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Research Paper

Capitalization of interconnected active transportation infrastructure

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ABSTRACT

This paper investigates the capitalized value of interconnected active transportation infrastructure in Franklin County, Ohio. We expand on the existing literature on preferences for local amenities by examining the impact of connections between local amenities and active transportation infrastructure on the sales price of single family homes. Hedonic results indicate that proximity to bike facilities results in positive capitalization, with on-road facilities driving this result. Extending the analysis to examine interconnectivity, we find that bike facility capitalization is heterogeneous depending on the types of local amenities and infrastructure links. For example, on-road facility connections with bus stop locations decrease nearby home values, while on-road facilities linked to local open space increase the value of proximate homes. Together, these results provide evidence that connectivity is an important input to active transportation planning.

1. Introduction

To address strategic goals ranging from walkable cities to healthier populations, city planners are increasingly focused on the importance of active transportation networks, with a particular emphasis on bike facilities and interconnectivity among existing infrastructure. Nationally, the number of protected bike lanes has quadrupled since 2010 (Brandt, 2014), and groups, such as the Rails-to-Trails Conservancy, are working locally and nationally to expand bike facility networks. As active transportation expansions are implemented and gain public awareness, understanding resident preferences is important in determining optimal development patterns. In addition, quantifying potential gains for residents and users is needed by policymakers to secure expenditure of scarce local resources on the implementation of these plans.

One component of active transportation design is the understanding of how homeowners view active transportation features, and how these transportation networks can complement existing infrastructure. Given the role of local governance in these decisions, the impact on nearby homeowners is a key component needed to analyze competing active transportation projects and target investment to areas with the greatest expected benefits. When designing active transportation plans, there is significant emphasis on the role of bike facilities. As a result, the analysis in this paper focuses on this key component of the active transportation network and examines how linkages between bike facilities and other commonly provided services, such as open space, contribute to the capitalized values of nearby homes.

Bike facilities offer both potential positive and negative impacts for nearby homeowners. While bike facilities may introduce congestion, noise, and other negative externalities to areas, they also increase recreation options, establish connectivity, and improve safety for bikers. Surveys commissioned to determine perceptions of bike facilities have shown a stated public benefit for bike trails from residents (Greer, 2000). One key component of the bundle of services provided by these facilities is the increased transportation interconnectivity created by linking bike facilities to existing public infrastructure. Thus, the value of a bike facility is likely to be influenced by its type and the degree of connectivity between a bike facility and heterogeneous local amenities, as well as existing transportation infrastructure.

Previous hedonic literature estimating the value consumers place on open space is suggestive of the potential for bike facilities to be capitalized into nearby home prices. For instance, prior research has found that consumers value proximity to green space and local parks (Bengochea, 2003; Bolitzer & Netusil, 2000; Espey & Owusu-Edusei, 2001; Klaiber & Phaneuf, 2010; Lindsey, Man, Payton, & Dickson, 2004; Roe, Irwin, & Morrow-Jones, 2004; del Saz Salazar & García Menéndez, 2007; Saphores & Li, 2012). In addition, there is evidence that these values vary across types, size, and other attributes of the open space and neighborhood in question (Anderson & West, 2006; Czembrowski &

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Kronenberg, 2016). Livy and Klaiber (2016) show that house price capitalization of public parks depends on the attributes of the proximate parks. Researchers have also considered the role of accessibility and maintenance in determining value for open space, and find that higher levels of these attributes are valued by residents (Panduro & Veie, 2013). Together, the existing research on open space suggests that bike facilities that connect to these amenities could potentially be considered valuable by homeowners, since open space values are heterogeneous.

Adding to the existing research on open space, positive house price premiums have been shown for both greenbelts (Correll, Lillydahl, & Singell, 1978) and rail trails (Moore, Graefe, & Gitelson, 1994; Siderelis & Moore, 1995). More closely related to this study, Asabere and Huffman (2007) found that while both trails and greenbelts had positive effects on housing prices, the impact was accentuated when the two were connected, demonstrating an added premium for interconnectivity. These results provide evidence that a potential premium for bike facilities could exist as well.

Despite significant research on greenbelts and open space, few studies have specifically focused on bike facilities, especially facilities located along, and on, roadways. Racca and Dhanju (2006) found that proximity to a bike facility had an approximately 4% positive impact on housing prices. However, the authors offered no analysis of linkages to other types of neighborhood infrastructure. Krizek (2006) used a hedonic model to analyze the heterogeneous impact of bike facilities on house prices, while also including a measure for open space, and found that proximity to both open space and some bike facilities were valued by residents. They demonstrated evidence of heterogeneity in potential capitalized benefits, finding that bike facilities appear to have different values depending on their locations. For suburban locations, they found that bike facilities on roadways lowered home values, whereas non-road bike facilities appeared to have little impact on home values. Our research builds on these papers by focusing on the connectivity of local active transportation networks and amenities, a key policy objective in many urban and suburban settings.

