Exploiting spatial and temporal variations in residential subdivision development to identify urban growth spillovers

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Exploiting spatial and temporal variations in residential subdivision development to identify the spillover effects of a growth control policy

Abstract

Minimum lot size zoning requirements are a frequent policy tool used to restrict the density and location of residential development. Zoning regulations are typically instituted and adopted locally, often with limited input from surrounding jurisdictions. Autonomous local land use regulations that constrain some, but not all development within a region create discrete differences in the returns to development across otherwise similar locations and are hypothesized to lead to a lower density, more scattered land development pattern. We examine the rural down-zoning policy in Baltimore County, Maryland in 1976 and its potential effect on creating urban growth spillovers in the adjacent counties. Using propensity score matching methods combined with a difference-in-difference econometric strategy, we find that this down-zoning policy resulted in significant spillover impacts to surrounding counties in areas observationally similar to those down-zoned in Baltimore County. To our knowledge, this is first analysis of regional spillover impacts resulting from zoning across county boundaries that relies on spatially disaggregated parcel-level data.

Keywords: Down-zoning; Propensity score matching; Low density development; Housing supply

I. Introduction

Urban growth spillovers generated by jurisdictional differences in local land use regulations have long been hypothesized to be a major contributor to urban sprawl across U.S. metropolitan areas (Ewing 1997). Particularly since the 1970s, when sustained urban decentralization first transformed many suburban areas from bedroom communities into employment subcenters, suburban jurisdictions facing rapid growth have responded with local growth controls intended to constrain new development (Byun et al., 2005). Most common among these is some form of down zoning, in which restrictions are placed on the maximum allowable developable lots for a given area. Autonomy in local land use regulations, but interdependence economically via regional labor and housing markets, are hypothesized to create the market incentives that generate growth spillovers in which down zoning in one jurisdiction leads to increased demand and development in unregulated adjacent areas. The result is an urbanization pattern that is hypothesized to be more dispersed and "sprawling" across the metropolitan region due to these spillovers effects across local jurisdictions. Such spillovers are regarded as common wisdom among many planners and often used to justify the need for regional growth management (Pendall 1999).

In light of the importance attributed to down-zoning spillovers, the empirical evidence of the spillover effect of growth controls is surprisingly weak. While a large literature has examined the effects of growth controls—including down zoning, land preservation and other constraints to development—on land and housing markets within the regulated jurisdiction, relatively few papers have considered the spillover effects of these regulations on the rate and pattern of development in adjacent jurisdictions. Identification of spillovers is made difficult by several empirical challenges. In part the challenge arises from identifying the effects of zoning changes that occurred many years ago, e.g., in the 1970s, when changes to residential zoning were first implemented by many fast growing suburban communities. Equally challenging is the lack of historical data that is commensurate with the spatial scale that is necessary for identification. Model estimation with aggregate data is more likely to be hampered by unobserved correlation and endogeniety concerns. Despite this, the few empirical studies that have examined spillovers have done so using aggregate data due to the lack of availability of historical land parcel data.

We take advantage of a rich data set that provides both the spatial and temporal detail needed to identify the spillover effect of a down zoning policy that was implemented in the rural area of Baltimore County in 1976 on the location and timing of development in the adjacent counties of Carroll and Howard. One of the key implications of this down zoning was the prevention of contiguous development within Baltimore County. As a result, it is possible that developers leapfrogged over the restricted area and began to develop areas in adjacent counties which were not restricted by zoning. Our primary interest is in determining whether this leapfrog type development occurred and if so, whether the action of down zoning led to changes in the rate and quantity of parcel subdivisions in adjacent counties. Using a unique GIS dataset of residential subdivision development from 1970 to 1981 for this three county area within the Baltimore metropolitan region, we use a reduced form approach that relies on the richness of these data to isolate the spillover effect of the down zoning in Baltimore County on residential development in Carroll and Howard counties. Specifically, propensity score matching techniques are used to identify observationally similar treated and control locations in the adjacent counties to the down-zoned locations within Baltimore County. The rate of development is analyzed for the five-year periods before and after the downzoning policy adopted in 1976. We then use a difference-in-difference type estimator to examine the spillover effect of down-zoning.

Using propensity score matching methods to identify locations in surrounding counties that are observationally equivalent to the down-zoned and non down-zoned locations in Baltimore County, we find that down-zoning resulted in a spillover effect equivalent to an increase in approximately 4.8 additional new houses within each square mile of similar, but unrestricted areas in the counties adjacent to Baltimore County. The next section of the paper provides additional background on growth controls and policy spillovers and is followed by a local description of zoning policies in the Baltimore region. Section IV describes the data used for our analysis and is followed by a description of the econometric strategy in section V. Section VI presents and results and section VII concludes.

II. Growth Controls and Policy Spillovers

Growth controls include such diverse regulations as urban growth boundaries, adequate public facility ordinances, variable minimum lot zoning, clustering requirements and purchase of or trade in development rights. A large literature has examined the effects of growth controls on housing and land markets located within the regulated jurisdiction. This literature identifies two effects of growth controls on the regulated housing or land values of properties: the reduction in the supply of developed lots results in a diminution of the property value that can be offset, however, by an increase in the per lot value due to the open space amenities that accompany the lower density development. Studies vary widely in their estimates of these two effects, the identification of which is hampered by heterogeneous land that can cause these effects to vary spatially at a parcel level. For example, Henneberry and Barrows (1990) find that the effects of exclusive agricultural zoning in Wisconsin on property values are negative effects for smaller parcels close to urban areas and positive for large parcels farther from urban areas. In a recent analysis that uses propensity score matching and instrumental variables to account for the zoning endogeneity, Lui and Lynch (2011) find that low-density zoning has differentiated impacts on rural land parcel depending on whether they are resource versus residential parcels. Specifically, resource parcels' land values are unaffected and residential parcels' values decrease by 20-50% with the low density rural zoning constraint.

Other studies have examined how growth controls impact the amount or rate of development within the regulated jurisdiction. For example, Burge and Ihlandfeldt (2006) use panel data on Florida communities to investigate whether housing construction is affected by development fees. Using fixed time and area effects to account for the endogeneity of policy, they find that development fees did not reduce new housing construction. Using spatially disaggregate data, that arguably is necessary for identification of growth control effects, Bento, Towe and Geoghegan (2007) consider the effect of an adequate public facilities ordinance in Howard County, Maryland. Using propensity score matching methods, they find that APFOs were effective in reducing new housing in the first two years. Other have considered the effect of downzoning or land preservation on the prevalence of low density residential development. McConnell, Walls, and Kopits (2005) examine the influence of low density zoning on residential subdivision development and find that zoning constraints may exacerbate low-density, residential sprawl development.

