions by auctions (vacant lots). <u>Land use type</u>: Residential only. <u>Location</u>: Singapore <u>Time:</u> 1994 to 2004. <u>Sample size:</u> 273.	Dummy variable for Singapore Government Land Sales (GLS) transactions.	Option Value is 45% of the market value of vacant land.
Grovenstein et al. (2011)	<u>Transaction type</u>: Unimproved land parcels. <u>Land use type</u>: Commercial, Industrial and Residential. <u>Location</u>: City of Chicago. <u>Time</u>: 1986 to 1993. <u>Sample size</u>: 836.	$OV\ Premium = \frac{Option\ Model\ Price - Intrinsic\ Value}{Option\ Model\ Price}$	Option Value Premium is calculated as a 6.6% average across all properties. 10.4% for residential properties. Magnitude of the option premium varies greatly across the individual land use types.
Redevelopment Option			
Clapp & Salavei, (2010)	<u>Transaction type</u>: Improved parcels. <u>Land use type</u>: Single-family residential houses. <u>Location</u>: Greenwich, Connecticut. <u>Time</u>: 1995 to 2007. <u>Sample size:</u> Ranges from 4,557, to 5,218.	(1) $Intensity_{Assessor} = \frac{Assessed\ Structure\ Value}{Assessed\ Land\ Value}$ (2) $Intensity_{Const} = \frac{Interior\ Square\ Footage\ (ISF)}{Average\ ISF\ Nearby\ New\ Construction}$ (3) Percent of neighboring sales recently torn down or having teardown potential where teardowns are identified by the town assessor. [a]	Using Intensity (Assessor): The value of the option to redevelop an old, low intensity is 5.8% (10.5% for larger lots). The value to redevelop median property is only 1.8% in the entire sample (3.5% for larger lots and 1.1.% for small lots). Using Intensity (Construction): 32% of market price is option value.
Clapp et al. (2012)	<u>Transaction type</u>: Improved properties. <u>Land use type</u>: Single-family residential properties. <u>Location</u>: 53 towns in Connecticut. <u>Time</u>: 1994 to 2007. <u>Sample size:</u> 162,454.	$Intensity_{Assessor} = \frac{Assessed\ Structure\ Value}{Assessed\ Land\ Value}$ $LINT = \ln(Intensity_{Assessor})$ $LINT' = Detrended\ component\ of\ LINT.$	20% of towns have significantly positive option value, with a mean value of 29%-34% for properties most similar to vacant land. Average town has option value of about 6%.

		$LINTZ' = \begin{cases} 10 \text{ if LINT}' \text{ is at its bottom 2\% values} \\ 0 \; Otherwise \end{cases}$ $LINT25' = \begin{cases} 10 \text{ if LINT}' \text{ is at its bottom 25\% values} \\ 0 \; Otherwise \end{cases}$ $LINT75' = \begin{cases} 10 \text{ if LINT}' \text{is at its upper 75\% values} \\ 0 \; Otherwise \end{cases}$	
Clapp et al. (2013)	Transaction type: Improved properties. Land use type: Single-family homes. Location: West Berlin. Time: 1978 to 2007. Sample size: 19,825.	$D(Development\ Potential) = \frac{Maximum\ Size\ of\ a\ Property}{Size\ of\ existing\ Property}$ They use the natural logarithm of D. Additionally, they have two dummy variables: fully developed (1 for all observations for which development potential is 0), and high development potential: 1 for all observations with development potential > 0.58.	The elasticity of house value with respect to development potential is 15% on average over the full sample period. For high development potential properties, the elasticity is 23%.
Munneke & Womack (2020)	Transaction type: Improved properties. Land use type: Single-family residential properties. Location: City of Miami, Dade County, Florida. Time: 1999 to 2002. Sample size: 5,493.	First stage: probit where the redevelopment decision is evaluated. Explanatory variables are a measure of the ratio of land value to property (Value Ratio), a concentration of teardown activity measure (Percent Teardowns) and a variable physical intensity (FAR) which is measured by a property's floor-to-area ratio. Second Stage: consists of incorporating the predicted probability (*option value variable*) in a traditional hedonic price model.	Spatial Model: option value accounts for 4% of property's selling price on average for all the properties in the sample. For properties exhibiting option value (38% of the sample), the average option value is approximately 12% of a property's selling price and about 25% of a property's land value. Non-spatial model: the average redevelopment option value ranges from 8% to 18% of the sales price.
Büchler et al. (2020)	Transaction type: Improved properties. Land use type: Commercia properties only. Location: 30 American cities. Time: 2001 to 2018. Sample size: 46,000.	Proxies for redevelopment: $N = \left(\frac{\overline{NOI}^{hbu}}{\overline{LS}^{hbu}}\right) - \left(\frac{NOI^{current}}{LS^{current}}\right)$ $F = \left(\frac{\overline{SS}^{hbu}}{\overline{LS}^{hbu}}\right) - \left(\frac{SS^{current}}{LS^{current}}\right)$ $HBU\ Property\ Type\ Similarity$ Where NOI is Net Operating Income, SS is Structure Size, LS is Land Size and hbu is High and Best Use.	100% of redevelopment potential increases property values between 9% to 17%.

Source: Authors' own calculations.

[a] This variable is proposed by the authors, but they do not use it explicitly in their calculations.

[b] Mean across years 2010 to 2019.

Theoretical Considerations

In this section we present the theoretical foundations for the inclusion of option value in traditional hedonic models. Additionally, we relate these concepts to the valuation of land and the use of option value to determine it.

The Option to Redevelop in Hedonic Models

Rosen's model of market equilibrium for differentiated products explicitly abstracts from the representation of properties as assets, but rather as consumption goods (Rosen, 1974). However, the dynamics in the housing market related to urban renewal processes are explained by dynamics of deterioration and consequent redevelopment, where owners make decisions to partially redevelop (renovate) or fully redevelop (tear down) their existing properties (Munneke & Womack, 2015). Consequently, these types of decisions can be studied from the point of view of investment projects and be included in equilibrium models of the housing market.

Clapp et al. (2012) propose a framework that builds on Rosen (1974) by incorporating Option Value Theory (OVT) in the hedonic price model, and specifically from the framework of real options. The call option model of land value is based on the idea that land ownership gives the owner the right without obligation to develop or redevelop her property. Hence, there is an underlying decision to either develop the property and incur in construction costs now, or delay development to some point in the future (Titman, 1985). The strength of this model lies in the determination of the option value as an additive term in the hedonic price function, which is very useful at the time of its estimation. Below, we provide a brief summary of the model and its theoretical consequences.

The first assumption of Clapp's model is to treat the option to redevelop as a single irreversible call option.[7] This assumption implies that once the land redevelopment investment has been made, the structure cannot return to the initial state due to nonzero demolition and construction costs (Clapp et al., 2021). The historical context of Detroit, marked by profound economic shifts and urban decay, further substantiates this irreversibility assumption. This assumption indicated that once redevelopment has occurred, the option to revert to the previous state is typically off the table, due to sunk costs. With the average cost of demolitions in Detroit being $20,000 (Paredes & Skidmore, 2017), and the prevalence of vacant lots, blighted neighborhoods, and underdeveloped land (Owens et al., 2020), it is clear that redevelopment decisions have enduring consequences and that reversal of such decisions is not readily accomplished. Finally, it is worth noticing that while we do not observe all individual choices of redevelopment, we have an opportunity to observe one from one agent: the local government. In the context of an urban policy, where the local government has been faced with a choice between demolition and redevelopment, the government's actions have led to a far greater number of demolitions compared to redevelopments (Alvayay Torrejón & Skidmore, 2023). This indicate how costly can be the redevelopment option.

In this model, the landowner (and developer) is risk-neutral and that at time t, she has a unit of land ($L = 1$) and an initial scale of housing ($\bar{Q}$). Then, at any time $s \geq t$, the landowner is able to

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[7] The single irreversible call option has the following investment characteristics: 1) Irreversibility, 2) Uncertainty, and 3) Timing. From the real option approach to investment, these characteristics are also present in the landowner's decision to develop his property. Irreversibility, because the initial investment cost is at least partially sunk, especially when construction and demolition costs are high. Uncertainty because there is an option to wait based on future rewards. And timing because there is a control of when the investment will be made.

redevelop land on a scale equal to Q. The functions of cost of redevelopment and rent per unit of the redeveloped property are given by equations (1) and (2), respectively.

$$C(Q,\bar{Q}) = Q^{\eta_2}\bar{Q}^{\eta_1} \tag{1}$$

$$R\big(Q,x(t)\big) = Q^{b}x(t) \tag{2}$$

Costs depend on the initial structure ($\bar{Q}$) and the scale or density of the new structure to be invested (Q). Costs are assumed to increase with Q ($\eta_2 > 0$), but there is no restriction for the case of $\bar{Q}$. However, for our case it is probable that costs increase with initial structure ($\frac{\partial C}{\partial \bar{Q}} > 0$) due to positive demolition costs. Also, we assume that rent per unit of the redeveloped property decreases with Q, at a decreasing rate ($0 > b > -1$). Likewise, the rent per unit of the existing property is giving by $R\big(Q,x(t)\big) = \bar{Q}^{b}x(t)$.

The developer's problem is to find the optimal time to execute the option and the optimal redevelopment scale that maximizes the expected net present value of the existing property (Poterba, 1984). Equation (3) summarizes the problem mathematically, where the first term is the expected present value of rents up to the redevelopment time T, the second term is the expected present value of rents since redevelopment time, and the third term corresponds to the expected present value of redevelopment costs. A risk-free interest rate is assumed that also corresponds to the discount rate, ρ.

$$z(x,\bar{Q}) = \max_{T,Q} E_t\left\{\int_t^T \bar{Q}^{b+1}x(s)e^{-\rho(s-t)}ds + \int_T^\infty Q^{b+1}x(s) - Q^{\eta_2}\bar{Q}^{\eta_1}e^{-\rho(T-t)}\right\}$$

$$st \qquad dx(t) = \alpha x(t)dt + \sigma x(t)dz(t) \tag{3}$$

Notice that the landowner's maximization problem is subject to the shocks on the demand side, $x(t)$ (x from now on). Unlike Quigg (1993) who introduces uncertainty in the cost function, Clapp et al. (2012) includes uncertainty in x. Therefore, the constraint in equation (3) indicates that the demand shocks follow a Geometric Brownian motion, where α is the constant growth rate, σ^2 is the variance of the growth rate, and $z(t)$ follows a standard Wiener process where $E[dz(t)] = 0$ and $E[dz(t)]^2 = dt$. Note that the Geometric Brownian motion is a special case of an Ito Processes to model the behavior of a non-stationary stochastic variable (Dixit & Pindyck, 1994).

The solution to the optimization problem determines an optimal development density and a critical demand level above which redevelopment becomes the preferable choice (see details of this calculation in the appendix section of (Clapp, Jou, et al., 2012). This optimization balances the present value of the existing property against the potential upside of redevelopment, inherently factoring in the option value. The insights of the model are particularly relevant in markets like the one of Detroit, where historical economic volatility and urban blight underscore the permanence of redevelopment decisions.

To map the option value to the hedonic characteristics space, x must be held constant at time t. We define $\bar{Q}_0$ as the lowest intensity level such that $x = x^*(\bar{Q}_0)$, and we focus on the case where $\bar{Q} > \bar{Q}_0$, that is, where it is better to delay the redevelop option of the existing property because the current state x still does not reach the critical optimal value. In this case, the value of the existing $(F(\bar{Q}) = P(\bar{Q}))$ is a function of the current development intensity, as indicated by equation (4)

$$F(\bar{Q}) = P(\bar{Q}) = B_0\bar{Q}^{b+1} + B_1\bar{Q}^{\alpha_0} \tag{4}$$

Where $B_0\bar{Q}^{b+1}$ represents the base value of the property, which is influenced by factors like the property size and the intrinsic value of the land without redevelopment, and $B_1\bar{Q}^{\alpha_0}$, on the other hand, captures the added value from potential redevelopment, reflecting the premium that the market is willing to pay based on the property development prospects[8] (Clapp, Jou, et al., 2012). Notice that $\alpha_0 < 0$, which implies that the option value will decrease with increasing intensity. Intensity can be understood as a scalar aggregation index of the amount of structure per unit of land value (Clapp, Salavei, et al., 2012). Second, $B_1 \geq 0$ because property owners have the right but not the obligation to redevelop. Therefore, the option value term cannot be negative.

Furthermore, the value of a property will be the sum of use value, the value of the land and existing structures in current use, and the option value, which is a function of the unrealized development potential of the property (see equation 5).

$$Market\ Value = Use\ Value + Option\ Value \tag{5}$$

There are two theoretical implications from equation (4) that can be tested empirically. First, notice that the first part of equation (4) is the classic hedonic model specification that include factors that determine value under the current use of the asset. The second part, which measures option value, enters to the equation in an additive form. The additive nature of the equation implies that models

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[8] The parameters represented by B_i and α_0 in equation (4) are functions of the level of scale $\bar{Q}_0$, the constant rate of interest, the rate of depreciation, the stochastic parameters, the parameters from the cost function, and solution to the fundamental quadratic equation.Within the valuation model, B_0 and B_1 serve as fixed parameters that encapsulate several economic and property-specific factors. B_0 is influenced by the intrinsic characteristics of the property, such as its location, land area, and current usage, which determine the baseline value of the property irrespective of redevelopment potential. It reflects the worth derived from the property's existing utility and the income it can generate in its current form. Conversely, B_1 represents the option value parameter. It is shaped by expectations of future market conditions, zoning regulations, and the potential for an increase in property value due to possible improvements or changes in land use. This parameter quantifies the additional value that the market assigns to the property based on its redevelopment potential—essentially, the financial advantage of holding onto a property until the optimal moment for redevelopment.

that do not directly measure option value assume that this second part is equal to zero. In practical terms, the option value is zero or close to zero in markets that are fully developed with relatively new properties (Clapp, Jou, et al., 2012).