In this paper, we extend the existing literature on the capitalized value of bike facilities by estimating capitalization using hedonic models of single family home prices. We further investigate the potential for heterogeneity in these capitalized values as bike facilities provide distinct linkages to heterogeneous community features. While previous hedonic literature has shed light on the value of open space or public transportation separately, significantly less attention has been paid to the role of interactions among these features. Filling this research gap, we find that the impact of bike facilities on property values is dependent on the type of facility and the connectivity of these facilities with other local infrastructure. This result implies that interconnectivity should serve as a key input into the planning of active transportation design.

The remainder of the paper is structured as follows: we briefly review the hedonic pricing model in the next section; this is followed by a discussion of our data, which covers Franklin County, Ohio containing the state's capital, Columbus, in Section 3; Section 4 presents our results; and is followed by a concluding discussion in Section 5.

2. Model

To investigate the effect of bike facility interconnectivity on real estate prices, we estimate a hedonic model. Developed by Rosen (1974), this model disaggregates the sales price of a house into the attributes of the home and the characteristics of the surrounding area. One benefit of this revealed preference method is that it uses a household's actual location decision to infer their preferences for local neighborhood amenities. Households are assumed to be utility maximizers who receive utility from their choice of home, which is a function of the house characteristics, neighborhood amenities, and bike facilities and their connections to existing infrastructure. Utility for household k is formally given by the equation

$$U_k = U(\boldsymbol{\alpha_k}, \boldsymbol{H_i}, \boldsymbol{N_j}, \boldsymbol{B_l}, b) \tag{1}$$

where i references a particular house, j denotes the neighborhood and l indexes the presence and connectivity of nearby bike facilities. Preferences are given by $\boldsymbol{\alpha_k}$ while **H**, **N**, and **B** are vectors of housing attributes, neighborhood attributes, and specific bike facility and connectivity attributes, respectively. The numeraire good, capturing other non-housing related expenditure, is given by b.

Households are assumed to maximize the utility in Eq. (1) subject to a budget constraint, which results in the well-known hedonic equilibrium price schedule

$$P_{it} = f(\boldsymbol{H_i}, \boldsymbol{N_j}, \boldsymbol{B_l}) \tag{2}$$

where the subscript t indexes the time of the housing sale. To specify a functional form, we estimated Box-Cox models for a number of specifications and found that the left-hand side transformation parameter associated with the price variable ranged from 0.27 to 0.29 across these specifications. Given similar qualitative findings for key parameters and the relative closeness to a semi-log transformation we adopt a semi-log specification in our empirical models (Cropper, Deck, & McConnell, 1988; Kuminoff, Parmeter, & Pope, 2010). In our empirical specification of the hedonic model, the natural log of a house's sales price is defined as a function of house and neighborhood characteristics, which can be written as

$$\ln P_{it} = \alpha + \sum_{h=1}^{H} \theta_h H_i + \sum_{l=1}^{L} \gamma_l B_l + \sum_{j=1}^{J} \delta_j N_j + \epsilon_i \tag{3}$$

Estimation of (3) provides estimates of the parameters associated with each housing characteristic $\hat{\theta}_h$, the bike facility and connectivity variables of interest $\hat{\gamma}_l$, and the coefficients on additional neighborhood control variables $\hat{\delta}_j$. The semi-log specification provides the interpretation that each estimated parameter reflects the percentage change in house price capitalization for a one unit change in the associated covariate, correcting for indicator variables (Halvorsen & Palmquist 1980).

Since unobserved variation at the neighborhood level can impact estimates, we control for unobserved time-varying neighborhood attributes N_{jt} through the use of block group by year fixed effects. Thus, we re-write Eq. (3) as

$$\ln P_{it} = \alpha + \sum_{h=1}^{H} \theta_h H_i + \sum_{l=1}^{L} \gamma_l B_l + \omega_{jt} + \epsilon_i \tag{4}$$

where ω_{jt} are the spatial–temporal neighborhood fixed effects. These fixed effects control for the unobserved variation in house prices across neighborhoods for each year. Therefore, identification is not biased by spatial–temporal yearly neighborhood variation in prices or unobserved attributes, such as changes in local amenities, which could be correlated with the variables of interest and impact estimates. However, within block group unobservables and the potential for sorting bias are possible limitations of the first stage hedonic method. Finally, we cluster the standard errors at the block group by year level to account for correlation in the errors within fixed effects groups (White, 1984).