In contrast to these and many other studies that have focused on the effects of growth controls on development within the regulated area, there are many fewer studies that explicitly examine the spillover effects of growth controls on development in adjacent areas. Those that have done so are largely descriptive in nature. A few papers have examined the correlations among political fragmentation, local growth controls and sprawl at the metropolitan scale and found positive correlations among aggregate measures of these variables (Carruthers and Uifarsson 2002, Pendall 1999, Razin and Rosentraub 2000). Other studies have examined the spillover effects of growth controls in one jurisdiction on housing prices in adjacent jurisdictions (Schwartz et al. 1981, Pollakowski and Wachter 1990). These studies provide evidence of spillovers in terms of price effects, but do not reveal the impacts on the amount or location of new development. Finally, a few papers have attempted to examine the spillover effects of growth controls on the amount of new construction in neighboring jurisdictions. For example, Byun et al. (2005) use community-level data to examine the influence of the stringency of local growth controls on new home building in neighboring communities. Their estimation strategy, which relies on predicting the amount of new construction in the absence of growth control differences using a reduced form model to control for these effects, is problematic. The problems with the identification strategy combined with the use of highly aggregate data make it difficult to assign any causal interpretation to these and other results reported by similar studies (Shen 1996, Levine 1999, Jun, 2004).

III. Background on Growth Management in Baltimore Region

We address this gap in the empirical literature by focusing on efforts to control urban expansion in the Baltimore region beginning in the late 1960s. Our study region is comprised of the adjacent three counties of Baltimore, Carroll and Howard. Baltimore County has the largest population with approximately two-thirds of the 1.2 million residents in this region. Baltimore County and the City of Baltimore, which is a distinct political entity, grew rapidly in the 1940's due the increased manufacturing activity for World War II. Thereafter, the population in the City of Baltimore peaked in 1950, while suburbanization accelerated in Baltimore County during the 1950's and 1960's as a result of decentralizing factors such as interstate highway construction and public school desegregation (Outen 2007).

Facing rapid population pressures, Baltimore County adopted an urban-rural demarcation line (URDL) in 1967 that limits municipal sewer and water service beyond this boundary (Pierce 2010). The URDL historically represents one of the first urban growth boundaries in the United States. Because there are no incorporated municipalities in Baltimore County, the county government alone determines zoning and land-use regulations for the entire county land area. The growth boundary initially did not face much public reaction for two reasons. First, the URDL was set to provide a generous amount of vacant land inside the boundary to accommodate several decades of expected suburban population growth. Second, although two-thirds of the county land area lies outside the growth boundary, the rural zoning at this time still allowed one-acre minimum lot size for residential development on septic systems and groundwater wells (Baltimore County Office of Planning 2000). Hence, there was considerable exurban development outside the URDL that resulted in significant losses to farmland and other resource areas.

For this reason, Baltimore County adopted resource conservation (RC) zoning areas in the 1975 Comprehensive Plan that became effective in 1976 (Outen 2007). This essentially created a massive downzoning policy in the rural area outside the URDL and included three main zoning types. Agricultural protection (RC2) zoning covered the majority of the rural area and originally had 25-acre minimum lot size in 1975, which was later increased to 50-acre minimum lot size in 1979. Watershed protection (RC4) zoning was designated to protect those watersheds associated with three regional reservoirs (Liberty, Loch Raven, and Prettyboy), which provide water supplies to 1.8 million residents in the Baltimore metropolitan area. The RC4 zoning allows five-acre minimum lot size. Rural residential (RC5) zoning allows two-acre minimum lot size and was used to provide residential development in appropriate rural areas, commonly designated in the vicinity outside the URDL and along Interstate Highway 83. In sum, this downzoning policy instituted in 1976 created a major push from the rural areas in Baltimore County that was not present with the URDL alone (Pierce 2010).

Carroll and Howard Counties are adjacent on the western border of Baltimore County. Carroll was relatively rural until the mid-1960s when the county began to experience large population growth for many of the same reasons as Baltimore. Carroll passed their first comprehensive plan in 1963 that allowed one house per acre in all areas without municipal sewer and water facilities. In 1978 Carroll passed its second major zoning plan as well as the Agriculture zoning ordinance. The Agriculture zoning ordinance restricted zoning to one house per 20 acres and covered over 65% of the land in the county. In addition, another 15% of the land in the county was zoned as Conservation, which restricted building to one house per three acres. Most of the Conservation lands in the county borders either a more densely populated area effectively allowing development in more rural areas or they border environmentally sensitive areas such as reservoirs or streams. Howard County had very limited restrictions on development throughout this period and, in fact, was the only county in the Baltimore area to never enact a significant downzoning policy since the mid 1970's.

IV. Identification Strategy

The econometric strategy employed overcomes two challenges in measuring the potential spillover effects of down-zoning to surrounding counties. First, the landscape facing developers is heterogeneous suggesting that not all locations are equally likely to develop due to surrounding land uses, development suitability, or proximity to infrastructure. As a result, traditional boundary discontinuity designs are problematic as the potential spillover effects of down-zoning are likely to occur in areas most closely related to those targeted by down-zoning regulations rather than in areas that are characterized only by their location in close adjacency to the down-zoned area. The second econometric challenge is to cleanly identify the spillover effects of down-zoning on the treated areas as distinct from the general level of development in the region. Our solution to these challenges is to combine propensity score matching techniques to identify observationally similar treated and control locations in counties adjacent to Baltimore County to the down-zoned locations within Baltimore County. We then use a difference-in-difference type estimator to examine the spillover effect of down-zoning.

Matching estimators have received increasing attention in the land use literature in recent years as a way to identify average treatment effects (Bento et al, 2007; Liu and Lynch, 2011; Lynch et al, 2007; McMillen and McDonald, 2002; Towe, 2010). The propensity score matching estimator was first described by Rosenbaum and Rubin (1985) and is often used to estimate the "mean treatment effect on the treated." The basic framework of the estimator begins by noting that we observe a discrete outcome for each observation indicating whether it was subject to treatment (down-zoning) or not. We define these outcomes such that D=1 indicates a treated location and D=0 indicates untreated. Using this information, the propensity score determines the probability of a location receiving treatment given a set of observable conditioning variables. The average treatment effect on the treated is obtained as a conditional difference in mean outcomes given by equation (1) where X denotes a set of conditioning variables with Y_1 indicating the outcome under treatment and Y_0 indicating the outcome with no treatment.

(1) $ATT = E(Y_1 - Y_0 | X, D = 1)$

Equation (1) can be re-written as in equation (2) to motivate the use of the propensity score.

