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New urbanism and housing values: a disaggregate assessment

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Abstract

In this paper, we attempt a formal analysis of the virtues of new urbanism, a movement hailed as the most significant movement in urban planning and architecture in this century. We proceed using the tools of Geographic Information Systems (GIS) to develop quantitative measures of urban form. We then incorporate those measures in a hedonic price analysis. We find that our measures of urban form capture meaningful differences in the characters of urban neighborhoods that could well have direct impacts on the utility of urban residents. Further, we find that such differences are capitalized into residential property values. The results imply that some but not all of the design features of new urbanism provide benefits for which urban residents are willing to pay.

Keywords: New urbanism; Housing price; Urban form; Quantitative measures

1. Introduction

In 1993, the Congress for the New Urbanism (CNU) was founded by a group of architects dedicated to "creat[ing] buildings, neighborhoods, and regions that provide a high quality of life for all residents, while protecting the natural environment" (CNU [13]). Through the redesign of regions, neighborhoods, and buildings, new urbanists promise no less than the end of urban sprawl, the recreation of communities, and improvements in the quality of life (NU [32]). New urbanism has been hailed as the most significant movement in urban planning and architecture in this century (Fulton [19] and CNU [13]).

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Though the movement has drawn criticism from much of the architectural academy, the ideas behind CNU's Charter have been gradually integrated into curricula at top planning and architecture schools. In brief, the principles of new urbanism include high density, mixed use neighborhoods; convenient public transit, bicycles paths and pedestrian-friendly street networks; strategically placed open spaces; and architecture designed to foster social interaction (NU [32]).

While the movement has elicited considerable discussion and debate among urban planners, urban sociologists, urban geographers, and architects for over a decade, new urbanism has received little formal analysis. The reasons are twofold. First, new urbanism is primarily about urban design, which is difficult to quantify and thus poorly suited for applying formal analytical tools. Second, new urbanism, like its close relative, smart growth, generally favors the use of government plans and regulations to address an ill-defined problem. Thus the movement is unlikely to draw the attention of those who favor formal analysis.

In this paper we attempt a formal analysis of the virtues of new urbanism. Using Geographic Information Systems (GIS) we first develop quantitative measures of urban form; we then incorporate those measures in a hedonic price analysis. In essence, our research strategy involves the disaggregation of new urbanism into its component parts and an examination of the implicit prices those parts yield in the market place. We do not argue that ours is the best approach to assess the contributions of new urbanist designs to social welfare. Such an examination would require an analysis of social benefits that accrue to nonresidents of new urbanist communities. We do argue, however, that our approach advances knowledge about this question both in the measurement of new urbanist features (or urban form) and in the identification of those features for which homeowners are willing to pay.

In the analysis that follows, we consider six sets of characteristics that affect the value of single-family homes: physical housing attributes of the homes, public service levels, location, amenities and disamenities, socioeconomic characteristics, and new urbanist design features in the neighborhood. By isolating the effects on price of these variables, we can estimate the contributions to single-family home values by features of urban form. We find that our measures of urban form capture meaningful differences in the character of urban neighborhoods that could well have direct impacts on the utility of urban residents. Further, we find that such differences are capitalized into residential property values. The results imply that some but not all of the design features of new urbanism provide benefits for which urban residents are willing to pay.

2. Research context

2.1. Previous studies on urban form and property values

Ours is not the first study to examine the impacts of urban form or architectural character on property values. Cao and Cory [12], for example, showed that increasing industrial, commercial, multi-family and public land uses tend to increase surrounding home values. They thus concluded that an optimal mix of land use activities should be sought in locating economic activities into neighborhoods. Guttery [22] examined the sale prices of 1672 houses located in the Greater Dallas-Fort Worth-Denton metroplex and found negative impacts from having rear-entry alleyways. Asabere [5] provided empirical evidence from Halifax, Nova Scotia, which showed that location on a cul-de-sac yields a 29 percent price premium over houses located on a grid street pattern. Benson et al. [9], Asabere and Huffman [7], and Grudnitski and Do [21] estimated the value of having scenic views of open space and from locating close to a golf course. Not surprising, they found that views and neighboring golf course increase property values. Finally, many have also examined the effects of proximity to transit on property values. Bowes and Ihlanfeldt [10] incorporated both the direct and the indirect effects of transit stations on the attractiveness of nearby neighborhoods. They found that stations located away from downtown have positive impacts on property values. They have also found that there are negative externalities from location near stations in low-income neighborhoods or close to downtown.

Other studies have measured the influence of architecture on property value. Asabere et al. [6] estimated the effect of residential architectural styles on housing prices in Newburyport, Massachusetts. They found premiums of 14 to 21 percent for four "older architectural styles," Colonial, Victorian, Federal, and Garrison, relative to Ranch style. Moorhouse and Smith [29] explored the effects of a major 19th century American urban architectural form, the row house. They found that specific architectural features are more highly valued when they differentiate one row house from its immediate neighbors. Vandell and Lane [40] estimated the impact of "good architectural design" on the value of commercial buildings in Boston. They found a strong influence of design on rents and a weak relationship between vacancies and design quality. Hough and Kratz [24] also estimated the effect of "good architecture" on commercial rents in Chicago. They found that tenants are willing to pay a premium to be in new architecturally significant office buildings, but saw no benefits associated with old office buildings that express recognized aesthetic excellence.

The studies above notwithstanding, "new urbanism" per se has received little attention by economists**.** Recent market research shows that there is a demand for denser, more walkable residential environments in the United States as a whole, and the growing demand is a result of changing demographics, changing tastes, and the closing of the suburban frontier (CNU [14], and Myers and Gearin [30]). Eppli and Tu [17], and Tu and Eppli [38] are published studies that have examined the premiums captured by new urbanist developments. They compared the prices of single-family homes in new urbanist and suburban neighborhoods and found consumers willing to pay a premium for houses in a new urbanist neighborhood. They did not, however, attempt to isolate which design elements of a new urbanist neighborhood produced the price premium. The work by Eppli and Tu presumes that there are only two kinds of neighborhoods: new urbanist and traditional suburban. In fact there are many different types of neighborhoods with many different design features, and consumers might have multifaceted housing preferences (AL [2]). As suggested by Myers and Gearin [30], "Neither traditional neighborhood design nor conventional suburban development may be the housing consumer's ideal. Rather, the ideal home style may be something else and may fall somewhere on the housing spectrum between there two design alternatives. Similarly, individual household preferences for a single ideal housing type may in fact include a spectrum of types, united by key design criteria."