The second implication is that equation (4) indicates that the option value is measured by the inclusion of a non-linear function of intensity, which is the size of the structure relative to land on a property. The literature offers several alternatives proxy measures for intensity (as shown in the next section). However, it is important to understand the interpretation of each measure. In this context, a larger structure relative to the size of the land suggests a higher intensity. Properties with such a characteristic might be close to optimal intensity, especially if they are newer. This near-optimal intensity implies a higher opportunity cost if the redevelopment option is exercised, as it would involve forgoing the income generated by the current structure. Consequently, the option value is lower for properties at or near optimal intensity because the benefits of redeveloping are not as pronounced relative to the costs.

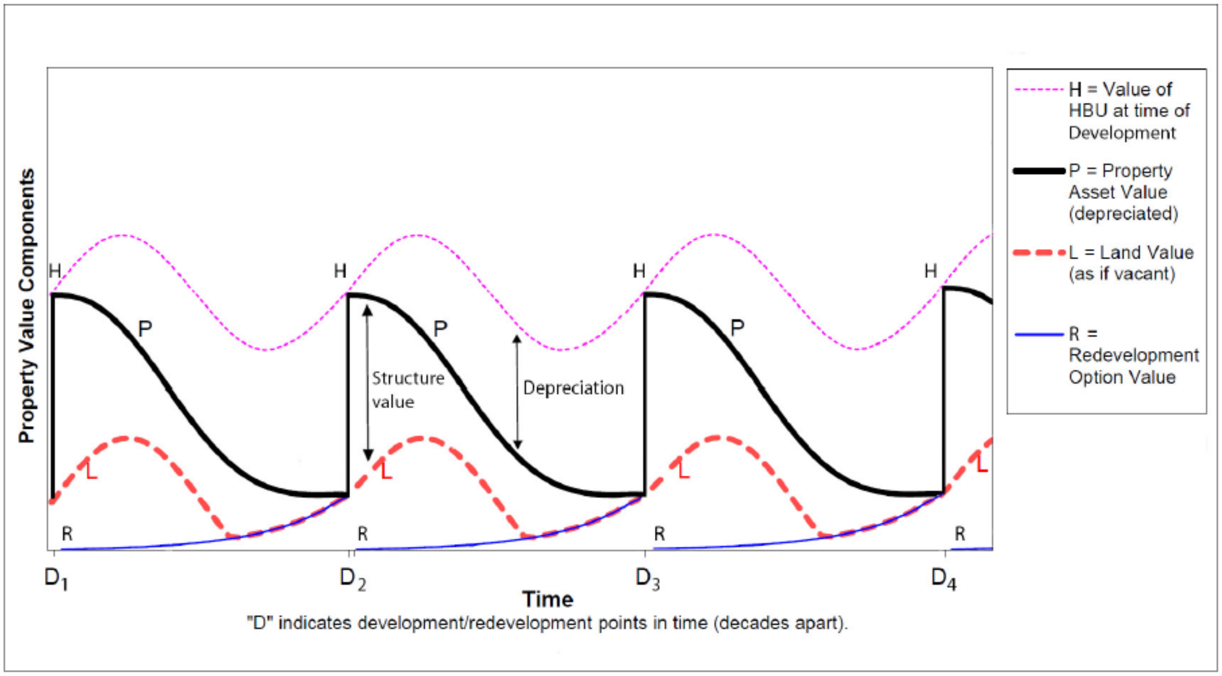
Conversely, a smaller structure relative to the size of the land indicates a lower intensity. Older properties that are smaller in scale may be further from optimal intensity, which can increase the option value. These properties, being further from the optimal point, carry a higher option value since the potential income from redevelopment, relative to the cost of redevelopment, is greater. This relationship is justified by the second part of equation (4), which is a function of the intensity scalar and the depreciation rate effects. Note that this relationship is simplified as long as factors such as demand shock, uncertainty, interest rate, depreciation rate, costs, and economic cycle factors are held constant.

Land Value and Option Value

The option value component in the hedonic model represents the value of the potential to redevelop a property in the future (see Figure 1). As a property approaches the optimal time for redevelopment, the option value gets close to the underlying land value. This occurs because just before redevelopment, the existing structure has little remaining useful life and therefore minimal value. Thus, the opportunity cost of redeveloping is low, and the redevelopment option value approximates the land value Büchler et al. (2020). In contrast, for a property that is far from the redevelopment point and at peak use value, the land value exceeds the option value. In this case, the current use of the land and improvements adds significant value above the raw land value. Therefore, the option to redevelop has a higher opportunity cost.

This framework suggests two potential empirical approaches to estimate land value using the hedonic model with option value. First, for properties near the redevelopment point, the estimated option value provides an approximation of land value. Second, for properties at peak use value, the combined estimated use value and option value provide an upper bound estimate of land value. The use value component measures the gross value added from existing structures. Subtracting use value from total value yields an estimate of land value. In summary, the relationship between option value and land value established in the theoretical model can be leveraged to empirically estimate land values for properties at different points in their lifecycle. This provides useful insights for the next section.

Figure 1: Relationship between land value and redevelopment option value



Source: Büchler et al. (2020).

Identification Strategy

This section describes our approach to calculate land values in Detroit. We first estimate hedonic regressions to identify/measure option value. We then explain how we use these estimates to compute land values.

Step One: Estimate Option Value for Detroit Residential Properties

According to Clapp & Salavei (2010), equation (6) can be estimated using several potential functional forms, starting with the logarithmic transformation. As a benchmark, the first specification that we estimate is the classic hedonic pricing model.

Standard Hedonic Model

$$lnP_i = \boldsymbol{\alpha}'\boldsymbol{q_i} + \varepsilon_i \tag{6}$$

In equation (7), $\boldsymbol{q_i}$ is the vector of the typical variables that measure property characteristics, location attributes, dummies variables indicating the year of sale, and a constant term. Of these variables, the greatest relevance are the intensity proxy variables: $InteriorFootage_i$ (interior area or building square footage), $Lotsize_i$ (lot size in square feet), and Age_i and Age_i^2, (polynomial function of building age as a proxy for depreciation).

Let $Intensity_i$ represent the intensity of land use as measured by the relative size of the structure land area for each property i, and $\ln Intensity_i$ as the natural logarithm of this variable. Equation (7) shows the first specification to be estimated, which is the standard hedonic model with the option value. Usually, this variable is measured as a ratio between structure and land which implies that $Intensity_i \geq 0$. The upper bound depends on the relative sizes of the numerator and denominator. However, if the structure is equal to zero (vacant properties) the logarithmic transformation may not be the most appropriate to measure the effect of the option value.[9]

First Specifications: Hedonic Model including the Option Value

$$lnP_i = \boldsymbol{\alpha}'\boldsymbol{q_i} + \beta_1 \ln Intensity_i + \varepsilon_i \tag{7}$$

The option value increases the market value of the property by discounting the future net benefits at the present value. At the same time, the option value is inversely related to the intensity of the property. Therefore, the hypothesis we test is $\beta_1 < 0$. Hence, the marginal effect will be multiplied by (-1) to obtain the interpretation of the option value effect (see equation 10).

$$\frac{\%\Delta Price}{\%\Delta Option\ Value} \approx \frac{lnP}{\ln Option\ Value} = -\hat{\beta}_1 \tag{8}$$

The second specification we estimate is intended to capture the theoretically predicted relationship between option value and the depreciation rate. Older and, therefore, more deteriorated property, will tend to have a higher option value. This effect occurs via the component in the cost of developing the option value, which is a function of the current value of the property. A high depreciation implies a lower structural value and thus a lower opportunity cost to exercise the option to redevelop. One approach to capture this effect is through the interaction of the intensity variable with the age of the structure. This specification is illustrated in equation (9):

Second Specification: Hedonic Model including the Option Value and Depreciation Effect

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[9] In this paper, the sample does not contain vacant lots, so we have no problem with the logarithmic transformation.

$$lnP_i = \boldsymbol{\alpha}'\boldsymbol{q_i} + \beta_1 \ln Intensity_i + \beta_2 \ln Intensity_i \times Age_i + \beta_3 \ln Intensity_i \times Age_i^2 + \varepsilon_i \tag{9}$$

Equation (10) captures the marginal effect of the intensity variable, which is now a function of age. The interpretation is that older structures have higher depreciation, and thus we expect a higher option value (or lower intensity).

$$\frac{\%\Delta Price}{\%\Delta Option\ Value} \approx \frac{lnP}{\ln Option\ Value} = \{-(\hat{\beta}_1 + \hat{\beta}_2 \times Age_i + \hat{\beta}_3 \times Age_i^2)\} \tag{10}$$

Finally, our last specification is shown in Equation (11).

Third Specification: Hedonic Model including the Option Value, Depreciation Effect and Neighborhood Housing Quality

$$lnP_i = \boldsymbol{\alpha}'\boldsymbol{q_i} + \beta_1 \ln Intensity_i + \beta_2 nhood_{quality_i} + \beta_3 \ln Intensity_i \times nhood\_quality_i \times nhood\_quality_i \times Age_i + \beta_4 \ln Intensity_i \times nhood\_quality_i \times Age_i^2 + \varepsilon_i \tag{11}$$

Equation (12) captures the marginal effect of the intensity variable, which is now a function of age and neighborhood quality.

$$\frac{\%\Delta Price}{\%\Delta Option\ Value} \approx \frac{lnP}{\ln Option\ Value} = \{-(\hat{\beta}_1 + \hat{\beta}_3 \times nhood\_quality_i \times Age_i + \hat{\beta}_4 \times nhood\_quality_i \times Age_i^2)\} \tag{12}$$

The neighborhood quality in our study is quantified through the construction of a blight index. Thanks to a newly rich publicly available data from the City of Detroit, we can know geolocated information on blight infractions within the city of Detroit, from 2008 to 2019. For each sale, we count the number of blighted properties within a 0.5 miles radius, within the three years prior to the sale year. To add depth to this count, we calculate the average fine amount reflecting on the severity of the infraction. Additionally, for each property we multiply the number of blight infractions times the average fine (Blight Intensity Score, BIS) amount that reflects both the prevalence of blight and the financial weight of its impact. To ensure comparability across different neighborhoods, we normalize this score by dividing it by the maximum BIS observed within each neighborhood, resulting in our final Blight Index measure.[10] This index serves as a nuanced indicator of neighborhood quality, capturing not just the presence of blight, but its economic significance as well.

To our knowledge, this is the first paper attempting to include neighborhood quality as an interaction effect with intensity. The hypothesis is that a neighborhood with higher blight scores (indicating more violations and potentially lower quality) could reduce the option value of a property. Investors might perceive properties in such areas as less desirable due to the potential for higher costs to address these issues or because they expect less appreciation in property values. Combining intensity with neighborhood quality adds another dimension to the redevelopment decision. A high-intensity score in a neighborhood with a poor blight index might be less favorable than the same score in a neighborhood with a better blight index. This can affect the interpretation of option value because the potential for redevelopment might be curbed by negative neighborhood factors.

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[10] Hence, blight score ranges from 0 to 1, with 1 indicating areas with more blight infractions and more serious ones as well.

Summarizing, the three hypothesis that we are testing (and the ones that will shed light on how good we are measuring option value) are the following ones:

- H1: Increased land use intensity decreases property prices, suggesting a rise in option value.
- H2: The devaluing effect of land use intensity on price intensifies with property age, indicating a greater option value for older properties.
- H3: Higher neighborhood blight scores diminish the option value, with the impact of intensity on price being less adverse in areas with more blight.

Construction of the Intensity variables

In this section, we present the methods we use to construct the two measures of option value. The database we are using contains information on assessed values in Detroit. Specifically, we have information on the assessed land value and the assessed value of improvements. Several papers in the literature use this information from the Office of the Assessors to create the intensity variables because, "…it has been shown that assessors add information through careful inspection of the property and the use of hedonic regressions that include numerous location factors… [and they are] able to observe whether the lot is suitable for development and assigns land value accordingly"(p.366, Clapp & Salavei, 2010). However, this may not be the case for Detroit. Skidmore and Sands (2015) present evidence that assessed valuations do not reflect market prices. Further, Hodge, et al. (2017) shows that properties with lower market values are significantly over assessed. Note, however, that the city underwent a citywide residential reassessment in 2016, which improved the situation. Nevertheless, in this paper we do not use assessment data to estimate the impact of intensity on property values, and particularly to estimate the value of land. Recall that our ultimate objective is to develop methods for improving land value assessments for tax purposes. However, the results of this exercise are available upon request, though the estimates are contrary to theoretical predictions.

1) <u>Relative 2D Intensity measure (neighbors within 0.5 miles)</u>

The first variable we use to examine option value is $Intensity_{2D\_05,i}$ (see equation 13). This variable measures the interior square footage of property i relative to the average interior square footage of neighbors j. This is a relative measure of the condition of the property with respect to the neighborhood.

$$Intensity_{2D\_05,i} = \frac{Interior\ Square\ Footage_i}{\frac{1}{J}\sum_{j \neq i}^{J} Interior\ Square\ Footage_j} \tag{13}$$

It is important to indicate that neighbors j of property i must meet certain conditions to fall into the category of neighbors and be included in the comparison group. First, the neighbors are all those properties that are within a radius of 0.5 miles around property i.[11] Second, we only include properties with an age equal to or less than 60 years. Third, the comparison group only includes properties that were sold within three years of the year of sale of property i, including the present

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[11] In the case of Clapp & Salavei (2010), they chose a radius of 1.25 miles. We chose a smaller radius based on the size of the city.

year.[12] For example, if a property was sold in 2015, neighbors are those properties around property i that were sold in 2015, 2014, 2013, and 2012. These conditions ensure that the comparison group in the denominator of equation (13) are relatively new properties that were recently sold.

Figure 2 presents a geographic representation of this process using 2012 data as an example. Figure 2 shows the mapping of two types of properties across Detroit. The first group are all those properties that sold in 2012 (marked with a yellow triangle). The second group includes all the properties that constitute potential neighbors according to requirements discuss above. The map shows that for each of the properties sold that year, a radius of 0.5 miles is calculated (the property marked with the red triangle is an example). Then interior footage square of each of the neighboring properties within that radius (those properties marked with blue) is averaged. Finally, the ratio is the interior square footage of the property divided by the average of its neighbors within a 0.5-mile radius. This procedure is repeated for each of the properties marked in yellow for all the years of the sample.