(2) $ATT = E(Y_1 | X, D = 1) - E(Y_0 | X, D = 1)$

In equation (2), the second term is the expected outcome of treatment for untreated observations, and is unobserved by definition. Because we do not observe the outcome for an untreated location which experiences the treatment (D=1) we instead use the propensity score to redefine the ATT in equation (2) to overcome this limitation. Defining the propensity score as the probability of selection for treatment conditional on observed characteristics, X, as in equation (3),

(3) $\mathrm{P(X)} = \mathrm{Pr(D = 1|X)}$

we substitute this expression into equation (2) giving a new definition for ATT in equation (4). This equation provides the foundation for the propensity score matching estimator.

(4) $ATT = E(Y_1 | P(X), D = 1) - E(Y_0 | P(X), D = 0)$

The propensity score defined by $P(X)$ is often estimated as a binary logit with the dependent variable given by an indicator for down-zoning as the treatment location. In our application, we use the agricultural zone (RC2) as the treatment area since it had the most severe down-zoning, while either or both of the rural residential zone (RC5) and watershed protection zone (RC4) are used as the control area.

At this stage, our estimation approach diverges from the traditional propensity score treatment effects literature in several regards. First, we are not attempting to recover ATT within Baltimore County, but rather we want to examine the impact that down-zoning in Baltimore County had on land conversion in surrounding counties which experienced no direct treatment in the form of down-zoning. As a result, we use the propensity score in a nearest neighbor matching algorithm to identify treated and control locations outside Baltimore County rather than to estimate the ATT shown in equation (4) which would typically be the case. Under the typical approach, we would use the propensity score to obtain matches between treated and untreated locations within Baltimore County itself and then calculate the ATT as in equation (4).

Detecting spillovers necessitates identifying treated and control properties located outside Baltimore County which form the basis for a quasi-experimental type of analysis. Because the effects of spillovers are most likely to be observed in areas observationally similar to the down-zoned locations in Baltimore County, the econometric challenge is to identify these locations. Using the propensity score to perform nearest neighbor matches between locations in Baltimore County to locations outside Baltimore County provides one mechanism in which to identify these treated and control areas. We perform this step twice, once to match locations in surrounding counties to *down-zoned* locations within Baltimore County, we call these the "treated" areas, and a second time to match locations in surrounding counties to *non down-zoned* locations in Baltimore County[1], and we call these the "control" areas. To reiterate, we match both policy relevant areas, down-zoned and non-down-zoned, within Baltimore County to observationally equivalent areas in the adjoining counties.

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[1] But outside the urban growth boundary.

Having identified treated and control locations in counties surrounding Baltimore County our final estimation step involves forming a difference-in-difference type estimator to control for time-varying unobservables and identify differences in the quantity of development between treated and control locations following down-zoning in Baltimore County. We exploit the time periods before and after the Baltimore down-zoning to define two time periods with the latter period identified by the variable $time = 1$ and the earlier time period by $time = 0$. We denote the matched treated locations by the variable $treated = 1$ with $treated = 0$ identifying the matched control locations, both of which are located outside Baltimore County and identified from the aforementioned propensity score matching. Using this notation, we test for the presence of spillover effects through the interaction between the time and treated indicator variable given by the parameter $\alpha_3$in equation (5), where N_t is a count of the total number of new houses built in each time period.

$$(5)\ N_t = \alpha_0 + \alpha_1 time + \alpha_2 treated + \alpha_3 time * treated + \epsilon$$

A positive and significant coefficient indicates that development increased in the treated locations relative to the control locations after down-zoning occurred in Baltimore County and that this difference is significantly different than the relative difference in development between treated and control locations prior to the down-zoning. Overall, a finding of a positive and significant coefficient would support the notion that spillover effects occurred in surrounding counties.

V. Data

The data were compiled from numerous sources including the Maryland Department of Planning, Maryland Department of Assessment and Taxation, USGS, NRCS, DOT, and the National Center for Smart Growth at the University of Maryland. Significant effort has been taken to attain and measure data as of the relevant date of 1970 and in a format that is consistent across the counties in our study area. One unique aspect of this work is the focus on these cross county policy spillovers.

Perhaps the primary hurdle from a data perspective is construction of our outcome of interest, the number of new homes constructed or housing starts. To calculate this outcome variable we must first establish a unit of aggregation from which we will count the new housing per unit. We choose to aggregate the underlying parcel and all independent variables into a grid which results in an observation for our analysis being a ¼ square-mile grid cell on the landscape. We rely on this featureless grid to remove potential aggregation induced endogeneity from a grouping using census based aggregation measures typical in the literature.

The estimation data correspond to many time invariant features of the grid including soils, slopes, distances to the predominant central business district of Baltimore, distances to amenities (parks and water), and some time variant features including land use, land cover[2], density of housing, number of landowners, and percentage of undeveloped land. Many of these variables are calculated from the neighboring grids utilizing queen contiguity as the definition of neighbor. Table 1 outlines the variables and summary statistics. One must keep in mind these variables are meant to construct the appropriate substitutable areas for development in the adjoining counties to the downzoned and not downzoned areas of Baltimore County outside the urban growth boundary.

Variables for each grid are primarily measured as a percentage of the grid and these include public land held by the Maryland Department of Natural Resources, parks (State, Local or National), and Federal lands such as military installations (*% DNR Land, % Parkland, % Federal Lands*). Time invariant measures of extreme slope, highly erodible, and high runoff potential (*%highly sloped, %very highly erodible, %high runoff*) are included to account for higher home construction costs in these areas. These variables are constructed using the Natural Soils Group data. Land cover measures include low and medium density housing, commercial areas, agriculture, and forest (*%land cover medium density, %land cover low density, %land cover commercial , %land cover agriculture, %land cover forest*) each with their own attraction and repelling effect on new housing starts. The percentage of each grid in a 100 or 500 year floodplain (*% in 100yr Flood, % in 500yr Flood*) as well as the percentage not included or incorporated areas not participating in Flood Insurance program (*% in ANI Flood*) are proxies for low lying areas likely less desirable for housing. It is possible that many of these flood prone areas may be

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[2] Measured as of 1973.

near desirable water features so we include a dummy variable for being with 2km of a lake or river (*waterFeature_2km*). Other distance to amenity based measures include an estimated travel time to Baltimore (*travTime_Balt*) as well as dummy variables for being with 2km of an interstate (*interstate_2km*), urban arterial (*urbanArterial_2km*), or park (*parks_2km*). Other variables include the number of owners of the grid (*number of owners*) which serves as another proxy for density but also proxies for the number of decision makers in the area that a developer may have to purchase land from. Finally, the percentage of the grid in an undeveloped state (% undeveloped) is updated to reflect the landscape as of 1970 is included to proxy supply of unencumbered land.