All together, considerable research suggests that certain elements of urban architectural style can be capitalized into property values. To date, however, there have been no studies that have focused on the features of new urbanism to determine if they, in isolation or combined, affect property values. We attempt to do so here.

2.2. Portland and new urbanism

Portland is Oregon's largest metropolitan area and has an international reputation as a leader in battle against urban sprawl.[1] In 1991, Metro, Portland's regional government, began work on the 2040 Plan. Following the principles of new urbanism, the goals of the plan include the transformation of the metropolitan area into a multi-nucleated urban form, the development of a multi-modal transportation system, and the designation of mixed use regional and town centers (Metro [27], Katz [25], and Calthorpe [11]). The Plan was approved in 1997 along with its implementation vehicle, the Urban Growth Functional Plan, which specified binding targets and performance measures for each of the subordinate cities and counties. Under Metro's Charter, cities and counties are required to change their comprehensive plans and subdivision regulations to assure that local plans comply with the Functional Plan. Armed with this charter, a State mandate to manage Portland's urban

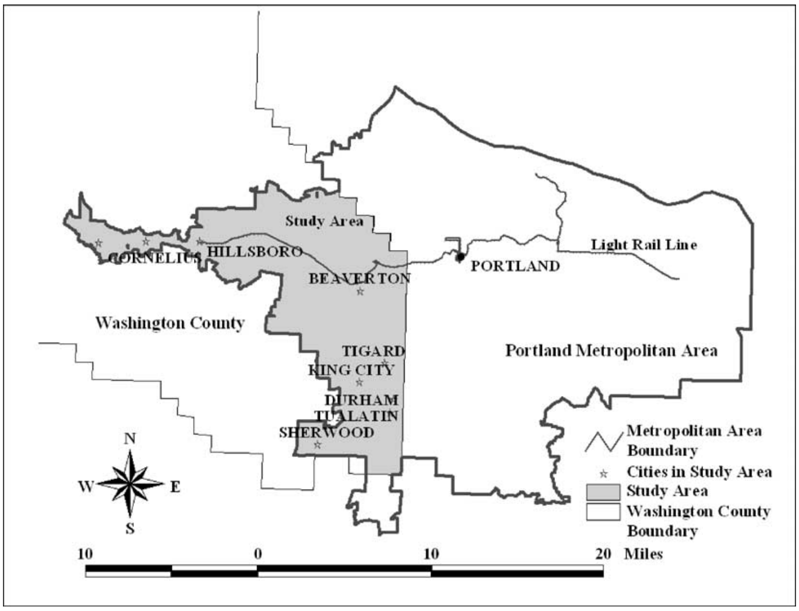

Fig. 1. Portland metropolitan area and study area.

[1] For more discussion on Metro, see Song and Knaap [36].

growth boundary, and a close association with Tri-Met, the regional transit district, Metro has substantial capacity to implement its new urbanist plan (Metro [28]).

Our study focuses on Washington County, which contains the western portion of the metropolitan area. As the most rapidly growing of the three counties within Metro's jurisdiction, the study area contains the cities of Beaverton, Hillsboro, Tigard, Sherwood, Tualatin, King City, Cornelius, Forest Grove, and Durham (see Fig. 1).

3. Data and method

3.1. Data

Our data come from three primary sources:

(1) The tax assessment files from Washington County;
(2) Regional Land Information System (RLIS) from Portland, Metro; and
(3) Census data from the US Census Bureau.

Prior to estimation, invalid transactions and multiple sales were omitted to ensure that sales reflect market clearing prices,[2] and to ensure independent observations. The cleaned dataset contains 48,070 real estate sales transactions in our study area for the period January 1990 through December 2000. The average sale price for the eleven-year period is $177,461, ranging from $50,000 to $916,300.

3.2. Measures of urban form

To begin our analysis, we define several measures of urban form that capture new urbanist neighborhood characteristics. We first divide the study area into 186 neighborhoods based on census blockgroup boundaries. What constitutes a neighborhood remains a matter of dispute. Lacking clear theoretical guidance, we explored three data-driven alternatives: census tracts, block groups, and sub-block groups. To choose among these we computed several measures of urban form for Washington County's 60 census tracts, 186 block groups, and 237 sub-block groups (where sub-block groups are formed by further partitioning block groups by major arterials). Then for each neighborhood (census tract, block group, and sub-block group), we assigned the age of the neighborhood by the median "year built" attribute of all single-family units it contained. We then explored, both visually and statistically, changes in our measures of urban form over time. We found that neighborhoods defined at the census tract level reveal less about changes in urban form over

[2] Following Eppli and Tu [17], we removed non-arms-length transactions and prevent coding errors based on the ratio of sale price to assessed value. Transactions that have a sale price that is 60 percent greater than the assessed value or that is less than 60 percent of the assessed value are deleted from the data set. In addition, properties with lots greater than two acres, or age older than 80 years are excluded to maintain a homogenous pool of transactions. Furthermore, we removed the transactions if their assessed value of the land is less than $1.00 per square foot or the assessed value of the improvements is less than $25.00 per square foot.

time due to aggregation. Neighborhoods measured at the sub-block group level, however, reveal little more information than those measured at the block group level. Thus we chose to use block groups as neighborhoods and divided the study area into 186 neighborhoods for the remaining analysis. We do not argue that census blocks are the best aerial unit for measuring urban form. We only claim that it is a convenient unit that illustrates the effects we seek to capture.[3]

For each block-group "neighborhood" we then computed five sets of urban form measures.[4] Definitions of each variable are provided in Table 1.