Bike facility variables are introduced using exclusive distance bands from the parcel to the nearest bike facility. Therefore, the estimates are interpreted as the approximate percentage change in housing prices for having a facility within the stated distance of a home. In addition to assessing the impact of all bike facility types on housing prices, we examine the existence and extent that capitalized values vary depending on the location of the facility on or off a roadway. As additional controls, we include proximity measures for public transportation and points of interest, including libraries, open space, the central business district (CBD), elementary schools, Ohio State University, and shopping. To interpret coefficients associated with distance, a positive coefficient indicates that the capitalized values increase as one moves away from each feature and a negative coefficient indicates that housing values increase as one moves closer and distance is reduced.

We introduce several connectivity variables with the bike facility types, including bus stops, libraries, public open space, and shopping to determine if the capitalized value of bike facilities is heterogeneous with respect to the connectivity that facility has with other attributes of the neighborhood. We also include a measure of whether a household lives near a busy road in order to differentiate the potentially negative impact of living in a congested area from preferences for the bike facilities which often are located along major roadways in our study area (Schälpfer, Waltert, Segura, & Kienast, 2015). Similarly, we include distance to open space and libraries as additional control variables for proximity to local amenities in our study area that often serve as terminal points for bike facilities. Fixed effects for the specific classification of the nearest bike facility are included in the estimation to control for differences within the on and off-road types considered in the models.

3. Data

Our data covers Franklin County, Ohio which has a population of over 1.2 million residents and contains 16 municipalities, including the state's capital of Columbus. Recently, this area has experienced an increased reliance on active transportation, with the addition of an estimated 13 miles of on-road bike facilities in just 2013 (Rouan, 2013). To analyze the impact of these facilities and their associated connectivity on housing prices, data is collected from multiple sources. We obtained single family residential property sales in Franklin County, Ohio that occurred between 2009 and the first quarter of 2013. These data were provided by the Franklin County tax auditor's office. To ensure data quality, we eliminated observations that were not single family homes, did not appear to have been market transactions based on deed type, sold for less than $20,000 or more than $2,000,000, had unrealistic attribute data, or were missing information on key structural attributes. In total, there are 21,133 cleaned observations.

In addition to property transactions data, we also obtained information on spatial amenities using GIS shapefiles of open space, community features, and roads in Franklin County. The spatial data was obtained from the Mid-Ohio Regional Planning Commission (MORPC). We supplemented information on local amenities with additional spatial data on transportation networks, including bus stop locations for the entirety of Franklin County obtained from the Central Ohio Transit Authority.

Structural attributes of single family detached homes included in our sample include the number of bathrooms, square feet, acreage, the number of stories, the age of the property, and dummy variables indicating presence of a fireplace, air conditioner, and basement. Housing summary statistics are presented in Table 1. The average house sold for nearly $147,000, was 45 years old, and was 1618 square feet. These summary statistics are consistent with a large urban center with many older homes in relatively densely developed neighborhoods, as reflected in the nearly 50 year old average home age. Approximately 87% of homes had a basement, 46% had a fireplace, and 87% had air conditioning.

Data on bike facilities in Franklin County were collected from the MORPC. This commission is tasked with guiding planning policy for the greater Columbus, Ohio area, including the creation of local bike facilities as part of an active transportation plan that seeks to develop shared goals and priorities across local community jurisdictions within the area. The location of the 1831 road and non-road bike facility segments in Franklin County, where each segment is approximately 600 m long, is shown in Fig. 1. The segments vary in size depending on location and facility type, as Fig. 1 demonstrates, and are spread relatively evenly throughout the study area, with the highest concentration occurring in the northern sections of the county. Importantly, these segments were created at different points in time, and are classified as segments by their continuity and built time, with some opening for use during our study period. To account for this, homes are linked to the specific facilities that existed at the time of each home sale. Fig. 2 presents the housing sale parcel and the entire bike facility network for the county, with segments created during our study in bold. The majority of facilities were established prior to 2009, and most of the added facilities are located in the downtown area where single family homes are less common. While one could extend our analysis to investigate the capitalization associated with time-varying opening of bike facilities using repeat sales methodologies, there were insufficient observations during our study period located in close proximity to new bike facilities to obtain proper identification.

Table 1
Summary statistics.