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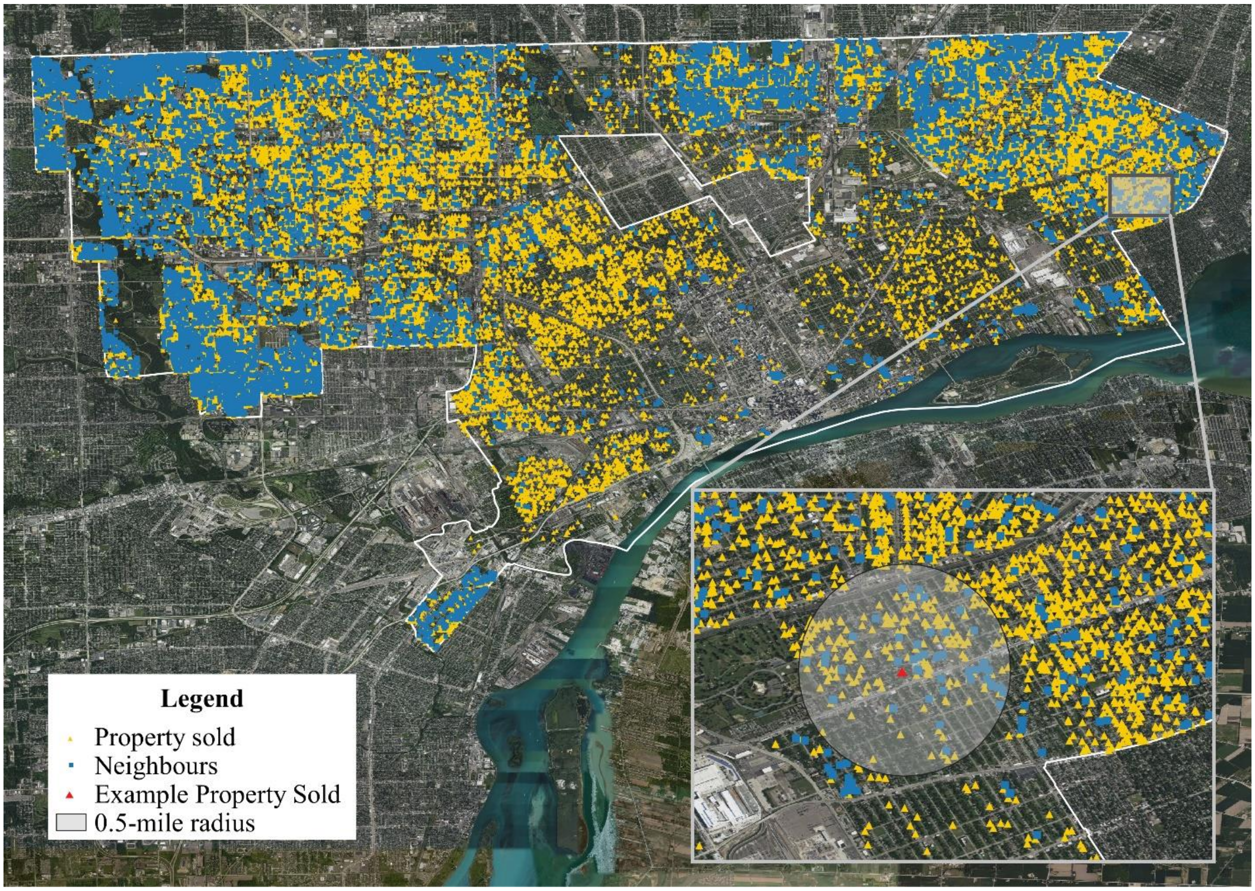
[12] In addition to these requirements, the filters made to the properties in the complete sample are added, which are detailed in the following Data section.

Figure 2: Example of the construction of the variable $Intensity_{2D_{05},i}$



Source: Authors' calculations. Note: This map presents an example of the construction of the $Intensity_{neighbor05,i}$ variable for 2012. The geographic location of properties sold that year is indicated with yellow triangles, while neighbors or comparison group is indicated with blue squares (read the main text for more detail regarding the construction of this group). Additionally, we provide a zoom to the map to show the construction process of the variable. For each property sold (as an example the property highlighted with a red triangle) a radius of 0.5 miles is set and the interior square footage of the structure as marked with blue squares is averaged. This procedure is repeated for each of the properties marked with yellow triangles. Note: The two areas within the city are the separate jurisdictions of Hamtramck and Highland Park.

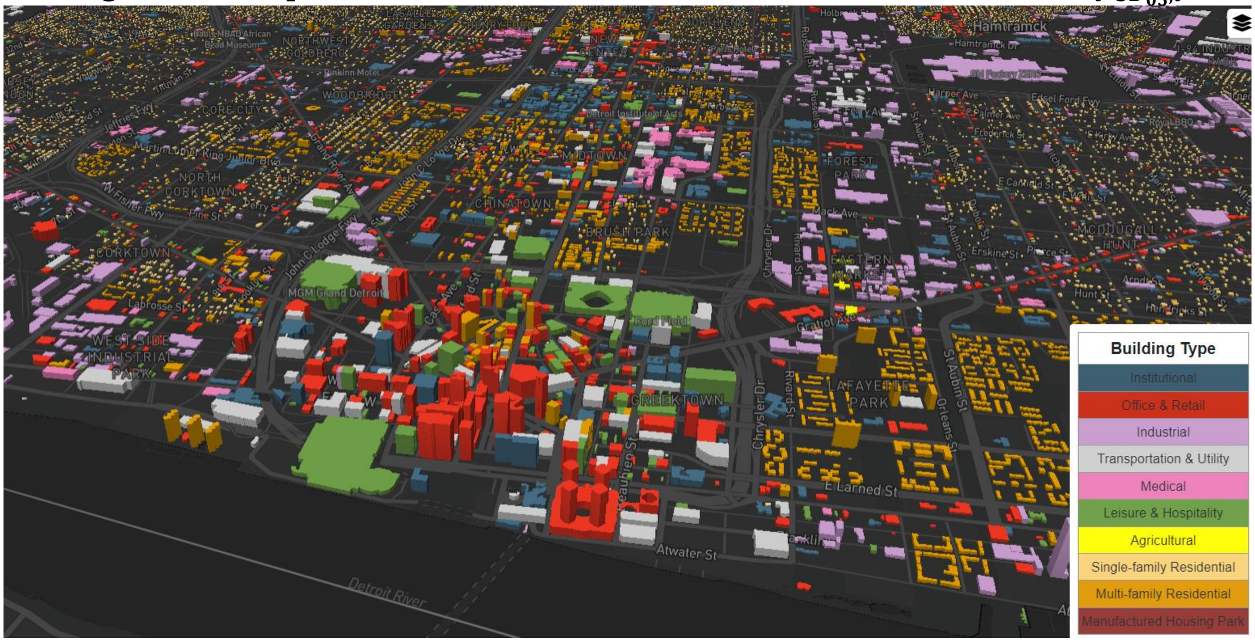
2) Relative 3D Intensity measure (neighbors within 0.5 miles)

The second intensity measure we propose, exploits current technological resources to include volume as a three-dimensional measure of the property infrastructure development. Equation (14) shows that the variable$Intensity_{3D_{05},i}$ is equal to the ratio between the volume of property i and the average volume of all properties j located within 0.5 miles from property i. Volume is defined as $interior\_sqft \times building\_height$.

$$Intensity_{3D_{05},i} = \frac{Volume_i}{\frac{1}{J}\sum_{j\neq i}^{J} Volume_j} \qquad (14)$$

Similar to the $Intensity_{neighbor05,i}$, neighbors must comply with all the requirements we mentioned. A 3D intensity variable provides a more comprehensive measurement by accounting for the volume of structures in addition to area (see Figure 3 as an example). This additional dimension could capture the real estate value more accurately, as it reflects the physical reality of structures better than a 2D measure. Certainly, there are still limitations regarding the physical and visual characteristics of the property, or the state of the infrastructure. Although we do not include a measure of infrastructure quality explicitly, the interaction with age allows us to at least control for part of the depreciation. In the Data section we present, discuss and compare the descriptive statistics for the three intensity measures.

Figure 3: Example of the information to construct of the variable $\boldsymbol{Intensity_{3D_{05},i}}$



Source: Building Footprint information from the Southeast Michigan Council of Governments (SEMCOG). Note: This 3D map presents an example of the building footprint information that we use to create $Intensity_{3D_{05},i}$.

Step Two: Estimating Land Value Using Option Value

First, we can calculate land values if we add to the option value the use value coming from the current use of the land and its location. We can measure the option value and use value components as proposed in equation (15) and (16). We use Poisson regression model to ensure positive predicted values, and to predict values in dollar amount.

$$P = f(OptionValue, UseValueofLand, Improvements) \tag{15}$$

$$E(P_i|\boldsymbol{X}) = \exp\left[f(\beta_i, Intensity) + \beta_5 Nhood + \boldsymbol{\alpha}'\boldsymbol{q_i} + \varepsilon_i\right] \tag{16}$$

As the reader noticed in the first step, we have three specifications to calculate $f(\beta_i, Intensity)$. We will use the third specification to simplify the analysis, and to test this new intensity variable that we are including in the option value literature. In equation (16), use value of land depends on lot size and location through a variable of neighborhoods. Notice that the $\boldsymbol{q_i}$ vector is composed of the variables that measure the improvements, such as the interior square footage, number of stories, number of bathrooms, type of heating system and the material of the exterior wall of the property.

We obtain the predicted price values from equation (16), $\hat{P}_i$. Then, we replace the intensity, age and neighborhood quality variables for each property to the maximum intensity, minimum age and best blight index within its neighborhood n, respectively. The idea here is to find the property developed at its Highest and Best Use (HBU) (this means with zero option value). We obtain predicted price values assuming the property its developed to the full potential, $\hat{P}_{maxint,i}$. Finally, the option value is going to be the difference between the actual development of the property and the counterfactual property in its HBU (see equation 17).

$$\widehat{OptionValue_i} = \hat{P}_i - \hat{P}_{maxint,i} \tag{17}$$

To estimate predicted land values, we calculate equation (18), where $P_{nooptionvalue} = P_i - (\widehat{OptionValue_i})$. This means the sale price removing the option value calculated in the previous step.

$$E\left(P_{nooptionvalue_i} \middle| \boldsymbol{X}\right) = \exp\left[+\beta_4 Lotsize\ +\ \beta_5 Nhood\ + \boldsymbol{\alpha}' \boldsymbol{q_i} +\ \varepsilon_i\right] \tag{18}$$

We do the same exercise as before. We adjust property characteristics to their minimum values within each neighborhood, and then predict values from equation (18). The assumption here is to predict the sale price for a property with no improvement and without option value, which constitutes the predicted land values without option value, $LV_{\widehat{nooptionvalue}}$. Finally, predicted land prices will be the sum between land value without option value, and option value, as shown in equation (19).

$$\widehat{LV} = LV_{\widehat{nooptionvalue}} + \widehat{OptionValue}_i \tag{19}$$

Importantly, we also compute land values using the teardowns property subsample. With this approach we identify those properties that were sold when they had smaller structures compared to their neighbors (low level of intensity, that is, relatively small properties), and we used building permits data to determine which properties were significantly altered after sale as determined by the estimate cost of the modifications. That is, we only included the higher cost modifications as a proxy for teardowns. This approach constitutes our best approximation to identify teardowns in the sample.

With this subsample we estimate $\widehat{LV} = \widehat{OptionValue}_i$ where the difference is that now we believe that for these properties the transaction occurred closer in time to the redevelopment point (see Figure 1), and therefore the option value should be equal to or very close to land value. That is, for this land value calculation we do not include the effects of lot size or location because they are already implicit in the option value.

Data

Data Sources

We use information from the ZTRAX database, which is real estate information provided by Zillow Inc., an American online real estate marketplace company. For the State of Michigan, there are nearly 3.5 million transactions recorded of which 940,805 correspond to transactions made in the City of Detroit.[13] ZTRAX contains two sources of information: 1) ZTrans, which is the property transaction database, and 2) ZAsmt, which is the tax-assessment information. We also use the geolocation of all the properties in combination with GIS to add information regarding neighborhood, and distances to the main database.[14] Furthermore, we add a data on building footprint to construct the three-dimensional measure of intensity.[15] To assess neighborhood quality, we incorporate Blight Violation Notices (BVN), a dataset documenting the issuance of citations to property owners who fail to maintain the exterior of their properties in accordance with City of Detroit ordinances.[16] These blight tickets, issued by city inspectors and other officials, reflect compliance with local property maintenance codes and are processed by the Department of Administrative Hearings. The integration of blight violations contributes to the construction of the

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[13] This is the number of transactions that have been collected by Zillow. The information includes transactions from the last century.

[14] See Table A2 in the appendix for further details on distances calculations.

[15] The data on Building Footprints is publicly available by the Southeast Michigan Council of Governments (SEMCOG). See here for more information: https://maps-semcog.opendata.arcgis.com/datasets/building-footprints-2020/explore?location=42.445079%2C-83.286436%2C9.44

[16] The data on Blight Violation Notices (BVN) is publicly available by the City of Detroit. See here for more information: https://data.detroitmi.gov/datasets/detroitmi::blight-violations/about.