3.2.1. *Street design and circulation systems*

According to critics of sprawl, contemporary suburban developments contain too many winding streets and cul-de-sacs, blocks that are too big, and road networks that lack connectivity. According to this point of view, better connectivity leads to more walking and biking, fewer vehicle miles traveled, higher air quality, and greater sense of community among residents (Benfield et al. [8]). Our measures of connectivity involve the number of street nodes and segments, total miles of streets in the neighborhood, the number and lengths of blocks, the proximity to cul-de-sacs, the lengths of cul-de-sacs, and the distance between points of access into the neighborhood.[5]

3.2.2. *Density*

According to critics of sprawl, contemporary urban development is dominated by single-family housing on large lots. To such critics, low-density development increases automobile dependence, consumes excessive farmland, and raises the cost of public infrastructure (APA [4]). We offer two measures of density: single-family residential (SFR) dwelling unit density and population density.

3.2.3. *Land use mix*

According to critics of sprawl, contemporary urban developments are homogeneous and lack a mix of land uses. To such critics greater mixing of uses facilitates walking and biking, lowers vehicle miles traveled, improves air quality, and enhances urban aesthetics (APA [4]). We offer two indices that measure land use diversity within a neighborhood. Both are based on the concept of entropy—a measure of variation, dispersion or diversity (Turner et al. [39]). The first measure includes single-family residential use and captures the overall mixture of land uses. The second measure excludes single-family use and captures the mixture of land uses in the non-single-family residential sector.

3.2.4. *Accessibility*

According to critics of sprawl, contemporary urban development is characterized by too much separation between uses and thus travel distances that are too long (APA [4]). Here

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[3] For more discussion on neighborhood definition, see Song and Knaap [36].

[4] All the calculations were computed using ARCInfo and ArcView with data from Metro's Regional Land Information System.

[5] Street segments are defined by the part of the street between two street nodes. Street nodes are defined as street intersections, T-sections and street dead ends. For more on connectivity, see Allen [1] and Southworth [37].

Table 1
Definition of variables measuring new urbanist features

Variable	Definition
(1) Street design and circulation systems	
INTCONN	Number of street segments divided by number of street nodes (DeMers [15]); the greater the *INTCONN*, the greater the internal connectivity.
STMILES	Linear amount of street network divided by number of housing units in a neighborhood.
BLOCKS	Number of blocks divided by number of housing units; the fewer the blocks, the greater the internal connectivity.
BLOCKSIZE	Median value of perimeter of the blocks in a neighborhood; the smaller perimeter, the greater the internal connectivity.
CULDESAC	Dummy variable indicating if the property is within 50 feet of the end of a cul-de-sac.
LENGTHCDS	Median length of cul-de-sacs; the shorter the cul-de-sacs, the greater the internal connectivity.
EXTCONN	Median distance between Ingress–egress (access) points in feet; the greater the distance, the poorer the external connectivity.
(2) Density	
SFRDNSTY	Single-family residential (SFR) dwelling units divided by the residential area of the neighborhood; the higher the ratio, the higher the density.
POPDNSTY	Number of households divided by area of the neighborhood; the higher the ratio, the higher the population density.
(3) Land use mix	
LUMIX	A diversity index $H_1 = -\sum_{i=1}^{s}(p_i)\ln(p_i)/\ln(s)$, where H_1 is diversity including SFR, p_i is proportions of each of the five land use types such as SFR, Multi-family residential (MFR), Industrial, Public, and Commercial uses, and s is the number of land uses, in this case $s = 5$. The higher the value, the higher land use mix.
NRMIX	A diversity index $H_2 = -\sum_{i=1}^{s}(p_i)\ln(p_i)/\ln(s)$, where H_2 is diversity excluding SFR, p_i is proportions of each of the four land use types such as MFR, Industrial, Public, and Commercial uses, and s is the number of land uses, in this case $s = 4$. The higher the value, the higher land use mix.
(4) Accessibility	
COMDIS	Distance in feet from the house to nearest commercial use.
BUSDIS	Distance in feet from the property to the nearest bus stop.
PARKDIS	Distance in feet from the property to the nearest park.
(5) Transportation mode choice	
HILLBO	Dummy variable indicating if the house is within half mile of Hillsboro downtown light rail transit (LRT) stations and if the sale occurred before the light rail line was operated.
HILLAO	Dummy variable indicating if the property is within half mile of Hillsboro downtown LRT stations and if the sale occurred after the light rail line was operated.
BEAVBO	Dummy variable indicating if the property is within half mile of Beaverton downtown LRT stations and if the sale occurred before the light rail line was operated.
BEAVAO	Dummy variable indicating if the property is within half mile of Beaverton downtown LRT stations and if the sale occurred after the light rail line was operated.
OTHERBO	Dummy variable indicating if the property is within half mile of suburban LRT stations and if the sale occurred before the light rail line was operated.
OTHERAO	Dummy variable indicating if the property is within half mile of suburban LRT stations and if the sale occurred after the light rail line was operated.
(6) Pedestrian walkability	
PEDCOM	Percentage of SFR units within one quarter mile of commercial uses; the greater the percentage, the greater the pedestrian accessibility.
PEDBUS	Percentage of SFR units within one quarter mile of bus stops; the greater the percentage, the greater the pedestrian accessibility.

we offer three measures of accessibility: distance to commercial uses, distance to a bus stop, and distance to a public park. Each is measured as the median distance from every single-family parcel centroid in the neighborhood to the centroid of the nearest commercial use, bus stop, or public park.

3.2.5. Transportation mode choice

A fundamental element of new urbanism is design that enables transportation mode choice (Katz [25]). Here we focus on access to Portland's light rail system. To explore the effect of accessibility to light rail stations, we proceed by disaggregating the effects of proximity to the stations into two time periods and by station location. That is, we identified properties that were located near stations before and after the line went into operation in downtown Hillsboro, in downtown Beaverton, and in between Hillsboro and Beaverton.

3.2.6. Pedestrian walkability

According to critics of sprawl, contemporary development patterns create great distances between destinations and thus discourage walking. Pedestrian access encourages residents to walk, lowers vehicle miles traveled, and improves human health (Frank and Englke [18]). According to conventional wisdom, pedestrians in the United States are willing to walk no longer than one-quarter mile (Duany and Plater-Zyberk [16]). Thus we measure pedestrian walkability as the percentage of single-family homes (again using lot centroids) that are within one-quarter mile network distance of commercial uses and bus stops.

3.3. Control variables

To control for the influence on price other than urban form we include five additional sets of variables. Definitions of each variable are provided in Table 2.