VI. Results

The primary unit of observation is defined as each ¼ mile grid overlaid on the landscape as illustrated in figure 1 for a small section of the study region. From this grid layout, we obtain 3,018 grids located in control areas (RC4 and RC5 zones) within Baltimore County and 3,054 grids located in treatment locations (RC2 zones). As discussed above, these locations within Baltimore County form the basis for estimating a propensity score which is later used to match observations between Baltimore County and surrounding counties. Appendix table A1 reports the binary logit results from the propensity score estimates associated with treated and control locations, respectively. We include two broad classes of variables – own-grid and surrounding grid --which we hypothesize are correlated with the down-zoning decision in Baltimore County. Overall, pseudo R^2 values approach 0.5 in both models suggesting these variables capture observable features correlated with down-zoning.

Figures 2 to 5 show the locations matched as either treated or control grids using the propensity score estimates shown above. As expected, these follow natural contours of the landscape, especially proximity to existing development and transportation. Perhaps more important is that the locations of treated and control grids appear in close proximity to each other and are "patchy" in nature. This suggests that our assigned treated and control locations closely match what would be expected for a traditional boundary indifference approach; however, our boundaries are not directly associated with political boundaries but instead are defined by observable characteristics which mimic the down-zoning locations in Baltimore County.

Having identified matched treated and control locations our primary focus is on estimation of equation (5). Results are reported in table 2. All variables in this regression are statistically significant and confirm our prior expectations. The positive and significant estimate for the intercept indicates that over our time period the average ¼ mile grid experienced an increase in housing development, both in treated and control locations. The negative and significant coefficient on the post down-zoning dummy variable reflects that across both treated and control locations, development slowed during the late 1970s. As figure 6 shows, this period experienced a large interest rate spike which peaked at over 17% in 1981 and is likely responsible for the slowing rate of new development.

The negative coefficient on matched treated locations is consistent with expectations that down-zoned areas in Baltimore County are likely further from existing development as they are intended to prevent sprawl leaving more easily developed areas free from down-zoning to encourage density. As a result, the matched control locations are more likely to be located in areas amenable to development and the negative coefficient on matched down-zoned locations should take on a negative value if that is indeed the case.

Our key variable of interest is the interaction between treated locations and the post down-zoning time period. The positive and significant effect of 1.19 units per ¼ square mile grid cell reflects that the impact of down-zoning on these locations resulted in an increase of approximately 4.8 homes per square mile being constructed, *certis paribus*. This result confirms the hypothesis that down-zoning in Baltimore County was effective in restricting development and pushing development to less constrained but otherwise similar locations. At an aggregate level, the model estimates suggest that as many as 3,000 new housing starts resulted from the spillover effects of down-zoning than would otherwise have occurred. To put this in perspective the decline in new housing starts in the control group was 43% while the increase in new housing starts in the treated groups was 53%. Though these percentages seem large one must keep in mind the difficult housing environment of this post treatment period which likely mitigated the robustness of the overall housing market.

VII. Conclusions

Spatial heterogeneity of the landscape and unobserved correlation greatly hamper the identification of policy spillover effects. We use propensity score matching techniques to identify treated and control locations in counties adjacent to Baltimore County that are observationally similar to the down-zoned locations within Baltimore County. We then use a difference-in-difference type estimator to examine the spillover effect of down-zoning. Our results show a modest effect of the down-zoning in Baltimore County on urban development in adjacent counties. Specifically, we estimate a spillover effect equivalent to an increase in approximately 4.8 additional new houses within each square mile of similar, but unrestricted areas in the adjacent counties or over 3,000 new housing starts in total in the adjacent areas that are attributable to the down-zoning spillover effect. The paper makes several contributions to the literature on policy spillover effects. First, we are the first analysis of regional spillover impacts resulting from zoning across county boundaries that makes use of spatially disaggregated parcel-level data. Identifying the spatial spillover effects of local policies is challenging due to the many unobserved factors that will cause development pressures in both the regulated and unregulated areas to be similar. By making use of spatially disaggregated parcel data, we are able to use a quasi-experimental approach that controls for these methodological problems that plague analysis with aggregate data. Second, we examine the oft-stated hypothesis that local growth control spillovers, such as the down-zoning policy that we examine here, have greatly exacerbated the extent of sprawling, low density development patterns. We find modest support for this hypothesis. Our results indicate that down-zoning in Baltimore County did indeed restrict development in the regulated areas and in so doing, pushed development to less constrained locations. However, the magnitude of this result is modest relative to the total amount of new development in the region at the time and thus, our results do not provide strong support for the notion that the lack of coordination among local jurisdictions has been a primary cause of metropolitan-wide patterns of low density sprawl.

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Table 1: Summary Statistics for all analysis variables

Variable	mean	sd	min	max
Own Grid Cell Variables				
% DNR Land	0.051	0.201	0.000	1.000
% Parkland	0.047	0.181	0.000	1.000
% Federal Lands	0.003	0.044	0.000	1.000
number of owners	4.192	8.382	1.000	173.000
% undeveloped	0.915	0.170	0.000	1.000
% very highly erodible	0.040	0.152	0.000	1.000
% high runoff potential	0.311	0.401	0.000	1.000
% highly sloped	0.139	0.268	0.000	1.000
% land cover medium density	0.016	0.095	0.000	1.000
% land cover low density	0.050	0.149	0.000	1.000
% land cover commercial	0.011	0.073	0.000	1.000
% land cover agriculture	0.534	0.374	0.000	1.000
% land cover forest	0.354	0.345	0.000	1.000
% in 100yr Flood	0.064	0.163	0.000	1.000
% in 500yr Flood	0.005	0.029	0.000	0.629
% in ANI Flood^	0.049	0.200	0.000	1.000
travTime_Balt	38.770	12.858	10.140	78.750
waterFeature_2km	0.657	0.475	0.000	1.000
interstate_2km	0.162	0.368	0.000	1.000
urbanArterial_2km	0.196	0.397	0.000	1.000
parks_2km	0.547	0.498	0.000	1.000

Continued next page

Table 1 continued: Summary Statistics for all analysis variables

Surrounding Grid Cell Variables				
% DNR Land	0.054	0.179	0.000	1.000
% Parkland	0.053	0.156	0.000	1.000
% Federal Lands	0.003	0.038	0.000	0.859
% undeveloped	0.913	0.110	0.031	1.000
number of owners	8.840	4.572	8.000	119.571
% land cover forest	0.359	0.244	0.000	1.000
% land cover agriculture	0.531	0.284	0.000	1.000
% land cover water	0.019	0.092	0.000	1.000
% land cover low density	0.050	0.088	0.000	0.877
% land cover medium density	0.016	0.067	0.000	0.958
% land cover commercial	0.011	0.048	0.000	0.753
% high runoff potential	0.311	0.347	0.000	1.000
% highly sloped	0.140	0.205	0.000	1.000
N=	18378			
Number by county				
Baltimore County	6617			
Carroll County	7533			
Howard County	4228			