Variable	Mean	Std Dev
price	$146,772	$102,972
distance to bike path (km)	0.82	0.66
distance to road bike facility (km)	0.98	0.74
distance to nonroad bike facility (km)	1.30	0.96
near road	0.08	0.26
distance to bus stop (km)	0.72	0.94
distance to library (km)	2.21	1.55
distance to open space (km)	0.44	0.34
distance to shopping (km)	0.84	0.66
distance to CBD (km)	11.94	4.63
distance to OSU (km)	11.17	4.77
distance to elementary school (km)	0.92	0.78
bathrooms	1.81	0.68
square feet (1/100)	16.18	5.90
acres	0.21	0.19
age	45.42	24.78
number of stories	1.43	0.49
fireplace (0/1)	0.46	0.50
air conditioning (0/1)	0.87	0.34
basement (0/1)	0.87	0.33
Observations	21,133	

Focusing on proximity to spatial amenities in Table 1, the average home was approximately 820 m from the nearest bike facility. Disaggregating the bike facility variable, homes had an average distance of 980 m to the nearest on-road facility and 1.30 km to the nearest non-road facility. Together, these statistics provide evidence that road bike facilities are in more residential areas and may provide different benefits from non-road bike facilities. Road bike facilities include bike boulevards, protected lanes, sharrows, and signed roadways, and the non-road facilities are comprised of shared and multiuse paths and trails. The mean distance from a home to the closest public open space was 440 m. This reflects the general provision of open space features common to many urban areas with an abundance of neighborhood local open space provided as part of the early neighborhood layout design. For other community attributes, households were located approximately 2.21 km from their nearest local library and 720 m away from their nearest bus stop, which are often located on major surface roads. Approximately 8% of households were located near a major roadway.

To investigate connectivity and the effect of distance on capitalization, the Euclidean distance from each parcel to the nearest existing bike facility segment is calculated. The bike facility data are then divided into non-inclusive distance bands for road and non-road categories based on the classification given by MORPC. Distances to bus stops, libraries, public open space, shopping, CBD, and other local features are also calculated. Open space is defined to include parks, recreation areas, golf courses, and green space. We excluded private forms of open space not accessible to the public from the sample. A near-road dummy that controls for whether a parcel is within 30 m of a major road is calculated to disentangle the effect of proximity to bike facilities from proximity to major roads, and their associated (dis) amenities, on house prices. These major roads include those with a

Fig. 1. Map of bike facilities and parcels.

major road functional classification, such as interstates, freeways or expressways, principal arterial roads, minor arterial roads, major and minor collector roads, and ramps in the road shapefile provided by MORPC.

Adding to the analysis of the capitalization of bike facilities, we examine several interactions to estimate the potential impact of bike facility interconnectivity to local infrastructure on the sales price of homes. As the value of a bike facility may be related to its ability to connect community infrastructure, we determine whether a household's nearest bike facility is connected to other public features such as open space, bus stops, shopping, or libraries; specifically, for each of these four categories mentioned above, we treat the closest bike facility segment as having a "connection" if it passed within 400 m of each land use feature, respectively. We test the robustness of this distance assumption for connectivity in the results section below, and find that results are stable across other tested distances.

4. Results

We present four sets of estimates associated with our primary hedonic specification from Eq. (4) in Table 2. As a robustness test, we estimate the model using driving road network distances in Appendix Table A1 and find similar results. The first specification contains baseline results for the capitalized values of proximity to local features, including bike facilities within distance bands, without connectivity terms. A model separating bike facilities into road and non-road bike facilities is presented in the second column, and the third column includes a measure of total connectivity associated with facilities within