3.3.1. Physical housing attributes

The physical characteristics of a house—such as the number or rooms, quality of construction, and presence of fireplace, garage, etc.—are widely known to affect its value (Grether and Mieszkowski [20]). Our data sources do not have complete information on such attributes. To capture differences in physical attributes we include three variables: lot size, square feet of floor space, and age of the house.

3.3.2. Public service levels

The value of public services is also widely known to affect housing values (Grether and Mieszkowski [20]). To capture these effects we include four variables: access to municipal services (measured as location within an incorporated municipality), the mean *SAT* score and student/teacher ratio of the pertinent school district; and the adjusted property tax rate.

3.3.3. Location

According to economic theory, location with respect to employment centers is a fundamental determinant of location rents (Grether and Mieszkowski [20]). To capture

Table 2
Definition of control variables

Variable	Definition
(1) Property physical housing attributes	
LOTSIZE	Lot area in square feet.
FLOORSPACE	Building area in square feet.
AGE	Age of the building in years.
AGESQUARE	Square of the age variable. This variable allows for a nonlinear relationship between property value and age.
(2) Public service levels	
INCITY	Dummy variable indicating if the house is located within the cities.
SAT	*SAT* score in the school district in which the house is located.
STU/TEA	Student/teacher ratio in school district in which the house is located.
HILLSC, *BEAVSC*, *TTSC*, *SHERSC*, *FGSC*	Binary variables presenting if the house is located in one of the following school districts: Hillsboro (*HILLSC*), Beaverton (*BEAVSC*), Tigard-Tualatin (*TTSC*), Sherwood (*SHERSC*), and Forest Grove (*FGSC*) School District.
TAXRT	Limited tax rate for the parcel.
(3) Location	
PORTCBD	Distance in feet from the property to the Portland CBD.
HILLCBD	Distance in feet from the property to the Hillsboro CBD.
BEAVCBD	Distance in feet from the property to the Beaverton CBD.
(4) Amenity and disamenities	
GOLF	Actual area of golf course in the neighborhood divided by number of housing units in a neighborhood.
ONWATER	Dummy variable indicating whether the property is within 150 feet of water bodies $(1 = \text{Yes}, 0 = \text{No})$.
MOUNTNVW	Dummy variable indicating whether the property has a mountain view $(1 = \text{Yes}, 0 = \text{No})$.
MINRDDIS	Distance in feet to the nearest minor road, where minor road includes major collector and collector.
ONMAJRD	Dummy variable indicating whether the property is within 150 feet of a major road $(1 = \text{Yes}, 0 = \text{No})$.
ONLRT	Dummy variable indicating whether the property is within 500 feet of the light rail line $(1 = \text{Yes}, 0 = \text{No})$.
(5) Socioeconomic characteristics	
PCTWHITE	Percent of population that is white in the neighborhood.
MEDINC	Median household income in the neighborhood.
TIMESALE	Binary variables representing the year of the sale.

these effects we include measures of distance to three central business districts: Portland, Hillsboro, and Beaverton.

3.3.4. Amenities and disamenities

Amenities and disamenities have direct effects on resident utilities and thus can also affect property values. To capture the effects of amenities we include measures of proximity to a golf course, waterbodies, views of the Cascade and Coast Range mountains, and minor roads. To capture the effects of disamenities we include measures of exposure to traffic, specified as within a 150-foot buffer of a major road, or within a 500-foot buffer of a light rail transit line.

3.3.5. *Socioeconomic characteristics*

Residents care about the social structure of their neighborhood. To capture these effects we include measures of racial composition, measured as percent of the white, and median household income of the neighborhood. Finally, to capture the effects of inflation we include the year the parcel was sold.

4. Hedonic price analysis

4.1. *Hedonic price equation*

To explore the effects of urban form on property values we use a standard hedonic price model. As semi-log is a common form of such a model, we specify the dependent variable as the log of sale price.

$$\ln(\text{sale\_price}) = \beta_0 + \beta_i x_i + \mathrm{e}, \tag{1}$$

where β_0 is the constant, β_i $(i = 54)$ are coefficients, x_i $(i = 54)$ are variables listed in Tables 1 and 2. Summary statistics for the dependent variable and all independent variables are provided in Table 3.

Table 3
Summary statistics for all variables

Variable	Unit of measure	Mean	Std. dev.	Minimum	Maximum
Dependent variables					
SALEPRICE	Dollar	177460.72	70218.13	50000	916300
LOGSALEPRICE	Log(dollar)	12.02	0.34	10.82	13.73
Independent variables					
(1) Property physical housing attributes					
LOTSIZE	Square feet	8674.81	5651.36	144.28	86971.23
FLOORSPACE	Square feet	1911.12	679.77	352	8244
AGE	Year	18.34	15.30	1	81
AGESQUARE	Year	570.31	894.59	1	6561
(2) Public service levels					
INCITY	Binary	0.56	0.50	0	1
SAT	Score	537.12	13.93	501.00	548.27
STU/TEA	Percentage	36.58	0.39	35.41	36.98
HILLSC	Binary	0.23	0.42	0	1
BEAVSC	Binary	0.52	0.50	0	1
TTSC	Binary	0.17	0.37	0	1
SHERSC	Binary	0.04	0.20	0	1
FGSC	Binary	0.04	0.20	0	1
TAXRT	Milrate	15.88	1.05	12.54	18.73
(3) Location					
PORTCBD	Feet	52108.18	18130.59	16787.99	120718.09
HILLCBD	Feet	43255.89	19387.78	609.95	85634.64
BEAVCBD	Feet	27935.82	16574.51	588.73	91980.70

(*continued on next page*)

Table 3 (*continued*)