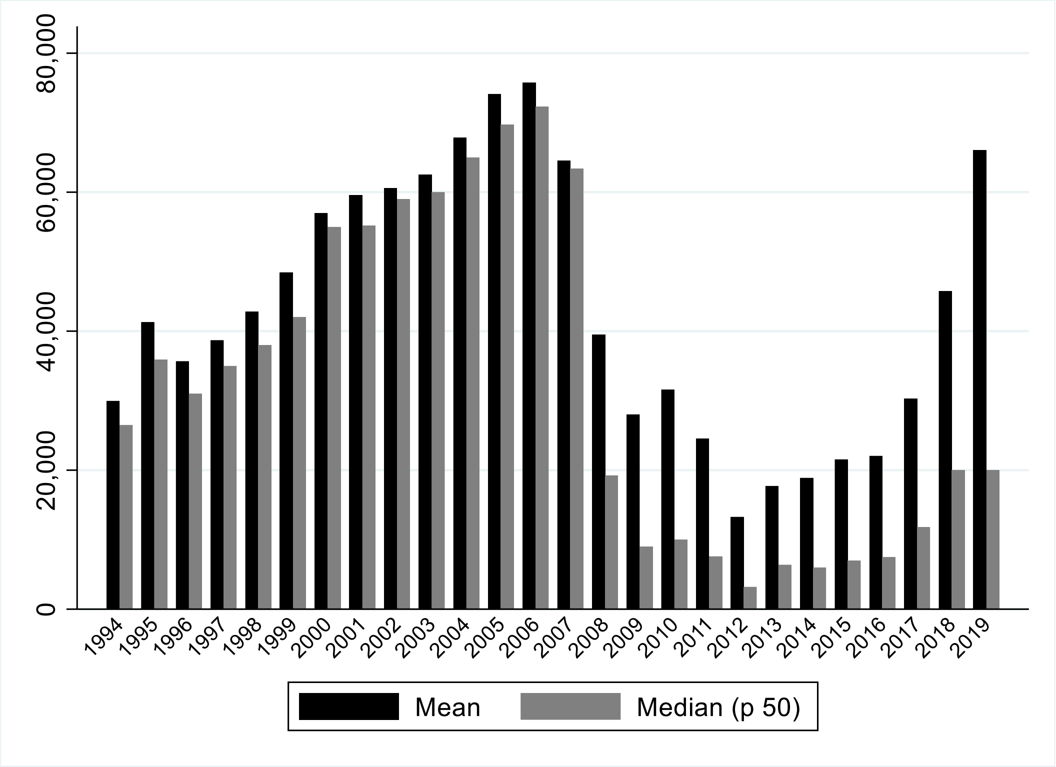
blight index, offering a robust indicator of neighborhood quality.We combined these data sources to create the dataset we use to estimate a set of hedonic regressions.

Identification of market transactions

In this subsection we review the filters we used to identify those transactions that are likely to reflect market value. First, we limited the time period of analysis to 2012-2019. The reason for choosing this time frame is that that the rate of redevelopment of a durable asset is affected by the economic cycle and thus is not a constant over time (Clapp et al., 2013). In boom periods, it is expected that the prices of properties with the highest option value will fluctuate the most. Therefore, we examine a period of housing market recovery following the real estate crisis where housing prices were in recovery.

It is important to note that we use sales from 2009 because the intensity variables are constructed with transactions that occurred up to three years prior. Therefore, although the study period begins in 2012, we also used transactions from 2009, 2010, and 2011 to generate the intensity measures. Figure 4 shows the fluctuations over time in the mean and median sales prices in Detroit. The graph shows the effect that the real estate crisis had on the housing market, including the slow recovery where the pre-crisis price levels have not yet been reached.

Figure 4: Mean and Median Sale Prices in Detroit



Source: Authors' calculations. Note: The calculation of this figure involves all the transactions carried out in Detroit according to the ZTRAX database.

Table A1 in the Appendix summarizes the steps we use to identify market transactions. The first step consists of removing observations with incorrect latitude and longitude information. Second, we select sales for years 2009-2019. The third step is to remove duplicate transactions. For steps five and six, we follow Nolte et al. (2021) to resolve issues with the ZTRAX database where the authors filtered transactions based on type of deed, document type, whether transactions occurred within families, and whether properties were tax exempt. Additionally, we selected residential properties for our evaluation. As one last step, we removed properties that sold more than seven times during the study period. We removed these properties because the repeat sales literature suggests that these properties are typically in worse condition relative to other properties. The second part of Table A1 presents the effect of each of these steps and filters on the distribution of key variables in our calculations.

Generally, property characteristics are very similar across all filtered subsamples. In terms of the dependent variable, the sale prices change with subsamples where the mean price decreases from \$31,179 to \$15,845. Although the price difference is notable, it is mainly the result of selecting the sample from sales in the recovery period. It is also important to note that the total number of observations in Table A1 will not necessarily match the total number of observations in the regression because: 1) the time period for Table 1 begins in 2009; and 2) the combination of missing values between the variables included in the regressions. The final sample of observations and descriptive statistics are discussed below.

Results

First Step Results: Evidence of Option Value in Detroit

Table 2 presents the descriptive statistics for all variables included in our evaluation, of which we discuss several key variables. In Panel A we show the dependent variable, sale price and natural logarithm of the sale price. In this first stage of the analysis, we use the natural logarithm of the dependent variable so that we can more easily compare our results with those in other articles. However, in the second stage of the analysis we use the sale price in dollars in order to facilitate a simpler interpretation that requires fewer assumptions to generate predicted land values.

The mean sale price is \$14,927 with a standard deviation of \$21,234. Low prices are common in Detroit during this period. Although it does not appear in the table, it is important to point out that the median sales price is \$6,200, which implies a high variance. The natural logarithm of the sale price has a mean of 8.6, and the number of observations on sales price is 122,177.

In Panel B we show the key independent variables, which are the two intensity variables were described in previous sections. First, $Intensity_{2D_{05}}$ has a mean of 1.1, i.e. on average properties have slightly more interior square footage than their neighbors within a 0.5-mile radius. There are properties that have interior square footage as small as 0.08 times that of their neighbors (minimum value), and properties that are 8 times larger than their neighbors in terms of interior square footage (maximum value). Furthermore, when we measure intensity with the relative volume of the property, on average, properties are more intense developed using this indicator (mean value of 1.34). This variable presents a greater variance in its distribution, which is why it could be capturing other elements of the infrastructure that the two-dimensional variable does not capture. For both measures, note again that neighbors constitute relatively new properties (less than or equal to 60 years of age) that were sold within three years of the sale of the subject property. The blight index has a mean value of 0.14, indicating that on average properties are located in good quality neighborhoods relative to the worse case scenario. Figure A6 in the Appendix shows the spatial distribution of this variable.

Panel C presents summary statistics for the property attributes. Note that the average age is 78 years. Additionally, the average number of stories is 2.6 and the average garage area is 228 square feet. In Table 4 we also include descriptive statistics for the categorical variables. First, as reflected in the year of sale, the highest percentage of properties sold in 2012, and this percentage decreases over the years we include in our evaluation. Second, we include data on heating system type and by exterior wall type. Most transactions have a forced air heating system and have a brick exterior. Finally, we show the distribution of observations across the 53 Detroit neighborhoods.

Table 2: Summary Statistics of the Full Sample (Continuous Variables)

Variable	Definition	N	Mean	SD	Min	Max
Dependent Variables ***(Panel A)***						
$Price$	Sale Price	122117	14927.05	21233.96	436.00	175830.00
$Ln\ Price$	Natural Logarithm of Sale Price	122117	8.64	1.53	6.08	12.08
Key Independent Variables ***(Panel B)***						
$Intensity_{2D_{05}}$	$\frac{Interior\ Square\ Footage_i}{\frac{1}{J}\sum_{j\neq i}^{J} Interior\ Square\ Footage_j}$ within a radius of 0.5-mile	122117	1.10	0.43	0.08	8.48
$Ln\ Intensity_{2D_{05}}$	Natural Logarithm of $Intensity_{2D_{05}}$	122117	0.04	0.32	-2.52	2.14
$Intensity_{3D_{05}}$	$\frac{Volume_i}{\frac{1}{J}\sum_{j\neq i}^{J} Volume_j}$ within the census tract	122117	1.34	0.82	0.04	16.97
$Ln\ Intensity_{3D_{05}}$	Natural Logarithm of $Intensity_{3D_{05}}$	122117	0.17	0.47	-3.18	2.83
$Blight\_index$	$\frac{No.Blighted\ Properties\ within\ 0.5\ miles\ x\ Avg\ Fine\ Amount\ within\ 0.5\ m}{Maximum\ Blight\ Intensity\ Score\ in\ the\ Nhood}$ This formulation yields a value between 0 and 1, where 0 indicates no blight and 1 indicates the most intense blight within the neighborhood comparison.	122117	0.14	0.18	0.00	1.00
Property Attributes (Continuous Variables) ***(Panel C)***						
Age	Sale Year - Year Built	122117	78.15	13.88	1.00	169.00
$Lot\ Size$	Lot Size	122117	4858.13	1908.88	958.32	53622.36
$Ln\ Lot\ Size$	Natural Logarithm of Lot Size	122117	8.45	0.26	6.87	10.89
$Interior\ Sqft$	Interior Square Footage	122117	1280.22	507.25	90.00	8664.00
$Ln\ Interior\ Sqft$	Natural Logarithm of Interior Square Footage	122117	7.09	0.34	4.50	9.07
$No.of\ Stories$	Number of Stories	122117	2.67	1.58	1.00	10.00
$Full\ Baths$	Number of full baths.	122117	1.11	0.38	1.00	7.00

$Garage\ Area\ SqFt$	Garage square footage area.	122117	228.40	193.18	0.00	4760.00
$Dist.to\ Primary\ Roads\ (m$	Distance to Primary Roads in miles	122117	0.95	0.77	0.02	3.96
$Dist.to\ Secondary\ Roads\ ($	Distance to Secondary Roads in miles	122117	1.03	0.79	0.01	4.54
$Dist.to\ Jails\ (miles)$	Distance to Federal, State or local Jails and/or detention centers in miles	122117	5.57	2.65	0.03	11.55
$Dist.to\ Airport\ (miles)$	Distance to the Airport in miles	122117	6.82	3.69	0.02	13.78
$Dist.to\ CBD\ (miles)$	Distance to the Central Business District (CBD) in miles	122117	7.79	2.34	0.50	14.20
$Dist.to\ Parks\ (miles)$	Distance to the nearest park in miles	122117	0.38	0.21	0.01	1.66

Source: Author's calculations.

Table 3: Summary Statistics of the Full Sample (Categorical Variables)

Variable	Definition	Observations	Categories	Observations by category	Percentage
Property Attributes (Categorical Variables)					
$Sale\ Year$	Year of property sale	122,117	2012	20011	16.4%
			2013	18421	15.1%
			2014	17677	14.5%
			2015	14307	11.7%
			2016	12673	10.4%
			2017	12802	10.5%
			2018	13084	10.7%
			2019	13142	10.8%
$Heating$	Heating System Type	122,117	Forced Air	105452	86.4%
			Hot Water	15829	13.0%
			Floor/Wall	721	0.6%
			Electric	58	0.0%
			Baseboard	52	0.0%

			None	5	0.0%
Exterior Wall	Exterior Wall Type	122,117	Brick	77477	63.4%
			Shingle	22760	18.6%
			Wood Siding	11257	9.2%
			Asbestos Shingle	10617	8.7%
			Siding (Alum, Vinyl)	6	0.0%
Neighborhood	53 Neighborhoods	122,117	Airport	575	0.5%
			Bagley	3659	3.0%
			Boynton	1220	1.0%
			Brightmoor	2251	1.8%
			Brooks	6251	5.1%
			Burbank	4304	3.5%
			Butzel	603	0.5%
			Cerveny / Grandmont	7657	6.3%
			Chadsey	2476	2.0%
			Chandler Park	984	0.8%
			Cody	3423	2.8%
			Condon	656	0.5%
			Conner	3576	2.9%
			Corktown	40	0.0%
			Davison	1409	1.2%
			Denby	5610	4.6%
			Durfee	2841	2.3%
			East Riverside	833	0.7%
			Evergreen	5899	4.8%
			Finney	6065	5.0%
			Foch	438	0.4%
			Grant	1773	1.5%
			Greenfield	4825	4.0%
			Harmony Village	5918	4.8%
			Hubbard Richard	99	0.1%

	Indian Village	60	0.0%
	Jefferson / Mack	285	0.2%
	Jeffries	150	0.1%
	Kettering	1139	0.9%
	Lower East Central	111	0.1%
	Lower Woodward	27	0.0%
	Mackenzie	5677	4.6%
	McNichols	1358	1.1%
	Middle East Central	326	0.3%
	Middle Woodward	1469	1.2%
	Mt. Olivet	5587	4.6%
	Near East Riverfront	23	0.0%
	Nolan	1820	1.5%
	Palmer Park	290	0.2%
	Pembroke	3453	2.8%
	Pershing	3954	3.2%
	Redford	3538	2.9%
	Rosa Parks	2109	1.7%
	Rosedale	3133	2.6%
	Rouge	6494	5.3%
	Springwells	1494	1.2%
	St. Jean	455	0.4%
	State Fair	228	0.2%
	Tireman	2032	1.7%
	Vernor / Junction	1261	1.0%
	West Riverfront	251	0.2%
	Winterhalter	2008	1.6%

Source: Author’s calculations.

Table 4 shows the results of the hedonic regressions, all of which include a measure of option value. In the first column, we show the results for the standard hedonic model where the estimated coefficients are consistent with and similar to previous research. For example, a 1% increase in lot size increases the selling price by almost 0.5%, while a 1% increase in interior square footage increases the average selling price by 0.58%. Both variables are statistically significant at a 1% significance level. Additionally, the age variable also has the expected negative sign, indicating that older homes are less valuable, other things being equal. Calculating the marginal impact of age, on average an additional year decreases the sale price by approximately 0.11% (statistically significant at 1%).

Additionally, the coefficients on property attributes have the expected signs. An additional story increases the sale value by 1.68%, and this coefficient is statistically significant. A large number of bathrooms have a positive the effect on prices, but the coefficient is not statistically significant. Regarding the heating system, the base category is forced air, which implies, for example that properties with a baseboard heating system have sale prices that are 79.5% lower than properties with forced air heating, when other factors are held constant. The base category for exterior wall material is brick. Hence, properties with shingle exterior walls are associated with a 71.6% decrease in sale price compared to properties with brick exterior walls, holding all other factors constant. Finally, the signs of the year effects coefficients and the neighborhood indicator variables behave as expected (the full table is available upon request).