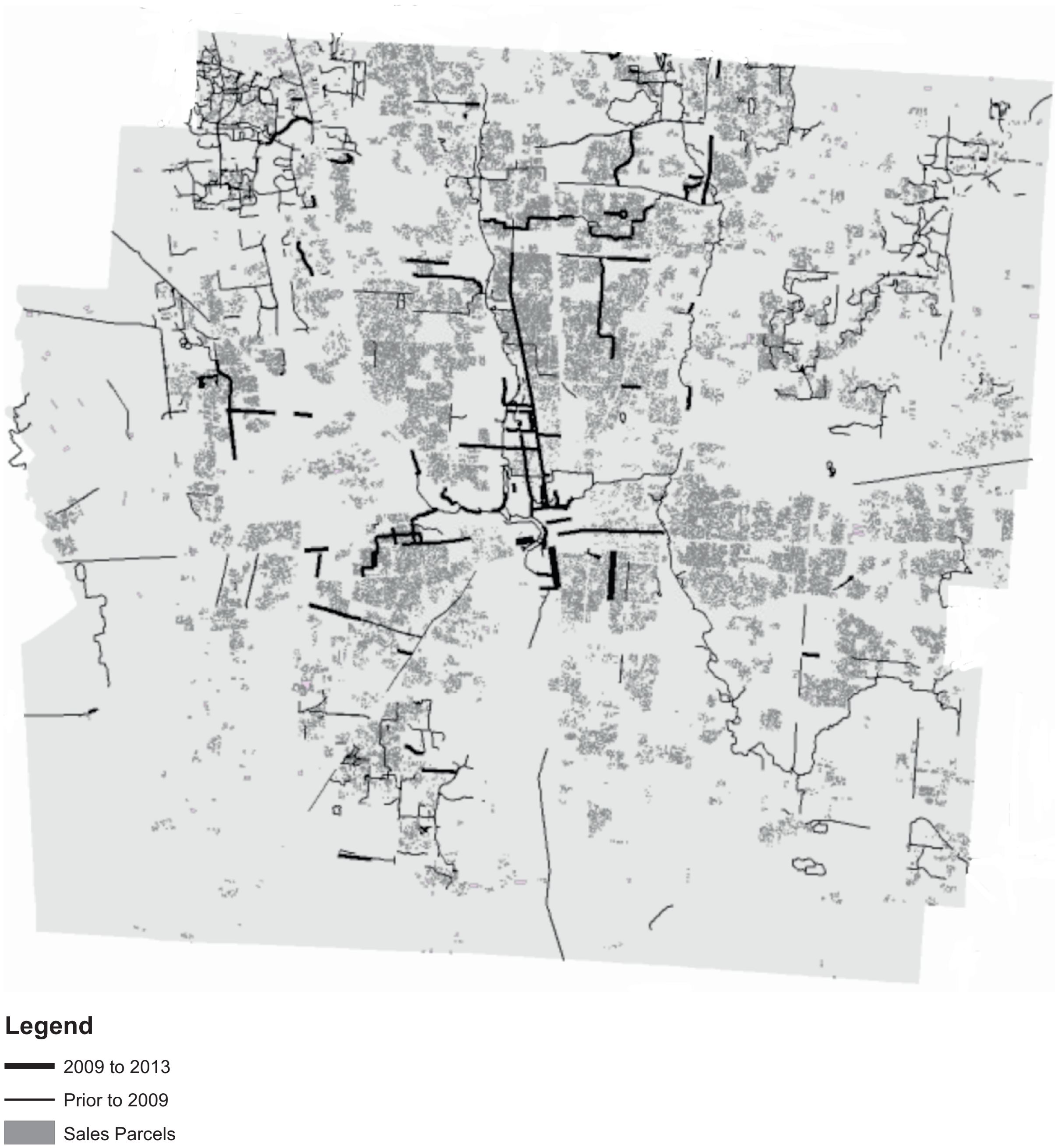

Fig. 2. Growth of the bike facility network.

500 m from each home. The fourth set of results introduces connectivity terms with bike facilities to measure the capitalized value of connections to specific features. Estimation for the specifications in columns 2, 3, and 4 include fixed effects for the classification of the nearest bike facility to account for differences beyond the road and non-road designations. However, the coefficients associated with these variables are generally insignificant, suggesting there are not strong preferences apart from facility location. For all sets of results, we include block group by year fixed effects to control for spatially and temporally varying unobservables that, if left unaccounted for, could introduce bias into our estimates. We also tested for multicollinearity issues with the main covariates and did not detect any associated issues. In each specification, standard errors are clustered at the block group level, by year, to allow for potential correlation within groups (White, 1984).

Focusing on the results of the first specification in the first column, the estimates for the standard housing attributes have the expected signs and significance. For example, the capitalized value of acreage, bathrooms, square feet, stories, fireplaces and basements are all positive and significant. Older homes sell for lower values than newer homes. Each of these structural housing attributes are expected and consistent with the existing literature.

Turning attention to the local attributes and bike facility estimates, the coefficients provide evidence that homeowners value proximity to bike facilities. This relationship is strongest when the nearest facility is within 100 m of the home and is associated with a positive impact on housing prices of nearly 5.2%. There is a positive and significant effect at the 500 m and 1000 m levels, with capitalizations of approximately 3.6% and 1.5%, respectively. We find that living near a major road is associated with a nearly 6% decrease in housing prices, suggesting that homeowners prefer to avoid the negative externalities associated with these roads. There is limited evidence of capitalization effects for homes located near bus stops, shopping centers, open space, or public libraries.

Table 2
Model estimates (dependent variable = ln(price)).