^Areas Not Included or incorporated areas not participating in Flood Insurance Program

Table 2: Difference in Difference Estimate

Outcome: Number of Housing Starts		
	Coeff.	Robust Std Err
post	-0.795***	0.237
matchTrt	-1.203***	0.242
interaction	1.190***	0.272
Constant	1.944***	0.227
Observations	8,864	
R-squared	0.004	

Std. Err. adjusted for 4,432 clusters in CellID

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix

Table A1: Logit Models for Propensity Score Estimation

VARIABLES	Control	
	Coeff.	Std Err
Own Grid Cell Variables		
% DNR Land	-1.012**	0.432
% Parkland	-0.744	0.553
% Federal Lands	0.11	1.721
number of owners	0.00216	0.00958
% undeveloped	-0.483*	0.254
% very highly erodible	2.929***	0.384
% high runoff potential	-0.281	0.303
% highly sloped	0.0773	0.228
% land cover medium density	1.220*	0.724
% land cover low density	0.993**	0.478
% land cover commercial	1.669*	0.908
% land cover agriculture	0.973**	0.405
% land cover forest	1.145***	0.399
% in 100yr Flood	1.242***	0.287
% in 500yr Flood	-0.322	1.037
% in ANI Flood^	0.709**	0.333
travTime_Balt	0.0132***	0.00338
waterFeature_2km	0.0363	0.0695
interstate_2km	0.933***	0.0779
urbanArterial_2km	-0.155	0.104
parks_2km	0.752***	0.0756

Continued next page

Table A1 continued: Logit Models for Propensity Score Estimation

Surrouding Grid Cell Variables		
% DNR Land	0.0385	0.446
% Parkland	2.705***	0.598
% Federal Lands	3.601**	1.721
% undeveloped	-0.566	0.426
number of owners	0.0292	0.0301
% land cover forest	0.0999	0.794
% land cover agriculture	-2.549***	0.789
% land cover water	0.462	0.84
% land cover low density	3.610***	0.883
% land cover medium density	3.130**	1.273
% land cover commercial	0.0291	1.792
% high runoff potential	-1.432***	0.384
% highly sloped	1.388***	0.297
Constant	-0.609	0.655
Observations	6,072	
Psuedo R2	0.2361	

*** p<0.01, ** p<0.05, * p<0.1

Note the Logit for treated results in reversed signs.