Columns 2 to 5 of Table 5 present the results of the first and second specifications in the Identification Strategy section. Column 2 presents the results for the first specification using $Ln\ Intensity_{2D_{05}}$. The estimated coefficient is negative and statistically significant at the 1% level.

Table 4: Hedonic regressions with option value measured as intensity.

		First Specification	*Second Specification*	*First Specification*	*Second Specification*	*Third Specification*	*Third Specification*
	(1) Standard Hedonic	(2) Option Value (2D Int O.5)	(3) Option Value with Depreciation (2D Int 0.5)	(4) Option Value (3D Int 0.5)	(5) Option Value with Depreciation (3D Int 0.5)	(6) Option Value (3D Int 0.5x nhood quality)	(7) Option Value with Depreciation (3D Int 0.5 x nhood quality)
Ln Lot Size	0.452***	0.440***	0.437***	0.441***	0.441***	0.441***	0.440***
	(0.0229)	(0.0173)	(0.0173)	(0.0173)	(0.0173)	(0.0173)	(0.0173)
Ln Interior Sqft	0.585***	1.045***	1.007***	0.786***	0.750***	0.786***	0.786***
	(0.0272)	(0.0340)	(0.0351)	(0.0268)	(0.0272)	(0.0268)	(0.0269)
Age	-0.00836**	-0.00887***	-0.00720**	-0.00645**	-0.00704**	-0.00643**	-0.00490*
	(0.00303)	(0.00246)	(0.00250)	(0.00246)	(0.00252)	(0.00246)	(0.00248)
Age^2	-0.0000224	-0.0000186	-0.0000296	-0.0000303	-0.0000242	-0.0000302	-0.0000396*
	(0.0000204)	(0.0000163)	(0.0000166)	(0.0000163)	(0.0000167)	(0.0000163)	(0.0000164)
No. of Stories	0.0172***	0.0145***	0.0153***	0.0274***	0.0247***	0.0274***	0.0270***
	(0.00445)	(0.00358)	(0.00358)	(0.00366)	(0.00367)	(0.00366)	(0.00366)
Full Baths = 2	-0.166***	-0.164***	-0.141***	-0.163***	-0.127***	-0.162***	-0.156***
	(0.0231)	(0.0178)	(0.0184)	(0.0178)	(0.0181)	(0.0178)	(0.0179)
Full Baths = 3	-0.101	-0.0978*	-0.0538	-0.0953*	-0.0310	-0.0936*	-0.0846*
	(0.0530)	(0.0386)	(0.0398)	(0.0387)	(0.0392)	(0.0387)	(0.0388)
Full Baths = 4	-0.122	-0.108	-0.0470	-0.114	-0.0200	-0.110	-0.0982
	(0.132)	(0.0841)	(0.0854)	(0.0841)	(0.0848)	(0.0841)	(0.0842)
Full Baths = 5	-0.382	-0.349*	-0.262	-0.373*	-0.239	-0.371*	-0.348*
	(0.295)	(0.160)	(0.162)	(0.160)	(0.161)	(0.160)	(0.160)
Full Baths = 6	0.712	0.833	0.673	0.769	0.634	0.762	0.792
	(0.738)	(0.450)	(0.453)	(0.451)	(0.452)	(0.451)	(0.451)
Full Baths = 7	0.362	0.336	0.400	0.390	0.569	0.279	0.0908
	(0.236)	(1.284)	(1.284)	(1.284)	(1.284)	(1.285)	(1.288)
Heating System= Base Category: Forced Air							
Hot Water	-0.00248	-0.00828	-0.00120	-0.00350	0.00646	-0.00398	-0.0000954
	(0.0164)	(0.0125)	(0.0125)	(0.0125)	(0.0125)	(0.0125)	(0.0125)
Floor/Wall	-0.246***	-0.244***	-0.244***	-0.263***	-0.260***	-0.263***	-0.261***
	(0.0509)	(0.0481)	(0.0481)	(0.0481)	(0.0481)	(0.0481)	(0.0481)
Electric	-0.731***	-0.721***	-0.777***	-0.706***	-0.830***	-0.705***	-0.737***

	(0.134)	(0.167)	(0.168)	(0.168)	(0.168)	(0.168)	(0.168)
Baseboard	-0.796***	-0.787***	-0.812***	-0.819***	-0.834***	-0.817***	-0.817***
	(0.227)	(0.176)	(0.176)	(0.176)	(0.176)	(0.176)	(0.176)
None	-1.010***	-0.987	-0.990	-1.021	-1.027	-1.019	-1.019
	(0.106)	(0.567)	(0.567)	(0.567)	(0.567)	(0.567)	(0.567)
Exterior Wall= Based Category: Brick							
Shingle	-0.715***	-0.703***	-0.705***	-0.708***	-0.711***	-0.707***	-0.708***
	(0.0138)	(0.0115)	(0.0115)	(0.0115)	(0.0115)	(0.0115)	(0.0115)
Wood Siding	-0.700***	-0.691***	-0.695***	-0.692***	-0.697***	-0.692***	-0.693***
	(0.0182)	(0.0146)	(0.0146)	(0.0146)	(0.0146)	(0.0146)	(0.0146)
Asbestos Shingle	-0.845***	-0.833***	-0.826***	-0.835***	-0.829***	-0.834***	-0.831***
	(0.0167)	(0.0145)	(0.0146)	(0.0145)	(0.0145)	(0.0145)	(0.0145)
Siding (Alum, Vinyl)	-0.313	-0.310	-0.526	-0.226	-0.622	-0.221	-0.296
	(0.262)	(0.522)	(0.523)	(0.522)	(0.523)	(0.522)	(0.522)
Garage Area SqFt	0.000476***	0.000472***	0.000466***	0.000469***	0.000462***	0.000469***	0.000467***
	(0.0000257)	(0.0000201)	(0.0000201)	(0.0000201)	(0.0000201)	(0.0000201)	(0.0000201)
Dist. to Primary Roads (miles)	-0.0272*	-0.0210*	-0.0217*	-0.0225*	-0.0232*	-0.0231*	-0.0224*
	(0.0112)	(0.00924)	(0.00925)	(0.00925)	(0.00925)	(0.00925)	(0.00925)
Dist. to Secondary Roads (miles)	0.0875***	0.0638***	0.0612***	0.0718***	0.0687***	0.0718***	0.0707***
	(0.0128)	(0.0104)	(0.0104)	(0.0104)	(0.0104)	(0.0104)	(0.0105)
Dist. to Jails (miles)	-0.574***	-0.537***	-0.537***	-0.558***	-0.557***	-0.559***	-0.557***
	(0.0252)	(0.0193)	(0.0193)	(0.0193)	(0.0193)	(0.0194)	(0.0194)
Dist. to Airport (miles)	0.564***	0.551***	0.551***	0.560***	0.560***	0.560***	0.559***
	(0.0220)	(0.0174)	(0.0174)	(0.0174)	(0.0174)	(0.0175)	(0.0175)
Dist. to CBD (miles)	0.122***	0.104***	0.103***	0.116***	0.113***	0.116***	0.115***
	(0.0162)	(0.0129)	(0.0129)	(0.0129)	(0.0129)	(0.0129)	(0.0129)
Dist. to Parks (miles)	-0.0769**	-0.0925***	-0.0933***	-0.0857***	-0.0864***	-0.0865***	-0.0868***
	(0.0242)	(0.0196)	(0.0196)	(0.0196)	(0.0196)	(0.0196)	(0.0196)
$Ln\ Intensity_{2D05}$		-0.475***	1.032***				
		(0.0268)	(0.259)				
$Age\ x\ Ln\ Intensity_{2D_{05}}$			-0.0316***				
			(0.00617)				
$Age^2\ x\ Ln\ Intensity_{2D_{05}}$			0.000161***				
			(0.0000369)				
$Ln\ Intensity_{3D_{05}}$				-0.192***	1.125***	-0.210***	-0.214***
				(0.0146)	(0.173)	(0.0157)	(0.0157)
$Age\ x\ Ln\ Intensity_{3D_{05}}$					-0.0252***		

					(0.00415)		
$Age^2\ x\ Ln\ Intensity_{3D_{05}}$					0.000112***		
					(0.0000249)		
$Blight\_index$						-0.0235	-0.00333
						(0.0270)	(0.0272)
$Ln\ Intensity_{3D_{05}} xBlight\_index$						0.127**	5.106***
						(0.0423)	(0.826)
$Age\ xLn\ Intensity_{3D_{05}} xBlight\_index$							-0.111***
							(0.0190)
$Age^2\ xLn\ Intensity_{3D_{05}} xBlight\_index$							0.000608***
							(0.000109)
Year Effects	YES	YES	YES	YES	YES	YES	YES
Neighborhoods Effects	YES	YES	YES	YES	YES	YES	YES
Constant	0.198	-2.838***	-2.599***	-1.199***	-0.902***	-1.193***	-1.237***
	(0.291)	(0.286)	(0.294)	(0.253)	(0.257)	(0.253)	(0.254)
Observations	122,117	122,117	122,117	122,117	122,117	122,117	122,117
R Squared	0.311	0.312	0.313	0.312	0.312	0.312	0.312

Source: Author's calculations. Note: Table reports OLS hedonic regressions coefficients from five separate regressions. The dependent variable in all regressions is the natural logarithm of the sale price. Column (1) presents the standard hedonic pricing model, columns (2) and (3) we show the models including the option value through the mean $Intensity_{2D_{05}}$, and columns (4) and (5) we show the models including the option value through the mean $Intensity_{3D_{05}}$. Standard errors are clustered at the property level.

*** Significant at the 5 percent level.

** Significant at the 1 percent level.

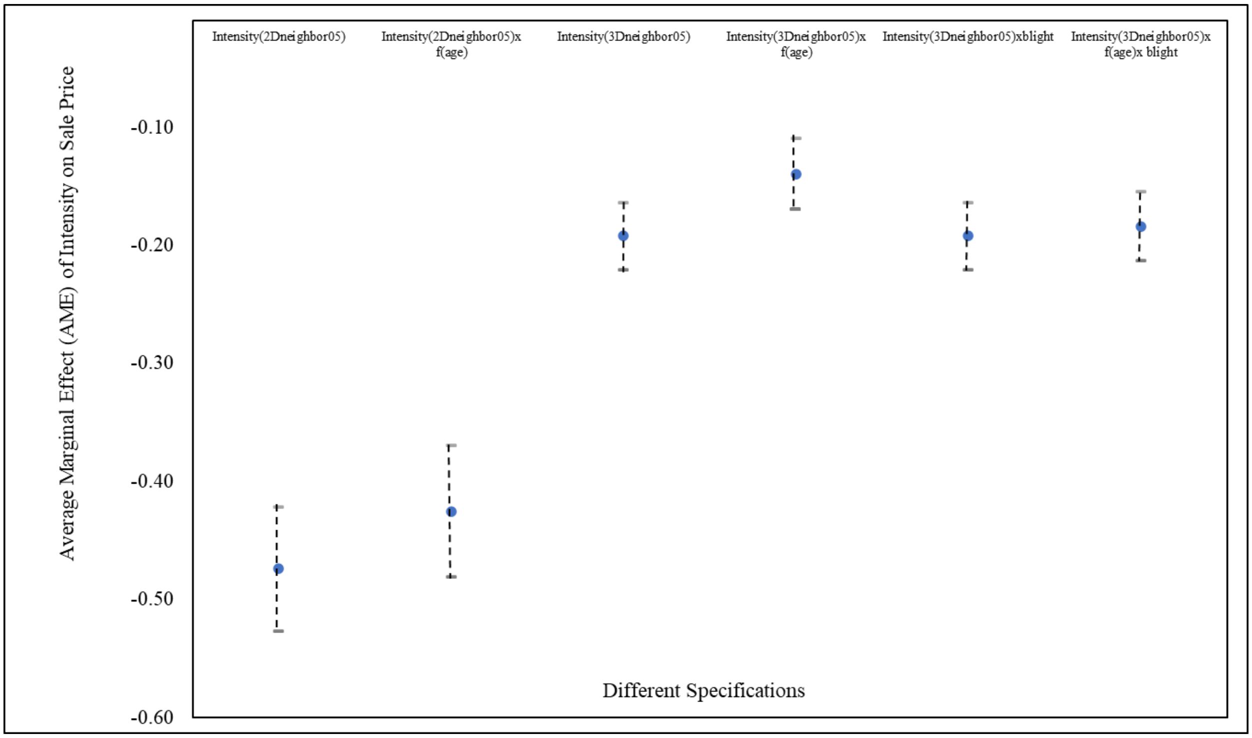
* Significant at the 0.1 percent level.

The interpretation in terms of option values is as follows: a 1% increase in the value of the redevelopment option increases the value of the property by 0.47%. To facilitate comparability of the average marginal effect (AME) across the models, consider Figure 5. The first point plotted in this figure corresponds to the column 2 coefficient of -0.47. The second coefficient plotted corresponds to the AME calculated from column 3. In this case, including the effect of depreciation, a 1% increase in the value of the redevelopment option increases the price of the property by 0.43%.

Columns 4 and 5 of Table 4 present the results of the same specifications as above, but in this case using $Ln\,Intensity_{3D\_05}$. For both specifications, the coefficients are of lesser magnitude than the previous ones but continue to be statistically significant at 1% level. In the case of the first specification, the coefficient is -0.19 and in the case of the second specification the coefficient is -0.14. Finally, using $Ln\,Intensity_{3D\_05}$ interacted with neighborhood quality measured with the blight index we find that the coefficient is -0.19 without the interactions with age, and -0.18 with the age interaction. That is, in our most conservative estimate, having a 100% of option value increases the value of the property by approximately 18%. Using the three-dimensional measure of intensity generates lower impact on price compared to the use of the two-dimensional measure, but including quality neighborhood effects increased the effect.