Variable	Unit of measure	Mean	Std. dev.	Minimum	Maximum
(4) Amenity and disamenities					
GOLF	Square feet	292.40	1647.47	0.00	28879.63
ONWATER	Binary	0.14	0.35	0	1
MOUNVW	Binary	0.10	0.29	0	1
MINRDDIS	Feet	83.83	34.53	0.42	867.04
ONMAJRD	Binary	0.06	0.25	0	1
ONLRT	Binary	0.01	0.08	0	1
(5) Socioeconomic characteristics					
PCTWHITE	Percentage	0.93	0.05	0.54	1
MEDINC	Dollar	40877.17	10163.69	16900	76093
YR91	Binary	0.03	0.16	0	1
YR92	Binary	0.04	0.2	0	1
YR93	Binary	0.06	0.25	0	1
YR94	Binary	0.08	0.26	0	1
YR95	Binary	0.08	0.28	0	1
YR96	Binary	0.11	0.31	0	1
YR97	Binary	0.13	0.34	0	1
YR98	Binary	0.16	0.36	0	1
YR99	Binary	0.16	0.37	0	1
YR00	Binary	0.13	0.33	0	1
(6) New urbanism neighborhood characteristics					
INTCONN	n.a.	1.30	0.11	1.04	1.80
STMILES	Feet /HH unit	70.21	30.41	38.22	395.93
BLOCKS	#of Blocks /HH unit	0.03	0.02	0.01	0.65
BLOCKSIZE	Feet	2658.11	1266.95	592.18	13442.12
CULDESAC	Binary	0.13	0.01	0	1
LENGTHCDS	Feet	242.20	71.17	0.00	2049.42
EXTCONN	Feet	475.09	152.73	175.57	1969.01
SFRDNSTY	#of HHunit/ acre	4.77	1.40	0.28	11.93
POPDNSTY	#of People /acre	2.28	1.79	0.07	41.30
LUMIX	Proportion	0.60	0.19	0.02	1.00
NRMIX	Proportion	0.39	0.25	0.08	1.00
COMDIS	Feet	2219.12	1321.54	52.14	8345.52
BUSDIS	Feet	1382.13	429.82	11.38	3984.98
PARKDIS	Feet	894.54	581.21	19.60	4183.17
HILLBO	Binary	0.0063	0.08	0	1
HILLAO	Binary	0.0068	0.08	0	1
BEAVBO	Binary	0.0027	0.05	0	1
BEAVAO	Binary	0.0026	0.05	0	1
OTHERBO	Binary	0.0137	0.12	0	1
OTHERAO	Binary	0.0123	0.11	0	1
PEDCOM	Percentage	0.18	0.21	0.00	1.00
PEDBUS	Percentage	0.34	0.26	0.00	1.00

4.2. Regression results and implications[6]

The results of our analysis, including the *t*-statistics and coefficients of each of the *significant* variables, are provided in Table 4.[7] The R^2 indicates that we were able to explain 84 percent of the variation in single-family home prices. Most of the coefficients have expected signs.

4.2.1. Control variables

Property physical housing attributes. As expected, *LOTSIZE* and *FLOORSPACE* are positively related to house price. The expected negative sign of *AGE* reveals that an older home is worth less than a newer home, and the positive sign of *AGESQUARE* indicates that the relationship between house value and house age is not linear.

Public service levels. Public services are capitalized into property values. As expected, *INCITY* is positively related to house price, reflecting the value of services provided by cities. The expected negative sign of *TAXRT* reveals that property taxes are capitalized in property values. The positive sign of *SAT* and negative sign of *STU/TEA* indicate that, as expected, home buyers prefer school districts with higher *SAT* scores and lower student/teacher ratios.

Location. Location matters. Negative signs of the variables *HILLCBD* and *PORTCBD*, indicate that housing prices fall with distance from the Portland and Hillsboro *CBD*s. Since the *CBD*s of Portland and Hillsboro are major employment centers, this was expected. The sign of the variable *BEAVCBD*, however, is positive. Though not expected, this likely reflects the character of downtown Beaverton as more of an automobile-oriented retail center than an employment center.

Amenity and disamenities. Amenities and disamenities affect housing prices as expected. The positive sign of *GOLF* is consistent with earlier studies. The positive coefficient on the binary variable *MOUTNVW* indicates that a view of the mountains increases property value. The sign of *MINRDDIS* has the expected negative sign, indicating that home buyers pay a premium for the houses with better accessibility to minor roads.

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[6] We have also performed the exercise of incorporating spatial effects into our hedonic price structure explicitly. From a subset of our dataset, the results indicated the presence of spatial error dependence. In other words, the error term at each location is correlated with values for the error term at other locations. This might be due to two of following reasons. First, measurement errors are likely to exist and to spill over across the spatial units since some data are collected and constructed at an aggregate scale. Second, some of the omitted variables, such as number of rooms, exterior material of the house and other house physical characteristics, are correlated and this might be another cause for the presence of spatial error dependence. In the presence of spatial error dependence and spatial heteroskedasticity, OLS estimates are still unbiased (Anselin [3]). Therefore, we present the results from OLS analysis in the paper.

[7] Eleven variables, *HILLSC*, *BEAVSC*, *TTSC*, *FGSC*, *ONWATER*, *PCTWHITE*, *MEDINC*, *Y91*, *BUSDIS*, *HILLAO*, *BEAVAO*, are dropped out from the model.