Figure 1: Example of Quarter Mile Grid with Parcel Underlay

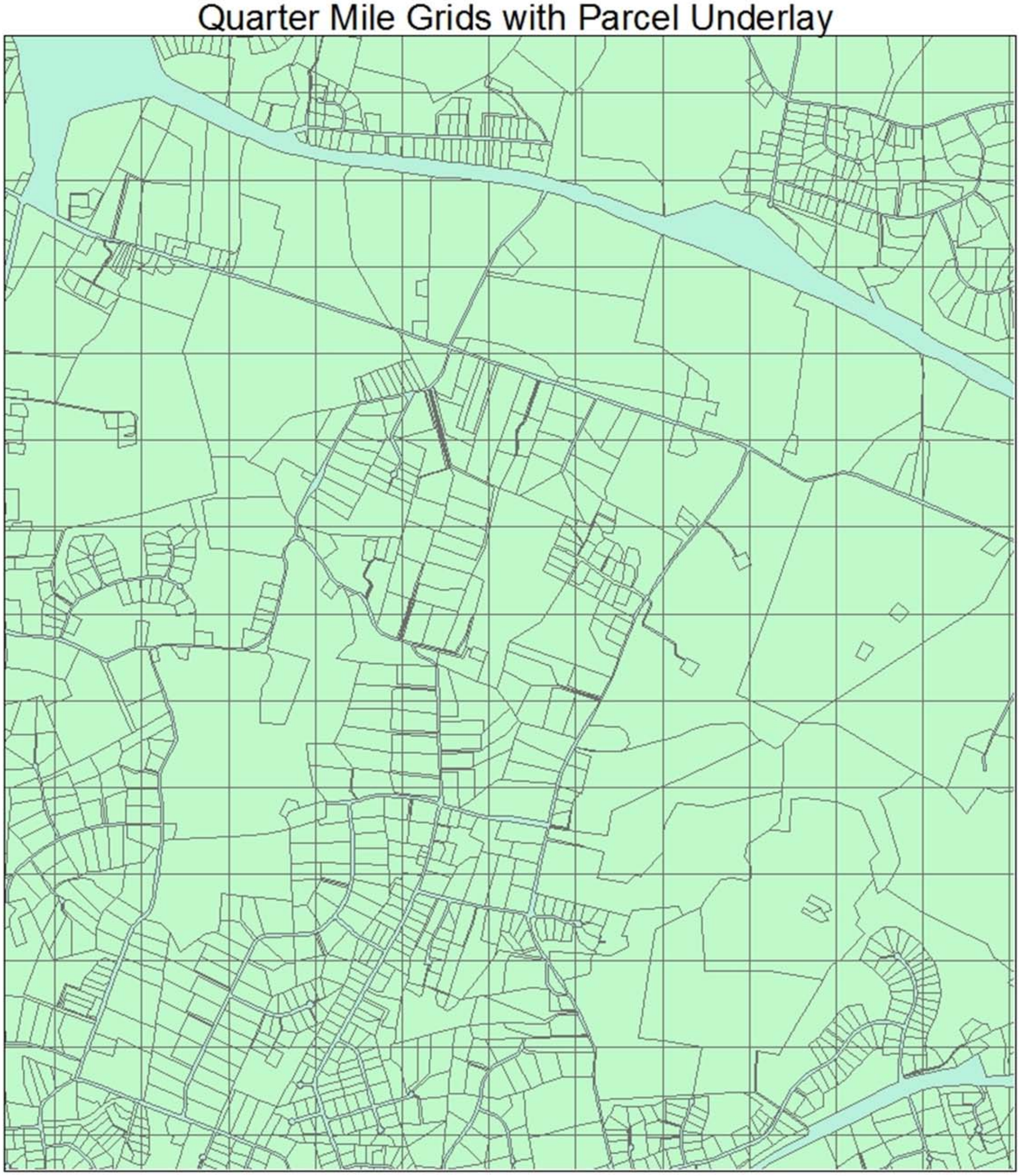


Figure 2: Study Area and Propensity Score Values Treated Group

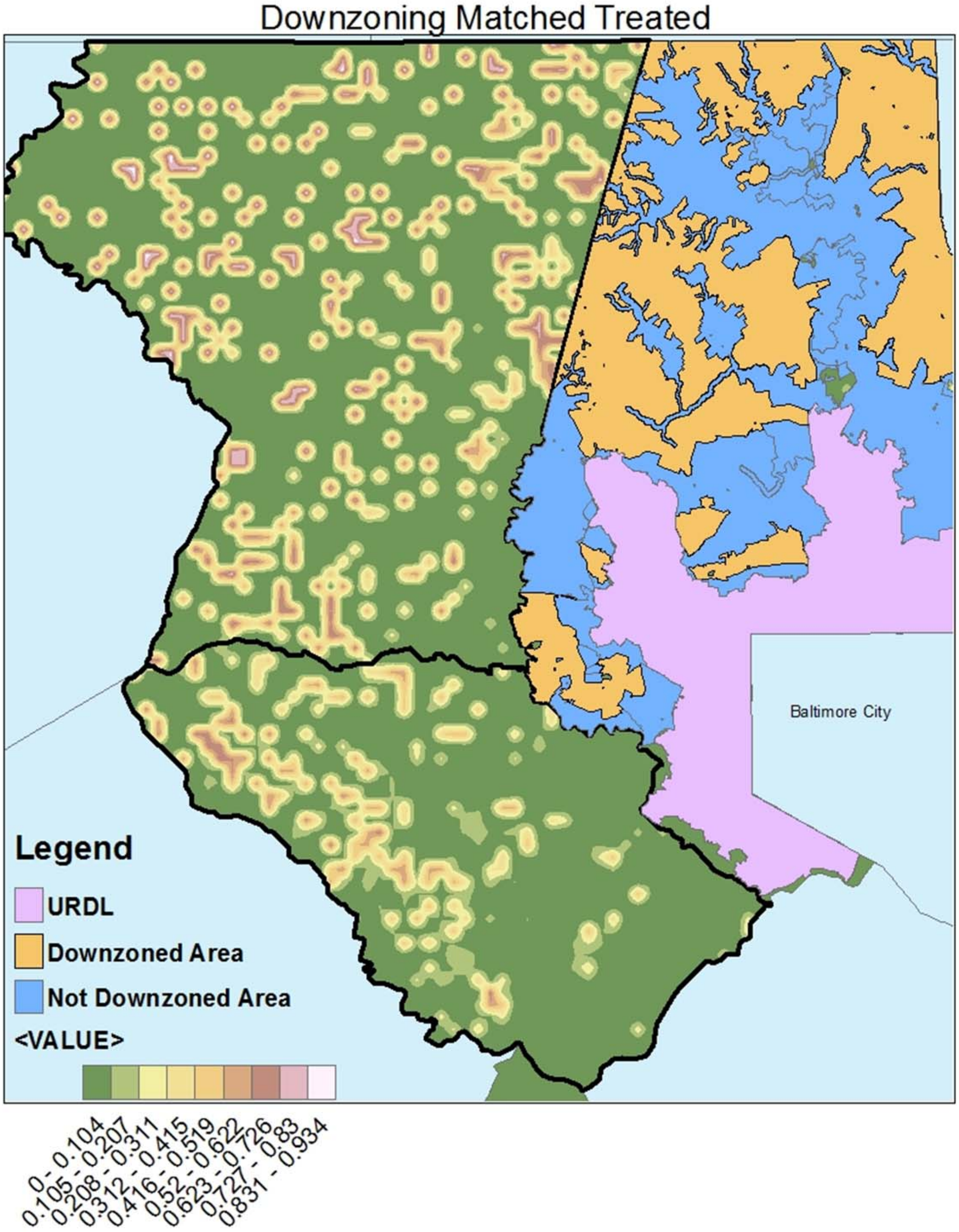


Figure 3: Study Area and Propensity Score Values Treated Group with Matched Treated Grids