In summary, these results offer evidence of option value in Detroit (the first hypothesis). In relative terms, our results are similar to other studies in magnitude using the three-dimensional intensity variable. Büchler et al. (2020), for example, in the largest magnitude coefficients, they found that having a 100% redevelopment potential increases the property price by 17%. The sharp difference in results between both measures of intensity its worth to research. The potential for redevelopment might vary based on building height. For example, properties with taller existing structures might have more limited redevelopment options compared to shorter structures, leading to a lower option value. Additionally, there might be economic or behavioral factors at play. For instance, developers might perceive properties with larger areas but shorter heights as having greater redevelopment potential due to fewer complications or costs associated with height (for example, lower demolition costs), leading to a stronger relationship in the 2D measure. Spatial patterns related to height is a future work.

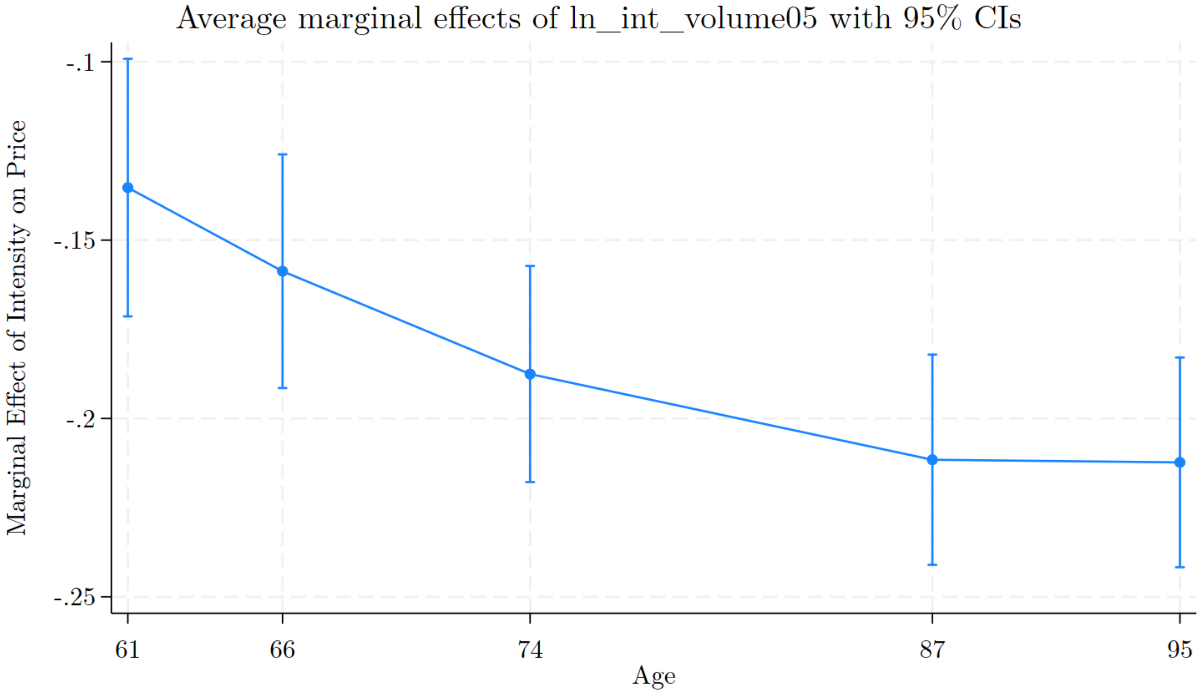
Figure 5: Evidence supporting H1: Average Marginal Effect of Intensity on the value of the property in different specifications



Source: Authors' calculations. Note: figure shows the average marginal effect of intensity on the sale prices. Intensity is measured in two ways: 1) interior square footage of the property divided by the interior square footage of neighbors within a 0.5-mile radius ("Intensity(2Dneighbor05)"), and 2) volume of the property divided by the volume of neighbors within the same census tract ("Intensity(3Dneighbor05)"). For both cases neighbors are properties that constitute new construction sold within the last three years. Calculations of the average marginal effects come from regressions in Table 3, columns (2) to (7), which also includes interaction with the age of the property ("Intensityxf(age)"), and interaction with neighborhood quality represented by the blight index. Each point and interval correspond to the estimated coefficient of intensity and to the dotted line display 95 percent confidence intervals through each coefficient. The sample size is 122,117. Standard errors are clustered at the property level.

In terms of our second hypothesis, we present an interesting result in Figure 6. This figure captures the main effects of intensity (measure with the three-dimensional intensity variable) and age on property price, respectively, holding all else constant. We use the specification of column 7, which means we are including neighborhood quality as mediating variable with respect to intensity. This figure suggests that the impact of intensity on sale prices is not constant but varies depending on the age of the property. This is in line with theory, indicating that older properties, which are more depreciated, have a different redevelopment potential. Additionally, more older properties should have higher redevelopment potential, hence, the negative slope. The older the property, the negative the impact of intensity on housing prices, meaning the positive the impact of option value on housing prices. This is consistent with the results found in Clapp & Salavei (2010).

Figure 6: Evidence supporting H2: Average Marginal Effect of Intensity on Price Across Different Age Groups

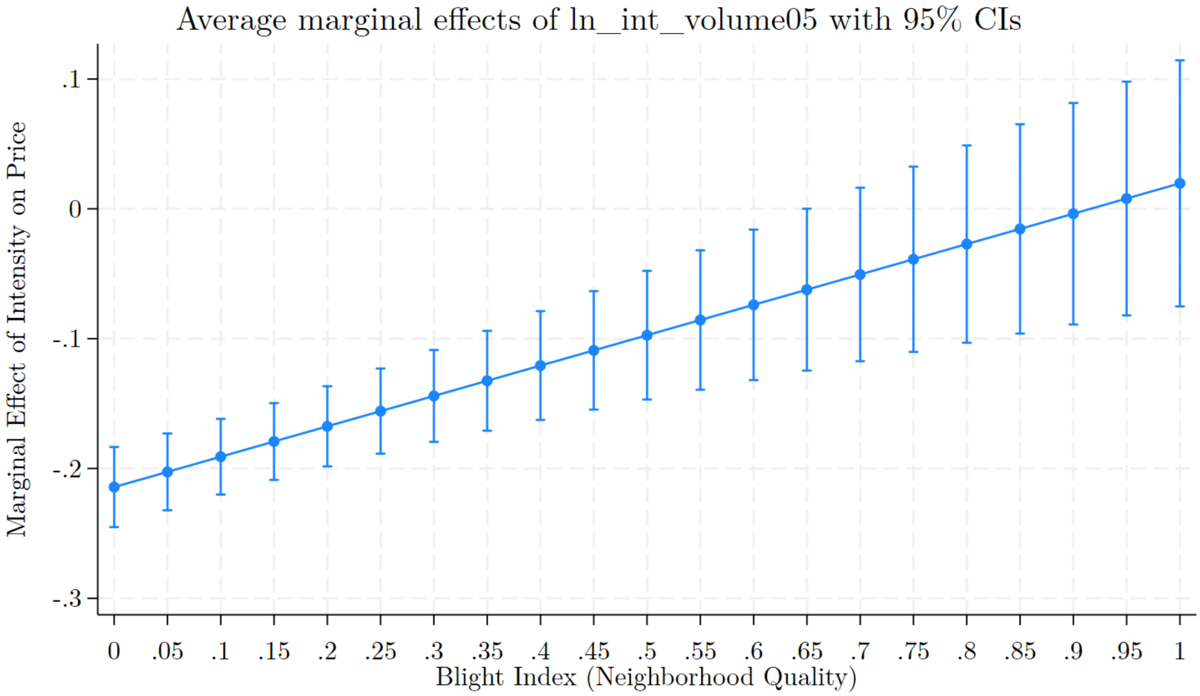


Source: Authors' calculations. Note: This graph illustrates the average marginal effect of property intensity (a measure of redevelopment potential) on property prices for different age groups. The negative slope suggests that older properties have higher redevelopment potential (measured by the negative significant effect of intensity on property prices). The error bars denote the

95% confidence intervals, indicating statistical significance for all age groups, except the first one. Results follow from the specification in column (7) of Table (4).

Finally, in terms of evidence supporting our third hypothesis, we present Figure 7. This figure presents the marginal impact of intensity on sale prices varying by different levels of the blight index, holding everything else constant. We can observe that worse quality neighborhoods, meaning values of the blight index close to 1, are associated with less impact of intensity on prices. The opposite is true as well, indicating that the marginal impact of intensity can reach a value close to 20% for neighborhoods with high quality. This is line with out hypothesis that the option to redevelop will be a function of the quality of the neighborhood.

Figure 7: Evidence supporting H3: Average Marginal Effect of Intensity on Price Across Different levels of the Blight Index



Source: Authors' calculations. Note: This graph illustrates the average marginal effect of property intensity (a measure of redevelopment potential) on property prices for different blight index level. The positive slope suggests that properties in good quality neighborhoods have higher redevelopment potential (measured by the negative significant effect of intensity on property prices). The error bars denote the 95% confidence intervals, indicating statistical significance for all age groups, except the first one. Results follow from the specification in column (7) of Table (4).

Second Step Results: Calculations of Predicted Land Values using Option Value

The previous analysis tested our three-hypothesis needed to confirm our intensity variable actually reflects option values in Detroit. The second portion of this analysis consists of predicting land values from the option value estimates. Interpretation of the results requires some clarifying discussion. First, we use a poisson model without logarithmic transformations because we want to predict the sale price and land value, not the natural logarithm of the sale price. Poisson model help us predict positive sale prices. Furthermore, we identify the subsample of teardowns properties as those much smaller compared to the total sample. The subsample constitutes properties that were: 1) sold when they had a lower intensity than their neighbors (less than .9); 2) issued a building permit after being sold; and 3) have an estimated construction cost of over \$15,000.[17] This implied 1,264 observations in which $\widehat{LV} = \widehat{OptionValue_{\iota}}$. For the rest of the observations, we include the use value of land in the prediction of land values. Table 5 shows the descriptive statistics for the prediction.

Table 5: Predicted Land and Option Value Statistics from Poisson Regression Analysis

Predictions	Observations	Mean	Std. Dev.	Min	Max
Predicted Land Values	122,117	9,316.013	6,638.227	0	189,088.5
Predicted Option Value	122,117	1,720.778	2,472.913	0	109,114

Source: Authors' calculations. Note: This table provides summary statistics for predicted land values and option values derived from a Poisson regression model, as per the identification strategy outlined for the study. The predicted land value accounts for the current use and location value, while the predicted option value quantifies the potential value of future property development.

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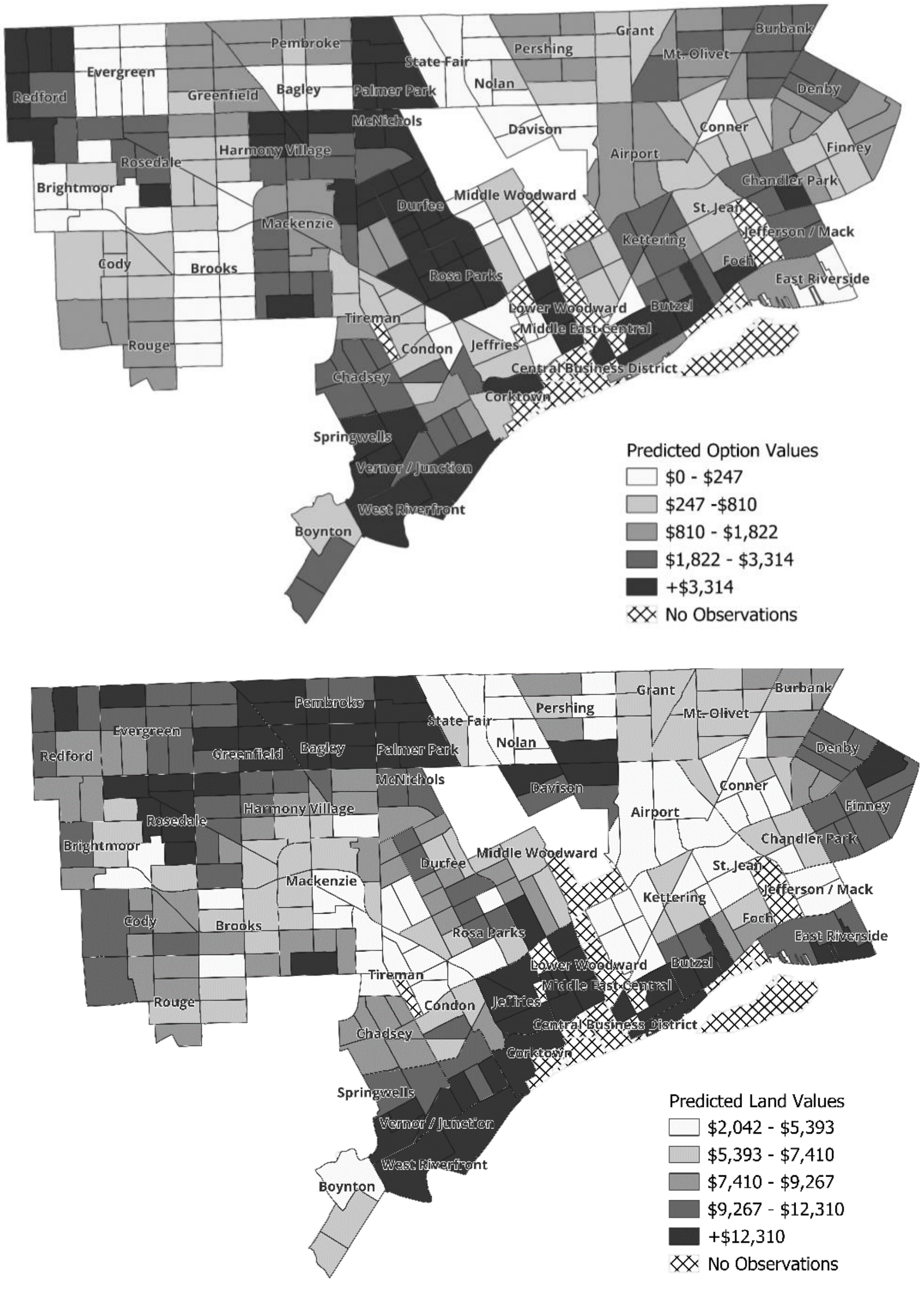
[17] From this value, estimated cost goes up to \$244,801.