Table 4
Regression results

Variable	Parameter estimate	Standard error	t value	$\Pr > \lvert t \rvert$
Intercept	11.52633	0.16160000	71.33	< 0.0001
(1) Property physical housing attributes				
LOTSIZE	0.00001	0.00000017	52.11	< 0.0001
FLOORSPACE	0.00031	0.00000126	244.02	< 0.0001
AGE	−0.00775	0.00014780	−52.45	< 0.0001
AGESQUARE	0.00005	0.00000234	19.46	< 0.0001
(2) Public service levels				
INCITY	0.03538	0.00266000	13.31	< 0.0001
SAT	0.00192	0.00011930	16.09	< 0.0001
STU/TEA	−0.03017	0.00387000	−7.80	< 0.0001
SHERSC	0.03943	0.00545000	7.23	< 0.0001
TAXRT	−0.00408	0.00123000	−3.33	0.0009
(3) Location				
HILLCBD	−0.00000	0.00000009	−6.57	< 0.0001
BEAVCBD	0.00001	0.00000016	32.71	< 0.0001
PORTCBD	−0.00001	0.00000017	−44.98	< 0.0001
(4) Amenity and disamenities				
GOLF	0.00001	0.00000040	14.12	< 0.0001
MOUNVW	0.06123	0.00293000	20.89	< 0.0001
MINRDDIS	−0.00021	0.00002217	−9.46	< 0.0001
ONMAJRD	−0.03898	0.00278000	−14.00	< 0.0001
ONLRT	−0.04582	0.00764000	−5.99	< 0.0001
(5) Socioeconomic characteristics				
YR92	0.001650	0.00607000	2.65	0.0082
YR93	0.006869	0.00583000	11.37	< 0.0001
YR94	0.014279	0.00574000	24.53	< 0.0001
YR95	0.021885	0.00569000	37.66	< 0.0001
YR96	0.029392	0.00558000	50.97	< 0.0001
YR97	0.034860	0.00554000	62.14	< 0.0001
YR98	0.037099	0.00550000	66.97	< 0.0001
YR99	0.038780	0.00549000	70.76	< 0.0001
YR00	0.041746	0.00555000	74.88	< 0.0001
(6) New urbanism neighborhood characteristics				
INTCONN	0.04468	0.00777000	5.75	< 0.0001
STMILES	0.00033	0.00003518	9.47	< 0.0001
BLOCKS	0.14644	0.04545000	3.22	0.0013
BLOCKSIZE	−0.00000	0.00000067	−3.23	0.0013
CULDESAC	0.00116	0.00159000	11.73	< 0.0001
LENGTHCDS	−0.00011	0.00001331	−8.27	< 0.0001
EXTCONN	0.00008	0.00000562	14.59	< 0.0001
SFRDNSTY	−0.00110	0.00072439	−4.52	0.0129
POPDNSTY	−0.00863	0.00048812	−17.69	< 0.0001
LUMIX	−0.04706	0.00550000	−8.56	< 0.0001
NRMIX	0.01401	0.00341000	4.11	< 0.0001
COMDIS	0.00001	0.00000068	13.45	< 0.0001
PARKDIS	−0.00001	0.00000126	−5.13	< 0.0001
HILLAO	0.04773	0.00825	5.78	< 0.0001
BEAVAO	0.02808	0.01220	2.30	0.0214
OTHERBO	−0.03592	0.00582	−6.17	< 0.0001
OTHERAO	0.00458	0.00630	8.73	< 0.0001
PEDCOM	0.05525	0.00456000	12.13	< 0.0001
PEDBUS	−0.00607	0.00336000	−3.81	0.0007
R-square	0.8420			
No. of obs.	48,070			

The binary variables for exposure to traffic characteristics all exhibit the expected relationships. The negative signs of *ONMAJRD* and *ONLRT* indicate that home buyers pay less for the houses that are within 150 feet of a major road, or 500 feet of the light rail line for possible noise nuisance effects.

Socioeconomic characteristics. Socioeconomic variables *PCTWHITE* and *MEDINC* are not significant, perhaps due to the lack of variation of race and income in our study area. The dummy variables that capture the year of sale (with sales in 1990 as the reference variable) indicate that single-family home prices have been increasing since 1992.

4.2.2. Measures of urban form

Street design and circulation systems. The positive sign of *INTCONN* indicates that home buyers pay a premium for an internally connective neighborhood. This is consistent with the positive sign of *STMILE*, indicating that people prefer more streets being provided within a neighborhood. The positive sign of *BLOCKS* indicates that home buyers prefer to be located in a neighborhood designed with more blocks per housing unit. This result is consistent with the negative sign of *BLOCKSIZE*, which indicates that home buyers pay a premium for a house located in a neighborhood with smaller blocks. The positive sign of *CULDESAC* indicates that home buyers pay more to be located by cul-de-sacs. The negative sign of *LENGTHCDS*, however, indicates that people prefer shorter dead-end streets. The positive sign of *EXTCONN* indicates that home buyers prefer to be located in a neighborhood that is less connected to the outside.

Density. The negative signs of both *SFRDNSTY* and *POPDNSTY* are consistent with the previous market surveys which reveal that people prefer neighborhoods with low population density and low dwelling-unit density.

Land use mix. The negative sign of *LUMIX* indicates that consumers prefer single-family residential as the dominant use in the neighborhood. The positive sign of *NRMIX* further shows that the other land uses such as multi-family residential, industrial, public, and commercial uses are preferred to be distributed evenly in the neighborhoods.

Accessibility. The positive sign of *COMDIS* is unexpected. The plausible explanation might be the nuisance effects brought by general commercial uses exceed the amenity effects of being closer to commercial uses. *PARKDIS* has the expected negative sign, indicating that home buyers pay a premium for the houses located closer to a park.

Transportation mode choice. The effects of proximity to light rail stations on housing price meet expectations. Properties sold at a higher price after the line was operated in all three areas: downtown Hillsboro, downtown Beaverton and those between Hillsboro and Beaverton. Before the line was operational, proximity to the stations had no effect on property values except for those between Hillsboro and Beaverton. The negative effect of proximity to stations between Hillsboro and Beaverton before the line was operated can be explained as follows. Before the light rail stations were constructed, this area was occupied mainly by vacant green spaces, and underdeveloped rural enclaves without established single-family neighborhoods. As planned, these areas were targeted for transit-oriented redevelopment and increased in value as a result. These findings are consistent with previous research (Knaap et al. [26]).

Pedestrian walkability. For variables measuring pedestrian walkability to commercial uses and bus stops, the results are mixed. The positive sign of *PEDCOM* indicates that consumers prefer to have more pedestrian accessibility to commercial uses, while the negative sign of *PEDBUS* indicates that home buyers do not prefer to be too close to bus stops.

Additional 11 cross-sectional regressions (results are not presented in this paper) were run to examine possible variations in the effects of urban form features on housing prices over time. Similar results to those reported above have been found.