Variable	Specification			
	(1)	(2)	(3)	(4)
bike facility within 100 m	0.052***			
	(0.013)			
bike facility within 500 m	0.035***			
	(0.010)			
bike facility within 1000 m	0.015*			
	(0.009)			
road bike facility within 100 m		0.046***	0.054***	
		(0.014)	(0.017)	
road bike facility within 500 m		0.031***	0.033**	
		(0.011)	(0.014)	
road bike facility within 1000 m		0.016*	0.016*	
		(0.009)	(0.009)	
non-road bike facility within 100 m		0.025	−0.001	
		(0.018)	(0.018)	
non-road bike facility within 500 m		0.010	−0.009	
		(0.012)	(0.012)	
non-road bike facility within 1000 m		0.005	0.005	
		(0.009)	(0.009)	
near road	−0.060***	−0.061***	−0.061***	−0.060***
	(0.010)	(0.010)	(0.010)	(0.010)
distance to bus stop (km)	0.007	0.010	0.012	0.008
	(0.010)	(0.011)	(0.011)	(0.011)
distance to library (km)	−0.004	−0.004	−0.003	−0.004
	(0.008)	(0.008)	(0.008)	(0.009)
distance to open space (km)	−0.005	−0.008	−0.004	−0.001
	(0.013)	(0.014)	(0.014)	(0.014)
distance to shopping (km)	0.014	0.015	0.016	0.017
	(0.010)	(0.010)	(0.010)	(0.010)
distance to CBD (km)	−0.043	−0.039	−0.037	−0.039
	(0.027)	(0.027)	(0.026)	(0.026)
distance to OSU (km)	0.016	0.011	0.010	0.010
	(0.027)	(0.027)	(0.027)	(0.026)
distance to elementary school (km)	−0.010	−0.011	−0.012	−0.011
	(0.009)	(0.009)	(0.009)	(0.009)
bathrooms	0.077***	0.077***	0.077***	0.077***
	(0.006)	(0.006)	(0.006)	(0.006)
square feet (100 s)	0.026***	0.026***	0.026***	0.026***
	(0.001)	(0.001)	(0.001)	(0.001)
acres	0.201***	0.202***	0.201***	0.199***
	(0.023)	(0.023)	(0.023)	(0.022)
age	−0.008***	−0.008***	−0.008***	−0.008***
	(0.001)	(0.001)	(0.001)	(0.001)
age squared	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
number of stories	0.033***	0.033***	0.034***	0.034***
	(0.006)	(0.006)	(0.006)	(0.006)
fireplace (0/1)	0.035***	0.035***	0.035***	0.035***
	(0.005)	(0.005)	(0.005)	(0.005)
air conditioning (0/1)	0.126***	0.125***	0.126***	0.125***
	(0.009)	(0.009)	(0.009)	(0.009)
basement (0/1)	0.115***	0.115***	0.115***	0.115***
	(0.009)	(0.009)	(0.009)	(0.009)
road total connections within 500 m			0.000	
			(0.004)	
non-road total connections within 500 m			0.017***	
			(0.005)	
road bike facility within 500 m × bus stop				−0.038***
				(0.014)
road bike facility within 500 m × library				−0.005
				(0.018)
road bike facility within 500 m × open space				0.057***
				(0.011)
road bike facility within 500 m × shopping				0.008
				(0.014)
road bike facility within 500 m × other/none				0.011
				(0.012)
non-road bike facility within 500 m × bus stop				0.009
				(0.016)
non-road bike facility within 500 m × library				0.027
				(0.027)
non-road bike facility within 500 m × open space				0.018
				(0.011)

(*continued on next page*)

Table 2 (*continued*)

Variable	Specification			
	(1)	(2)	(3)	(4)
non-road bike facility within 500 m × shopping				0.014 (0.018)
non-road bike facility within 500 m × other/none				-0.018^{*} (0.010)
constant	11.346^{***} (0.089)	11.346^{***} (0.098)	11.345^{***} (0.098)	11.368^{***} (0.098)
Observations	21,133	21,133	21,133	21,133
Block Group by Year Fixed Effects	YES	YES	YES	YES
Facility Class Fixed Effects	NO	YES	YES	YES

Note: Block group by year clustered standard errors in parenthesis. *, **, and *** represent significance at the 0.10, 0.05, and 0.01 levels, respectively.

These findings are consistent with some of the mixed evidence of the value of local parks, or other spatial attributes, in the existing literature (Anderson & West, 2006; Bolitzer & Netusil, 2000; Livy & Klaiber, 2016; Lutzenhiser & Netusil, 2001).

Insignificance of some of the location specific control variables, such as distance to Ohio State University, is likely attributable to the inclusion of the spatial–temporal fixed effects which absorb significant variation in these variables. To the extent that these attributes capitalize across larger spatial scales this capitalization is subsumed by our use of fixed effects (Abbott & Klaiber, 2011). Given our primary focus on local, proximate linkages to bike paths, which are likely capitalized across small spatial distances, the larger scale capitalization concerns for control variables are unlikely to cause issues in our ability to obtain identification of bike facility capitalization. To address the impact of the proximity variables on the results, we estimate a more parsimonious specification in Appendix Table A2 and determine that the inclusion of the near distance variables does not significantly alter the bike facility or housing coefficients.