Figure 8: Quantile Map of Average Predicted Land Values and Predicted Option Values in Detroit

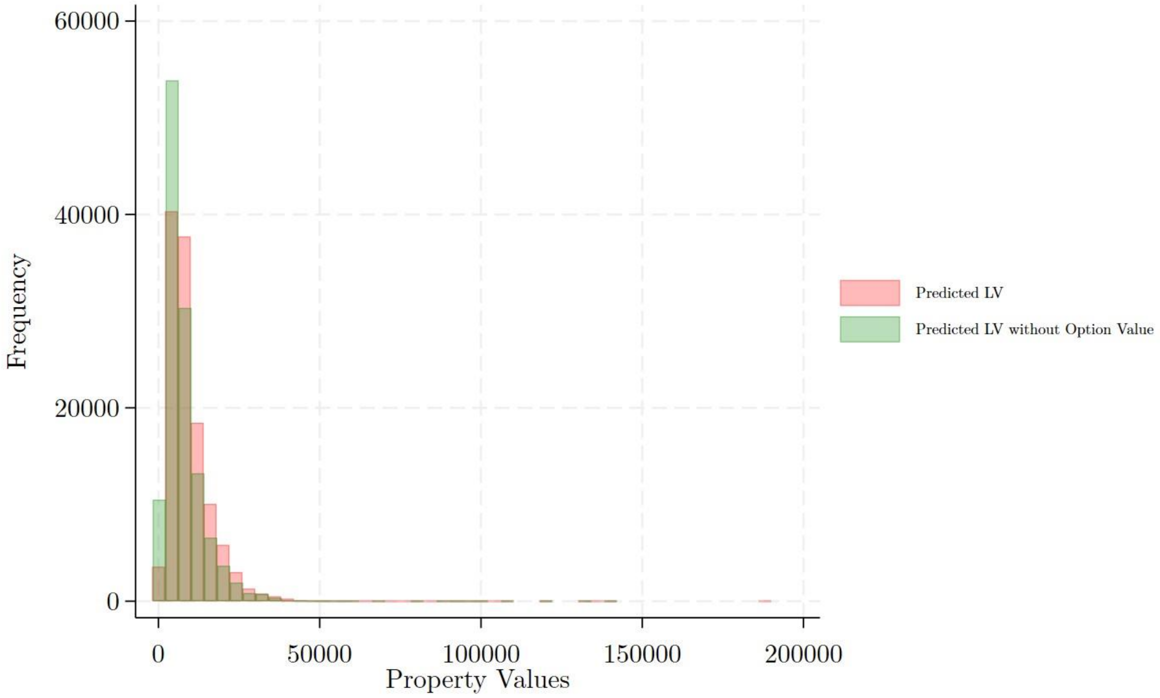


Source: Authors' calculations. Note: The quantile map shows the predicted option values and land values for properties in Detroit, based on the Poisson regression analysis. The map categorizes average option values and land values per census tract into quantiles. Higher option values may suggest areas with greater development potential, while lower values could imply that the current use is closer to the property's perceived best use. This spatial representation provide identification of spatial patterns and potential hotspots for investment and redevelopment.

Figure 8 provide a view of the spatial patterns of these predicted values. Neighborhoods such as Rosa Parks, Durfee, and Winterhalter stand out with higher average option values compared to other neighborhoods, suggesting a latent potential for redevelopment not readily apparent from current land values alone. In contrast, the land values themselves do not peak as sharply, indicating that while the present use and improvements do not drive high valuations, there is a significant untapped future value. Moreover, the spatial pattern of predicted land values resonates with the observations made by Hodge et al. (2015), particularly the “donut-shape” distribution where higher values encircle the central business district and spread into the suburbs. Understanding these dynamics is crucial for policymakers and investors alike, as it signals where strategic development could catalyze change and where the market may already be valuing future possibilities.

Finally, Figure 9 shows the distribution of predicted land values with and without the option value. Notice that predicting land values without option values can underestimate the land value of properties. Additionally, for higher values properties, option value can account for a large portion of the property price. This is important in terms of policy implications, if a split-tax rate is implemented in Detroit, then calculating land values including the option to redevelop can make a significant difference in the final calculation of property taxes.

Figure 9: Histogram of Predicted Land Values with and without Option Value



Source: Authors’ calculations. Note: The histogram shows the distribution of predicted land values with and without the option value.

Conclusions

In the context of proposing an alternative property tax system in the City of Detroit, the idea of the split-rate tax is being considered by policy makers at both the state and local levels in Michigan. However, a key challenge with implementing a split-rate tax is obtaining accurate valuations for both land and structures separately. One approach that could potentially address this challenge is estimation of option value in the context of real options theory. Using that approach, we provide empirical evidence of option value in Detroit through the inclusion of an additive component in hedonic pricing models of residential property values.

Using Zillow's rich ZTRAX database, we construct two variables that have been used in the option value literature. These variables are based on the relative infrastructure intensity of properties. A higher intensity implies a higher value of construction and improvements relative to land value. A property with relatively less intensity (smaller low-quality structure on a relatively large piece of land) will have a higher option value.

The paper investigates the impact of redevelopment potential, measured through property intensity, on property values in Detroit from 2012-2019. The analysis is done in two stages. First, hedonic pricing models are used to test if intensity, as a proxy for option value, significantly affects sale prices. The results provide evidence that higher intensity (i.e. lower redevelopment potential) decreases property prices, suggesting the presence of redevelopment option value. This effect is stronger for older properties and those in higher quality neighborhoods. Using a two-dimensional measure of intensity (property interior square footage relative to neighbors), a 1% increase in intensity decreases prices by 0.47% on average, indicating higher redevelopment potential increases prices. Creating a three-dimensional intensity measure (property volume relative to neighbors), a 1% increase in intensity decreases prices by 0.18%, a smaller but still significant effect. The marginal effect of intensity on prices becomes more negative for older properties, aligning with theory that redevelopment potential increases with depreciation. In higher quality neighborhoods, intensity has a larger negative impact on prices, suggesting redevelopment options are capitalized more in better locations.

Second, the paper uses a Poisson regression to predict land values based on the estimated option values. The spatial analysis of predicted values shows neighborhoods like Rosa Parks, Durfee, and Winterhalter have relatively high option values compared to predicted land values, implying redevelopment potential not captured by current use. Including option value significantly increases predicted land values, especially for higher valued properties, versus excluding it.

In summary, the paper demonstrates that accounting for redevelopment potential through option value theory provides evidence of latent property values not apparent from existing uses. The spatial modeling highlights areas where strategic redevelopment could potentiate revitalization. The results have implications for property valuation, land use policy, and urban planning in Detroit.

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Appendix

Table A 1: Description of the steps to filter the database and identify market transactions.

Step Number	Description	Observations
0	All transactions in Detroit	387,738
1	Remove observations with coordinates with missing values	387,530
2	Select transaction from 2009-2019	338,841
3	Remove duplicate observations	324,538
4	Identify transactions prices that reflect fair market value	171,479
	4.1 Filter by type of deed (268,405)	
	4.2 Filter by document type (217,969)	
	4.3 Filter by intra family sale (217,784)	
	4.4 Filter by transfer tax exempt (171,479)	
5	Select residential properties	170,667
6	Remove sales price outliers and properties that sold more than seven times	162,222
	6.1 Removing prices below p1 and above p99 (168,044)	
	6.2 Eliminate properties with more than 7 sales (162,222)	

How do the key variables change in each of the filter steps?

Variable	Statistics	Step 0	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Price	obs.	190,461	190,361	166,061	161,599	133,286	132,658	126,182
	Mean	$31,179	$31,148	$26,478	$20,977	$20,161	$19,976	$15,845
	Sd	$118,757	$118,680	$115,831	$57,599	$58,256	$57,537	$23,139
	p1	$410	$410	$400	$400	$500	$500	$500
	p25	$2,000	$2,000	$1,800	$1,714	$1,500	$1,500	$1,500
	p50	$8,000	$8,000	$6,965	$6,500	$6,873	$6,800	$6,500
	p75	$30,000	$30,000	$25,000	$23,000	$22,000	$22,000	$20,100
	p99	$308,000	$307,000	$271,000	$201,015	$216,000	$210,500	$120,000
Lot Size	obs.	383,091	382,898	335,897	321,677	170,618	169,844	161,770
	mean	5,990.5	5,984.9	5,981.1	5,957.5	5,331.1	5,315.0	5,215.8
	sd	232,441.9	232,500.0	248,222.0	253,643.2	4,486.6	4,414.9	4,015.9

	p1	2,787.8	2,787.8	2,831.4	2,831.4	2,831.4	2,831.4	2,831.4
	p25	4,007.5	4,007.5	4,007.5	4,007.5	4,051.1	4,051.1	4,007.5
	p50	4,660.9	4,660.9	4,660.9	4,660.9	4,660.9	4,660.9	4,617.4
	p75	5,401.4	5,401.4	5,401.4	5,401.4	5,357.9	5,357.9	5,314.3
	p99	43,560.0	43,560.0	43,560.0	43,560.0	43,560.0	43,560.0	19,863.4
Interior Sqft	obs.	387,738	387,530	338,841	324,538	171,479	170,667	162,222
	mean	1,342.2	1,342.2	1,330.2	1,330.6	1,298.5	1,297.8	1,290.5
	sd	615.7	615.7	603.3	600.8	560.2	559.4	540.5
	p1	672.0	672.0	672.0	672.0	672.0	672.0	672.0
	p25	960.0	960.0	960.0	960.0	954.0	954.0	951.0
	p50	1,170.0	1,170.0	1,162.0	1,162.0	1,142.0	1,141.0	1,139.0
	p75	1,529.0	1,529.0	1,513.0	1,514.0	1,479.0	1,478.0	1,473.0
	p99	3,552.0	3,552.0	3,481.0	3,480.0	3,292.0	3,285.0	3,199.0
Age	obs.	387,534	387,326	338,651	324,385	171,393	170,581	162,137
	mean	78	78	78	78	78	78	78
	sd	16	16	16	16	15	15	14
	p1	19	20	21	23	44	44	46
	p25	68	68	67	67	67	67	67
	p50	77	76	76	76	75	75	75
	p75	90	90	89	89	88	88	88
	p99	114	114	113	113	112	112	112
No. of Stories	obs.	381,555	381,389	334,032	320,207	169,476	168,736	160,817
	mean	2.8	2.8	2.8	2.8	2.7	2.7	2.7
	sd	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	p1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	p25	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	p50	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	p75	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	p99	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	obs.	387,731	387,523	338,834	324,533	171,476	170,664	162,219

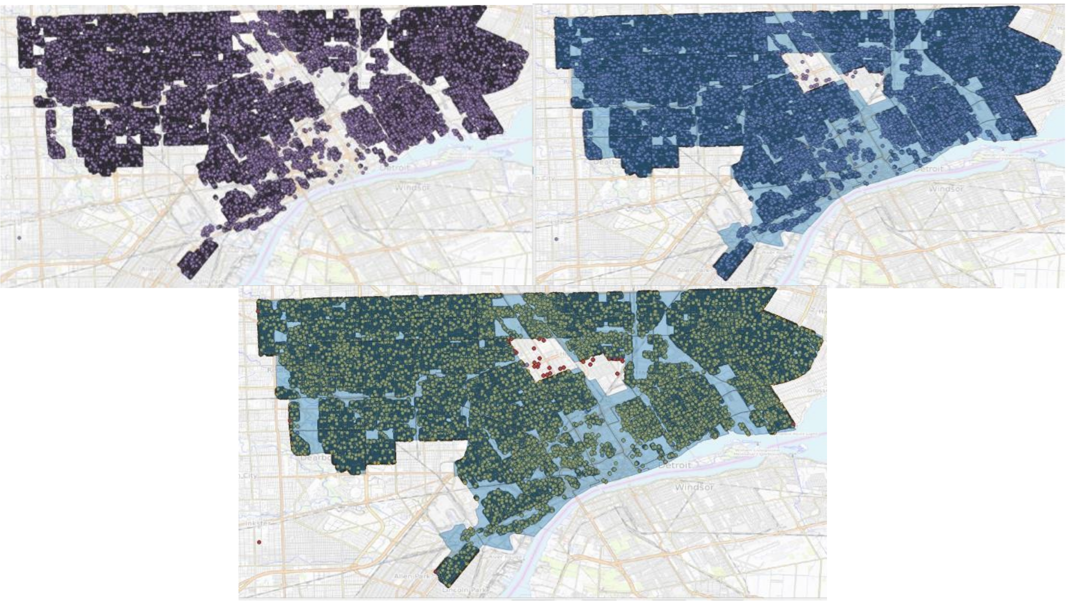
No. of Full Baths	mean	1.2	1.2	1.2	1.2	1.1	1.1	1.1
	sd	0.5	0.5	0.5	0.5	0.4	0.4	0.4
	p1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	p25	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	p50	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	p75	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	p99	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Garage Area Sqft	obs.	387,738	387,530	338,841	324,538	171,479	170,667	162,222
	mean	236.0	236.0	236.0	237.4	229.0	229.0	229.1
	sd	201.6	201.6	200.8	200.1	196.5	196.3	195.7
	p1	0	0	0	0	0	0	0
	p25	0	0	0	0	0	0	0
	p50	280.0	280.0	280.0	280.0	280.0	280.0	280.0
	p75	400.0	400.0	400.0	400.0	396.0	393.0	392.0
	p99	672.0	672.0	660.0	662.0	640.0	639.0	624.0

Source: Author’s calculations.

Table A 2: Detailed explanations on Distances Calculations

We have information of longitude and latitude coordinates for all properties in the dataset. This allows us to plot the information for Detroit. Additionally, we eliminate all properties that are spatially outliers using the neighborhood layer information. Figure A1 show the identified spatial outliers.