4.3. Evaluating the premium from new urbanist features

To evaluate the premium that home buyers pay for homes in new urbanist neighborhoods we compute the predicted value of a standardized house in two distinctly different neighborhoods in the study area (Fig. 2). The first is a hypothetical neighborhood characterized by the mean values of all the urban form measures in Washington County. The second is the Orenco Station neighborhood. This neighborhood is located next to an Intel plant and a light rail line, and has gained a great deal of notoriety as an exemplar

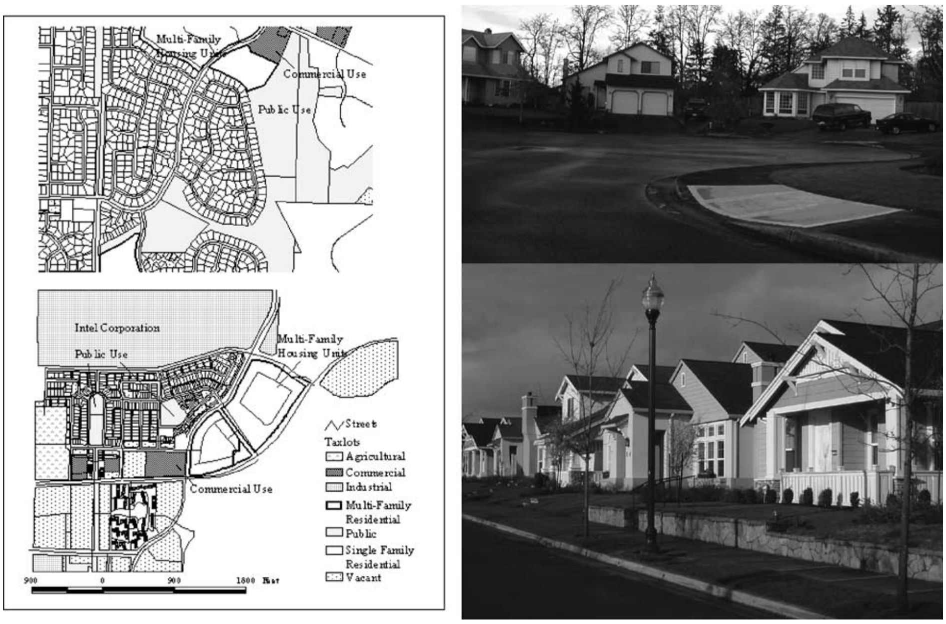

Fig. 2. Forrest Glen (upper) and Orenco Station neighborhood (lower). (The urban form measures of the Forrest Glen neighborhood approximate the median values of all neighborhoods in the study area.)

of a successful new urbanist development (NAH [31]). The values of the urban form measures for the hypothetical and Orenco Station neighborhood are highlighted in bold in Table 5. The data in Table 5 reveal that the hypothetical and Orenco Station neighborhoods differ significantly in most measures of urban form. Orenco Station has smaller lots, better internal street connectivity, more and smaller blocks, more streets but shorter cul-de-sacs, higher population and single-family dwelling unit densities, more mixing of land uses, better access to parks and commercial areas, more transit mode choices, better pedestrian walkability to commercial stores and bus stops, but lower external connectivity than the typical neighborhood. This comparison suggests that our measures of urban form appear

Table 5
Interpreting the estimation results

Variable	e^{β} with βs as coefficients from Table 3	Premium (at 150,000)	Variable value for suburban SFR house	Variable value for house in a NU neighborhood	Premium from NU neighborhood
Intercept	113859		11.64272	11.64272	
(1) Property physical housing attributes					
LOTSIZE	1.000009	1.30	**8675**	**3500**	**−5766.05**
FLOORSPACE	1.000306	47.97	**1911**	**1911**	**0.00**
AGE	0.992280	−1158.01	18	18	
AGESQUARE	1.000045	6.72	570	570	
(2) Public service levels					
INCITY	1.035547	5332.08	1	1	
SAT	1.001882	282.27	537	537	
STU/TEA	0.967974	−4803.89	36.58	36.58	
SHERSC	1.039168	5875.14	0	0	
TAXRT	0.996088	−586.85	15.88	15.88	
(3) Location					
PORTCBD	0.999992	−1.14	52108	52108	
HILLCBD	0.999999	−0.10	43256	43256	
BEAVCBD	1.000005	0.78	27936	27936	
(4) Amenity and disamenities					
GOLF	1.000006	0.87	**292**	**0**	**−220.98**
MOUNVW	1.062123	9318.49	0	0	
MINRDDIS	0.999786	−32.07	84	84	
ONMAJRD	0.961808	−5728.74	0	0	
ONLRT	0.963580	−5463.03	0	0	
(5) Socioeconomic characteristics					
YR92	1.012659	1898.92	0	0	
YR93	1.016879	2531.83	0	0	
YR94	1.014325	2148.69	0	0	
YR95	1.021765	3264.82	0	0	
YR96	1.029038	4355.64	0	0	
YR97	1.035146	5271.83	0	0	
YR98	1.037434	6615.04	0	0	
YR99	1.039570	6935.47	1	1	
YR00	1.042368	7355.19	0	0	

(*continued on next page*)

Table 5 (*continued*)

Variable	e^{β} with βs as coefficients from Table 3	Premium (at 150,000)	Variable value for suburban SFR house	Variable value for house in a NU neighbor-hood	Premium from NU neighbor-hood
(6) New urbanism neighborhood characteristics					
INTCONN	1.031393	5882.93	**1.30**	**1.45**	**759.28**
STMILES	1.000384	57.60	**70**	**204**	**6929.35**
BLOCKS	1.202509	25260.78	**0.03**	**0.15**	**2973.39**
BLOCKSIZE	0.999999	−0.15	**2658**	**830**	**244.59**
CULDESAC	1.001091	313.83	**1**	**0**	**−274.47**
LENGTHCDS	0.999890	−16.56	**242**	**106**	**1985.40**
EXTCONN	1.000083	12.49	**475**	**1016**	**6649.89**
SFRDNSTY	0.999311	−103.42	**4.77**	**11.93**	**−647.03**
POPDNSTY	0.990882	−1367.73	**2.28**	**2.62**	**−408.59**
LUMIX	0.952391	−7141.41	**0.60**	**0.37**	**1480.66**
NRMIX	1.014088	2113.25	**0.39**	**0.30**	**−165.58**
COMDIS	1.000009	1.39	**2219.12**	**834**	**−1673.35**
PARKDIS	0.999995	−0.79	**895**	**296**	**416.21**
HILLAO	1.048887	7333.11	0	0	
OTHERBO	0.964717	−5292.38	0	0	
OTHERAO	1.004591	688.58	**0**	**1**	**602.19**
BEAVAO	1.028478	4271.69	0	0	
PEDCOM	1.054641	8196.08	**0.18**	**0.78**	**4357.32**
PEDBUS	0.995500	−674.98	**0.34**	**1**	**−390.56**
			Housing price		
			Suburban	NU	Difference
Total value			132, 731	156, 986	24, 255

to capture meaningful differences between a typical suburban neighborhood and a highly touted new urbanist neighborhood.[8]