The set of results reported in the second column examines the difference in housing price capitalization associated with road and non-road bike facilities. Concentrating on these variables, the road bike facility coefficients are positive and significant across all distance bands and decreasing in magnitude with distance as one would expect. The non-road bike facility coefficients are not significant, suggesting that homeowners have preferences for road facilities and not for non-road facilities near their residence. The estimates for all non-bike facility covariates are largely unchanged from the first specification.

To examine the importance of connectivity between bike facilities and local infrastructure, we estimate two additional models. In column 3, we consider the value of the total connections associated with the road and non-road facilities within 500 m of a home, and these connections are separated in column 4 to determine the extent of heterogeneity in the capitalized value of connections. For each model, a bike facility is deemed to have a connection if it is associated with a facility that is within 500 m of a home. Thus, these variables are associated with the presence of a facility within the 100 m or 500 m distance bands. Across both sets of estimates, the housing attribute coefficients are consistent. Focusing on the third column, the coefficient for the total number of connections with road bike facilities is not significant, while road facilities are associated with a positive and significant capitalization at the 100, 500, and 1000 m levels. The value of aggregate connections associated with non-road facilities is positive and statistically significant, suggesting that connecting local infrastructure to nearby non-road bike facilities has a significant impact on housing prices.

Expanding on the results in column 3, we estimate a model in column 4 to determine the extent of heterogeneous capitalization across connection types. The other and none category is included for trails that do not have connectivity with the amenities studied. The results show that road bike facilities connected to bus stops impart a negative value on nearby homes. We find no evidence of capitalized value associated with connectivity to local public libraries or shopping centers for road bike facilities. In contrast, proximity to road bike facilities which provide linkages to local public open space is positively capitalized into nearby housing prices. There are no significant positive capitalization effects associated with proximity to non-road bike facilities with connections to any of the primary considered features, indicating that residents value the number of connections, instead of specific types of connections, due to the positive total connectivity estimate in column 3. We test the assumption of connections being included if they are within 400 m of a facility in Appendix Table A3 and find that the estimates are qualitatively similar at the 200 m and 600 m distances. These results provide evidence that planners need to account for potential heterogeneity in values when designing bike facilities as part of an interconnected active transportation network.

Table 3 converts the semi-log estimates reported in Table 2 to dollar values using the mean housing price of $146,772 reported in Table 1. Due to space concerns, only the bike facility and connectivity variables are included, and we omit measures when the coefficients are not significant at the 0.10 level or higher. A 95% confidence interval is included below each of the point estimates. For the first column, a bike facility within 100 m of a home is associated with a positive capitalization of nearly $7,700, and there is a nearly $2,500 decrease in this capitalization of the nearest bike facility as the distance bands grow from 100 m to 500 m and from 500 m to 1000 m. Focusing on the specifications for different bike facility types, in column (2), only the road bike facilities are capitalized by housing prices. Connectivity to bus stops and open space for road facilities within 500 m of a home have capitalizations of −$5,412 and $8,572, respectively. Together, these results demonstrate that a significant amount of money is capitalized by housing prices as the result of the presence and connectivity of local bike facilities.

5. Discussion

Active transport networks have become an increasingly important focus of local policymakers across the United States as communities seek to develop local transportation. These networks are often viewed as a method of improving health and increasing recreation and commuter options. For example, New York City added 250 miles of bike lanes between 2006 and 2010 (Goodman, 2010), and an economic analysis suggested that New York's investment in bike infrastructure

Table 3
Estimated capitalization ($).

Variable	Specification (1)	(2)	(3)	(4)
bike facility within 100 m	$7,725.68 [$3,787.95–$11,766.39]			
bike facility within 500 m	$5,287.56 [$2,300.63–$8,334.33]			
bike facility within 1000 m	$2,240.82 [−$222.62 to $4,745.66]			
road bike facility within 100 m		$6,952.98 [$2,657.99–$11,371.42]	$8,153.84 [$3,009.20–$13,475.17]	
road bike facility within 500 m		$4,596.64 [$1,483.30–$7,775.34]	$4,913.02 [$849.91–$9,087.98]	
road bike facility within 1000 m		$2,340.10 [−$187.82 to $4,911.60]	$2,297.74 [−$224.70 to $4,863.60]	
non-road bike facility within 100 m		–	–	
non-road bike facility within 500 m		–	–	
non-road bike facility within 1000 m		–	–	
road total connections within 500 m			–	
non-road total connections within 500 m			$2,565.18 [$988.12–$4,204.65]	
road bike facility within 500 m × bus stop				−$5,412.21 [−$9,157.90 to $1,564.56]
road bike facility within 500 m × library				–
road bike facility within 500 m × open space				$8,572.74 [$5,229.59–$11,989.40]
road bike facility within 500 m × shopping				–
road bike facility within 500 m × other/none				–
non-road bike facility within 500 m × bus stop				–
non-road bike facility within 500 m × library				–
non-road bike facility within 500 m × open space				–
non-road bike facility within 500 m × shopping				–
non-road bike facility within 500 m × other/none				−$2,622.77 [−$5,453.56 to $264.74]