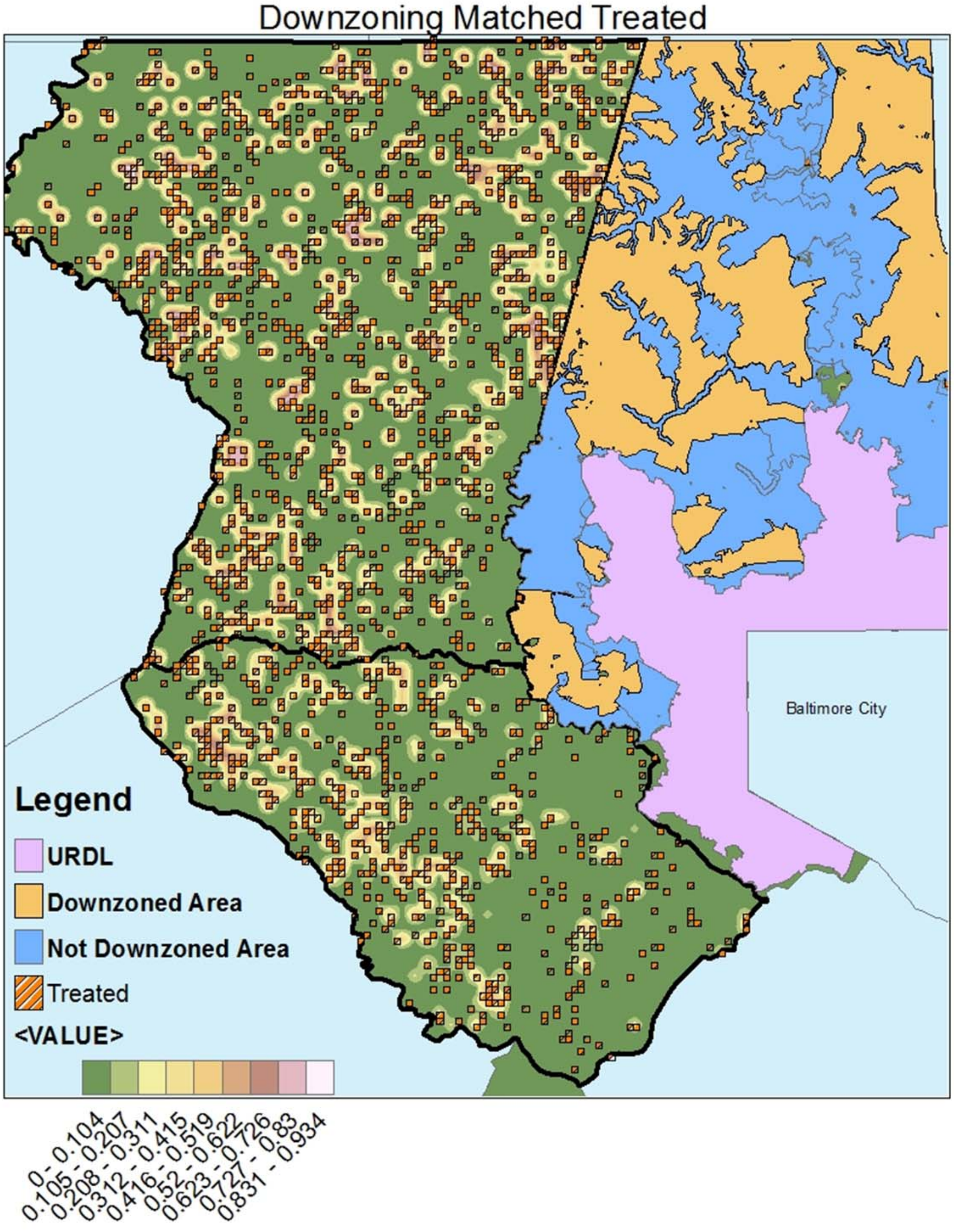


Figure 4: Study Area and Propensity Score Values Control Group

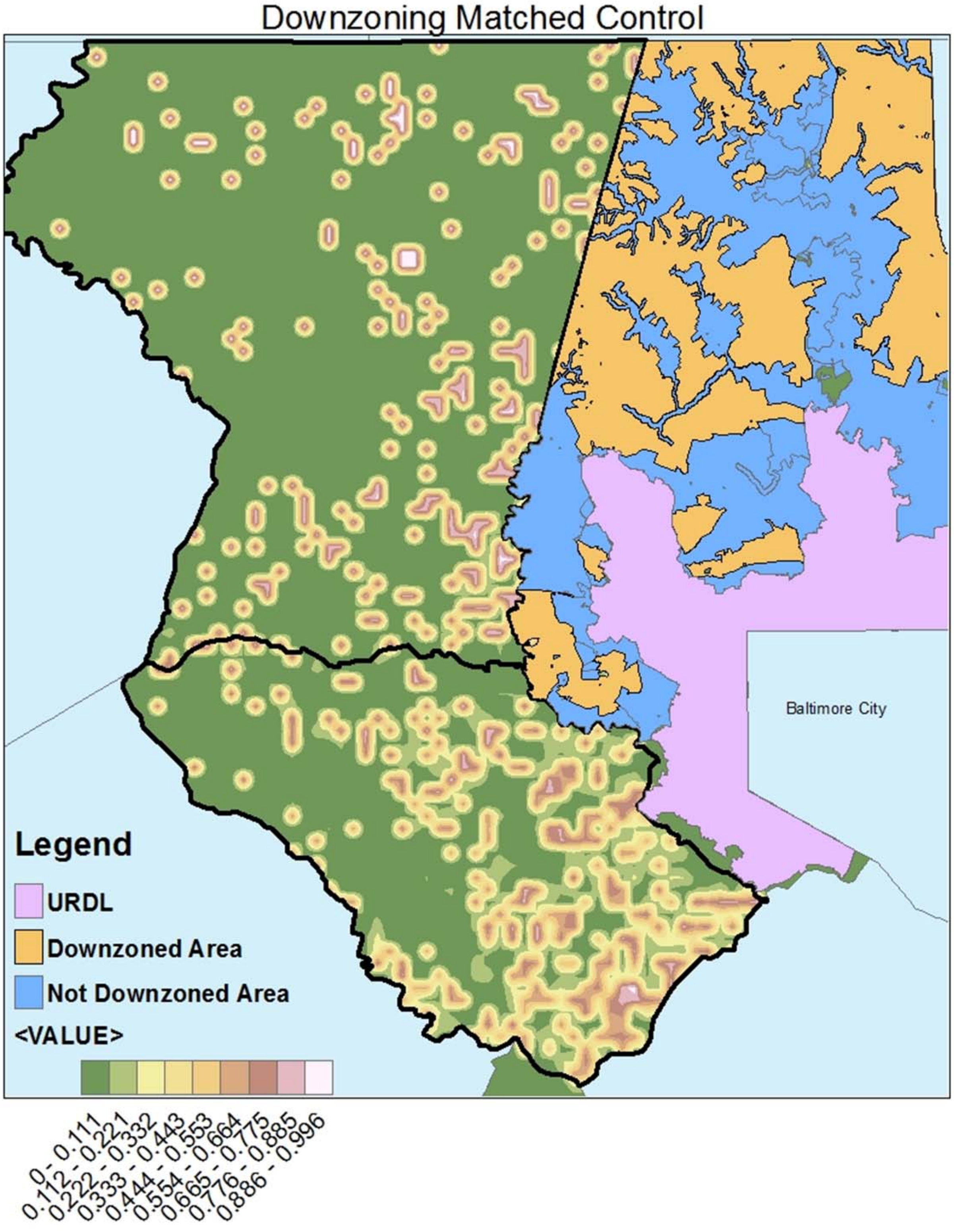


Figure 5: Study Area and Propensity Score Values Control Group with Matched Control Grids