We then determine the estimated sale price based on the set of explanatory attributes. Using the estimated coefficients from the regression model, we convert the unit of measure to dollars using the following equation:

$$\text{sale\_price} = \exp\bigl(\hat{\beta}_0 + \hat{\beta}_i x_i\bigr). \tag{2}$$

We then compute changes in sale price resulted from one-unit change in one of the independent variables while holding all other predictors constant. For example, ratio of the new price to the original price, when x_1 is changed to $(x_1 + 1)$, can be computed by $\exp(\hat{\beta}_0 + \hat{\beta}_1(x_1 + 1) + \hat{\beta}_2 x_2 + \cdots)/\exp(\hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \cdots) = \exp\hat{\beta}_1$. This expression for each independent variable corresponds to the values shown in the second column of Table 5. The value of premium (or discount) of sale price for a house with an original price of \$150,000, from changing x_1 to $(x_1 + 1)$ while holding other attributes constant, can then be computed by $(\exp\hat{\beta}_1 - 1) * 150{,}000$. This value for each independent variable

[8] For more on a comparison of urban form measures for all 186 neighborhoods in the study area, see Song and Knaap [36].

is shown in the third column.[9] Using this procedure, we evaluate the premium that home buyers pay for a house in a new urbanist neighborhood. As discussed above, the fourth and fifth columns of Table 5 provide the attributes' values of our two hypothetical single-family homes: one in a typical suburban neighborhood and the other in a new urbanist neighborhood. To calculate the sale prices for our two examples, the values of each of the attributes are inserted into Eq. (2), and the values of the coefficients are culled from Table 4. The overall prices for these two examples ($132,731 and $156,986) and the difference between the two ($24,255) are shown in the last row of Table 5. Following the above approach, the change in the value of a typical suburban house ($132,731), that resulted from a change in one attribute from suburban (x_{1_S}) to new urbanist (x_{1_NU}), can be computed by $[\exp \beta_1(x_{1\_NU} - x_{1\_S}) - 1] * 132,731$. This value for each independent variable is shown in the last column of Table 5. Our calculations show that a house in a new urbanist neighborhood, even though it has a smaller lot than one in a typical neighborhood (3500 square feet vs. 8675 square feet), sells for $156,986—a $24,255 premium over one in a neighborhood with more conventional suburban attributes.[10] The last column of Table 5 further indicates that much of the premium comes from new urbanist features such as more internally connective street networks, more blocks, more street miles, better pedestrian access to commercial uses, and proximity to operating light rail stations. The comparison reveals that, holding other attributes constant, properties located in a neighborhood with new urbanist features command an estimated 15.5 percent premium.[11]

5. Conclusions

In this study, we develop several measures of urban form and use them to characterize various neighborhoods in Washington County, Oregon. We find that the measures capture meaningful differences in the design character of urban neighborhoods. Our measures reveal, for example, that new urbanist neighborhoods indeed differ from traditional neighborhoods in ways that can be measured and used for analysis.[12] Further we find that such differences are capitalized into residential property values. Specifically, we find that residents are willing to pay premiums for houses in neighborhoods with more

[9] First two columns of Table 5 offer additional knowledge of determining implicit value of each independent variable. For example, for variable *FLOORSPACE*, β was estimated to be 0.00000126. This number indicates that people prefer to pay $\exp 0.00000126 = 1.000306 = 100.0306\%$ of the original house price if the floor space is increased by 1 square foot; if the original house price is $150,000, consumers pay $48 more.

[10] $24,255 is the difference between the overall values of the two houses. It is not calculated by adding up all the marginal effects in the last column, which would be wrong due to nonlinearity of the exponential.

[11] Critics have suggested that the premium resulting from new urbanism development might indeed reflect higher production costs of construction and highly perceived risks of investment in new urbanism communities (Rybczynski [35], Gyourko and Rybczynski [23]). To address this issue, analysis can be expanded to a two-stage estimation using the methodologies provided by Rosen [34]. If we can obtain the production functions for new urbanist construction, we would be able to estimate the underlying supply and demand functions of new urbanism development. We leave this for further research.

[12] In other papers, for example, we have used these measures to examine changes in urban form over time (Song and Knaap [36]) and to estimate the effects of urban form on transportation mode choice (Rajamani et al. [33]).

connective street networks; more streets, shorter dead-end streets; more and smaller blocks; better pedestrian accessibility to commercial uses; more evenly distributed mixed land uses in the neighborhood; and proximity to operating light rail stations. We also find residents are willing to pay less for houses in neighborhoods that are dense, contain more commercial, multifamily, and public uses (relative to single-family uses), and contain major transportation arterials.

When combining these features in composite sketches of new urbanist and traditional neighborhoods, we find that homes in a new urbanist neighborhood command an aggregate price premium. What is more, we find that this premium more than compensates for the severe price discount for the small size of new urbanists lots. Much of the premium comes from improvements in internal connectivity that stem from smaller blocks, and shorter streets. Some of the premium also stems from lesser external connectivity, or greater transport isolation. Some of the premium also comes from pedestrian accessibility to commercial uses—even though those uses are not valued in the neighborhood. It is dangerous, of course, to generalize from the attributes of a single new urbanist development as other developments that could be described as new urbanist could well differ in character a great deal from Orenco. But the Orenco example supports previous research that new urbanist neighborhoods do provide a price premium.

More importantly, our results show that the price premium, or discount, of any particular neighborhood depends on the particular design characteristics it has to offer. In short, design matters. Further, though the price of a single-family home is difficult to predict, the statistical relationships among design characteristics and 48,000 sales observations are robust and compelling. Based on market signals, the results suggest that the virtues of new urbanist neighborhoods include enhanced internal connectivity, improved pedestrian access to commercial uses, better transit access, and *less* external connectivity. The detractions of new urbanist neighborhoods include, higher densities, greater mixture of land uses, and smaller lots.

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