Figure A 1: Spatial outliers identified with the geolocated information of the properties



1) Main Roads Calculations

We use the information from the United States Census Bureau that provides GIS information across United States.[18] The roads database contains information on various types of roads in a geographic space larger than Detroit. Therefore, we first need to cut the shapefile to the size of

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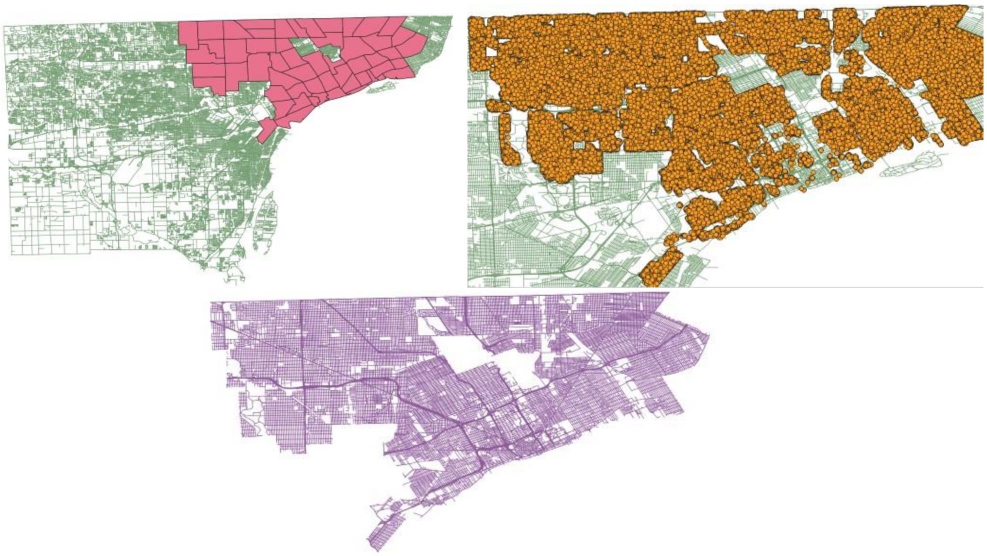
[18] See https://www.census.gov/cgi-bin/geo/shapefiles/index.php.

Detroit. We do this using Neighborhood information boundaries (see Figure A2). The roads database contains two important variables: RTTYP code and MFTCC code.[19] Both codes allow us to identify the main roads and the secondary roads. Finally, the shortest distance between the property and the road is calculated (see Figure A3), in miles.

Figure A 2: Identifying the roads in the city of Detroit



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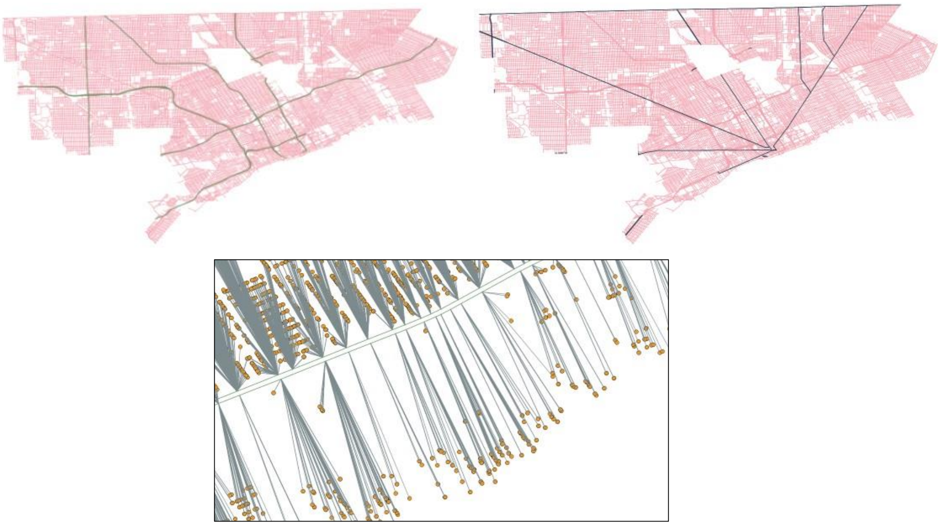
[19] The following link contains information regarding the RTTYP code, https://www.census.gov/library/reference/code-lists/route-type-codes.html. The next link contains information regarding the MFTCC code, https://www2.census.gov/geo/pdfs/reference/mtfccs2021.pdf. S1100 and S1200 are used to identify the primary roads and secondary roads, respectively.

Figure A 3: Main roads, secondary roads, and calculation of the minimum distance from the properties to the roads.



2) Federal, State or local Jails and/or detention centers

We calculate the minimum distance to either of these jails or detention centers. First, we identify all the landmarks in Detroit.[20] Then we did a filter by jail code or detention center. Table A1 shows the selection of the places to which we calculate the minimum distance.

Table A 2: Selection of jails, federal agencies or detention centers according to code

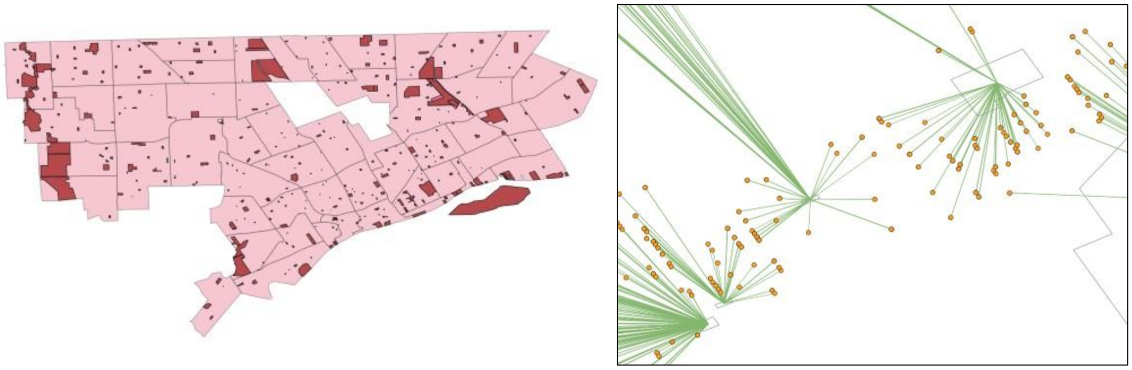
FULLNAME	**MTFC C Code**	**Definition**
William Dickerson Detention Faclty	K1236	K1236 Local Jail or Detention Center One or more structures that serve as a place for the confinement of adult persons in lawful detention, administered by a local government (county, municipal, etc.)
Old Wayne County Jail	K1236	K1236 Local Jail or Detention Center One or more structures that serve as a place for the confinement of adult persons in lawful detention, administered by a local government (county, municipal, etc.)
Andrew C Baird Detention Faclty	K1236	K1236 Local Jail or Detention Center One or more structures that serve as a place for the confinement of adult persons in lawful detention, administered by a local government (county, municipal, etc.)

Wayne County Juvenile Detention Faclty	K1235	K1235 Juvenile Institution A facility (correctional or non-correctional) where groups of juveniles reside; this includes training schools, detention centers, residential treatment centers and orphanages.
Mound Corr Faclty	K1237	K1237 Federal Penitentiary, State Prison, or Prison Farm Potential Living Quarters Y N Y An institution that serves as a place for the confinement of adult persons in lawful detention, administered by the federal government or a state government
Ryan Corr Faclty	K1237	K1237 Federal Penitentiary, State Prison, or Prison Farm Potential Living Quarters Y N Y An institution that serves as a place for the confinement of adult persons in lawful detention, administered by the federal government or a state government
Detroit Capstone Acdmy	K1235	K1235 Juvenile Institution A facility (correctional or non-correctional) where groups of juveniles reside; this includes training schools, detention centers, residential treatment centers and orphanages.

3) Other Landmarks

Finally, we calculate the distance to specific landmarks such as the Airport, parks[21], and the Central Business District (CBD).

Figure A 4: Location of Parks in Detroit and calculation of minimum distance to a Park



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[20] The definition with the code of landmarks is in the following link https://www2.census.gov/geo/pdfs/maps-data/data/tiger/tgrshp2009/TGRSHP09AF.pdf.

[21] See https://portal.datadrivendetroit.org/datasets/parks-and-landmarks-detroit/explore to obtain the information on parks across the city.

Figure A 5: Identification of the CBD and calculation of the minimum distance

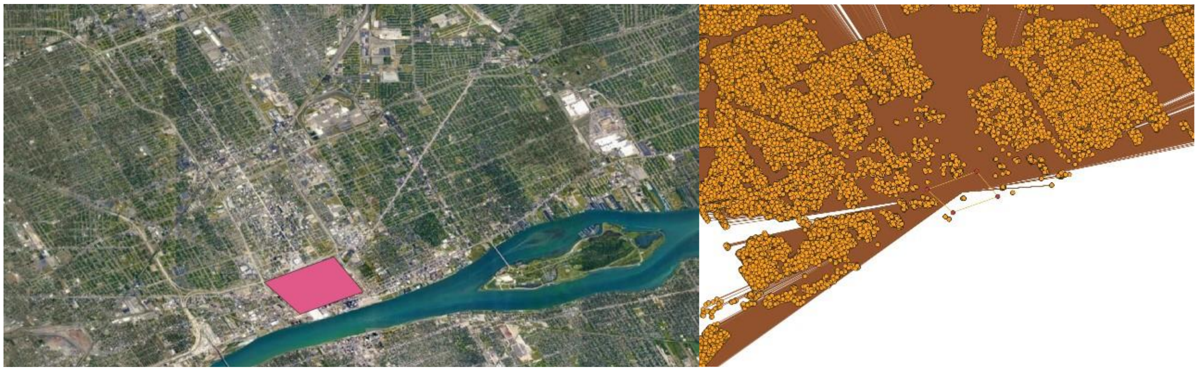
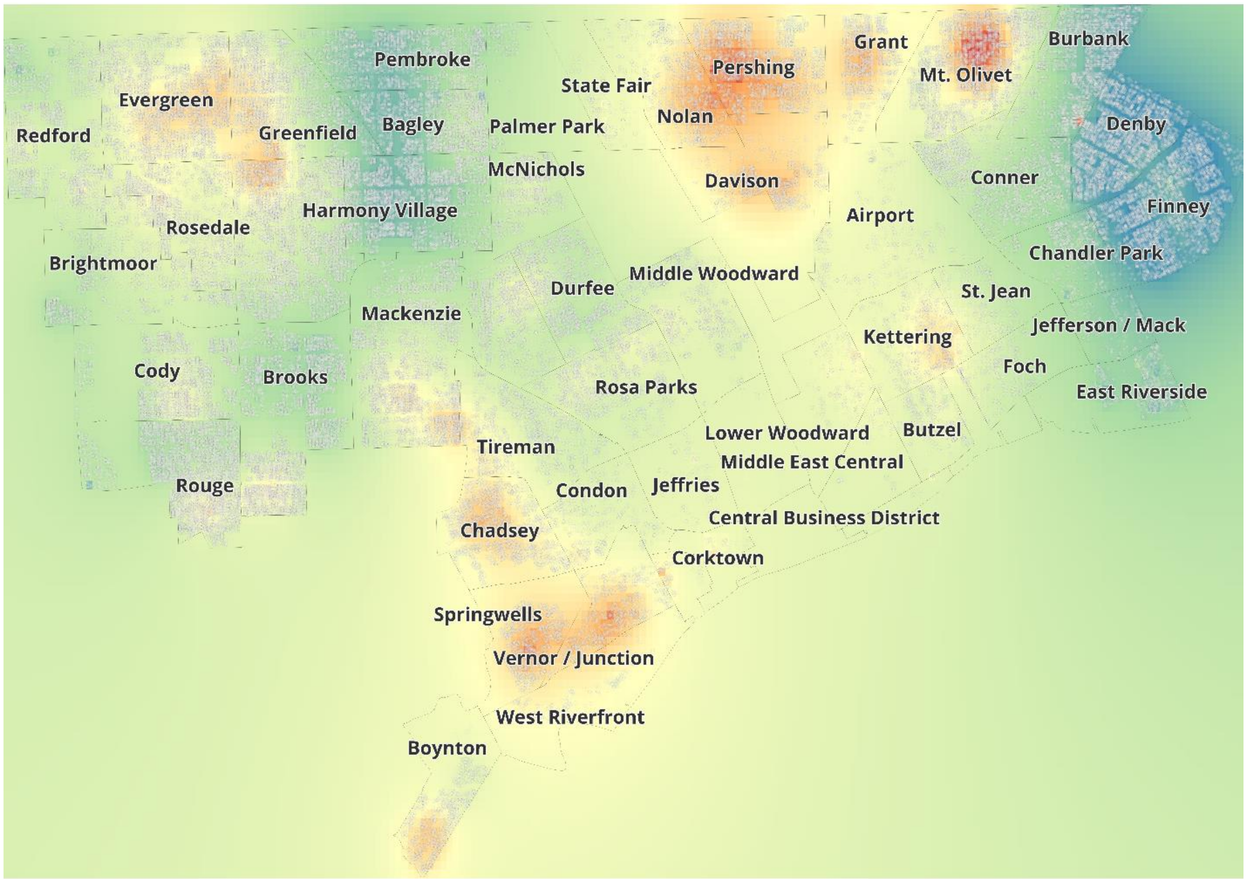


Figure A 6: Heat Map of the Blight Index



Source: Authors' calculations. Note: This heatmap was constructed using the Inverse Distance Weighting (IDW) interpolation method. IDW is a deterministic technique for spatial interpolation whereby values at unsampled points are estimated by averaging the values of nearby sampled points, inversely weighted by their distance. Thus, closer points have a higher influence on the interpolated value than those further away. The heatmap provides a visual representation of the neighborhood quality across the studied area (using the blight index). Red Areas represent neighborhoods with a higher blight index, indicating poorer quality areas. Blue Areas represent neighborhoods with a lower blight index, indicating better conditions and higher quality of life.