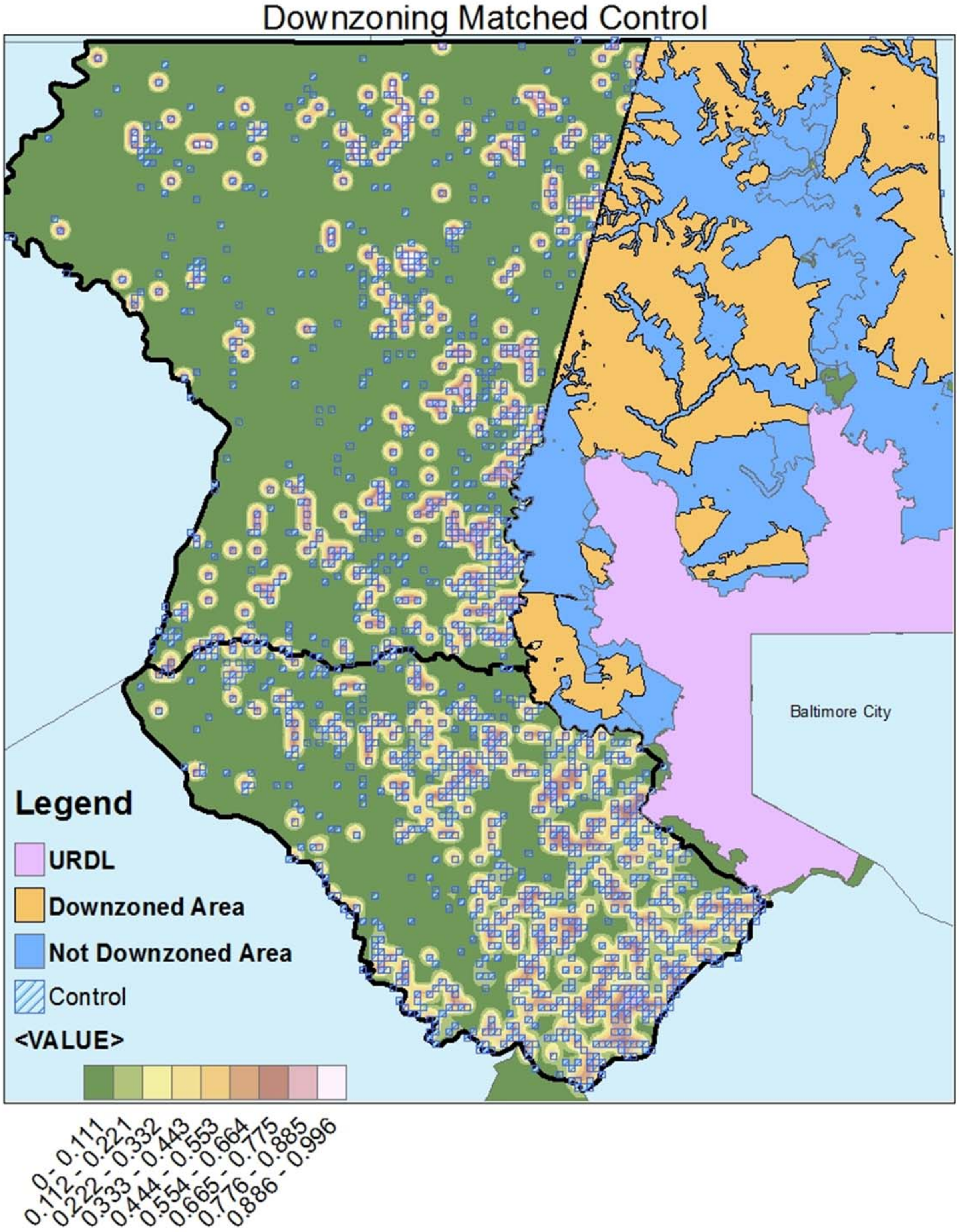
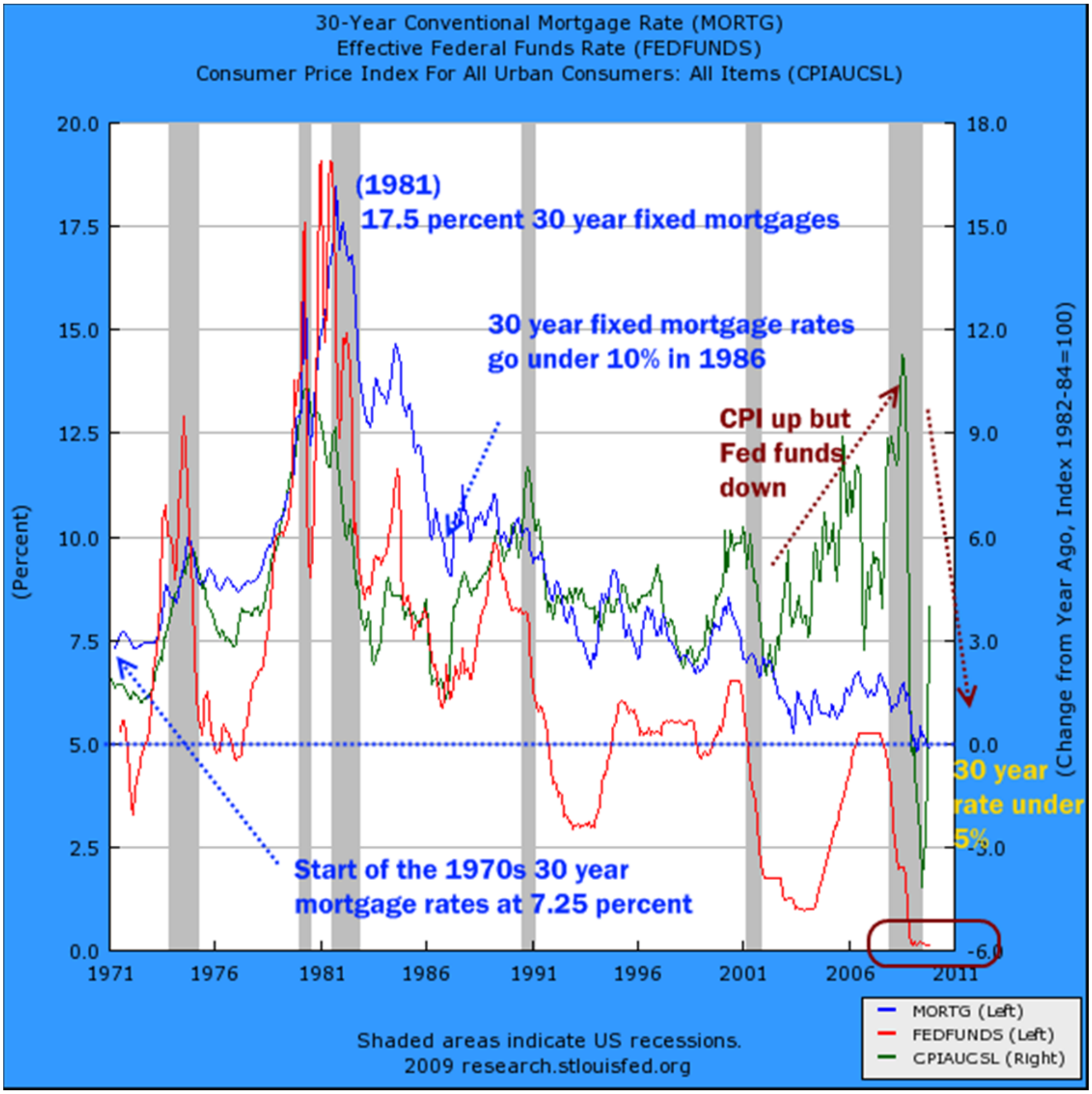


Figure 6: Historical rates



30-Year Conventional Mortgage Rate (MORTG)
Effective Federal Funds Rate (FEDFUNDS)
Consumer Price Index For All Urban Consumers: All Items (CPIAUCSL)

(1981)
17.5 percent 30 year fixed mortgages

30 year fixed mortgage rates go under 10% in 1986

CPI up but Fed funds down

30 year rate under 5%

Start of the 1970s 30 year mortgage rates at 7.25 percent

Shaded areas indicate US recessions.
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