Note: Insignificant estimates are given as "–". 95% confidence intervals given in brackets below each estimate.

was a cost-effective way to improve public health (Gu, Mohit, & Muennig, 2017). Due to the potentially large and significant upfront costs to taxpayers and continued maintenance costs associated with expanding active transportation, it is necessary for policymakers to understand how differences in facility types and connectivity are capitalized into nearby home prices as a key component of active transportation design.

In this paper, we provide new evidence of the value of connected active transportation, with a focus on bike facilities. Understanding the capitalized values of these active transportation networks in surrounding home values is an important piece of information needed by local planning commissions tasked with designing new route networks through the creation and extension of bike facilities. In addition, the potential benefits that may accrue to nearby homeowners are a key component of benefit-cost analysis that is needed to justify the use of limited public funds for active transportation infrastructure.

Focusing on Franklin County, Ohio, the location of the state's capital, Columbus, we estimate the value that households in this setting place on bike facility accessibility, and how this value changes depending on connectivity to other common forms of local infrastructure. Using single family detached housing transactions from 2009 through 2013, we estimate first-stage hedonic models of the capitalized value of bike facility infrastructure. The results provide evidence that there is an overall positive housing price capitalization associated with proximity to bike facilities, with on-road facilities driving this result. We further the analysis to investigate how this value varies with connectivity to local land use features. When bike facilities are connected to bus stops, their capitalized value decreases; however, the opposite finding is true when bike facilities are used to connect to local public open space features.

These results provide evidence that communities can create value by establishing active transportation networks, often using bike facilities, that improve the interconnections between types of existing land use. However, these results also suggest that a one-size-fits-all goal of providing connectivity is unlikely to result in the highest value to homeowners. For policymakers seeking public support for transportation expenditure, designing connectivity in ways that maximize stakeholder value is likely to be a primary objective. We show that careful attention to the types of connectivity provided by new active transportation linkages can aid in maximizing values to local communities. While this research establishes the value that interconnected bike facilities can bring to cities, further research could benefit from better understanding the heterogeneity of consumer connectivity preferences across distinct urban to rural gradients (Wolch, Byrne, & Newell, 2014).

Appendix

See Tables A1–A3.

Table A1
Road network robustness (dependent variable = ln(price)).

Variable	Specification			
	(1)	(2)	(3)	(4)
bike facility within 100 m	0.029**			
	(0.013)			
bike facility within 500 m	0.015*			
	(0.009)			
bike facility within 1000 m	0.010			
	(0.008)			
road bike facility within 100 m		0.009	0.013	
		(0.015)	(0.021)	
road bike facility within 500 m		−0.001	0.002	
		(0.009)	(0.017)	
road bike facility within 1000 m		0.005	0.004	
		(0.008)	(0.008)	
non-road bike facility within 100 m		0.032*	0.012	
		(0.017)	(0.020)	
non-road bike facility within 500 m		0.025**	0.006	
		(0.011)	(0.015)	
non-road bike facility within 1000 m		0.010	0.010	
		(0.009)	(0.009)	
near road	−0.061***	−0.061***	−0.061***	−0.060***
	(0.010)	(0.010)	(0.010)	(0.010)
distance to bus stop (km)	0.008	0.008	0.009	0.007
	(0.010)	(0.011)	(0.011)	(0.011)
distance to library (km)	−0.004	−0.004	−0.003	−0.003
	(0.008)	(0.008)	(0.008)	(0.008)
distance to open space (km)	−0.008	−0.008	−0.007	−0.006
	(0.014)	(0.014)	(0.014)	(0.014)
distance to shopping (km)	0.013	0.013	0.014	0.013
	(0.010)	(0.010)	(0.010)	(0.010)
distance to CBD (km)	−0.038	−0.036	−0.035	−0.038
	(0.027)	(0.027)	(0.027)	(0.027)
distance to OSU (km)	0.011	0.009	0.008	0.010
	(0.027)	(0.027)	(0.027)	(0.027)
distance to elementary school (km)	−0.013	−0.013	−0.014	−0.014
	(0.009)	(0.009)	(0.009)	(0.009)
bathrooms	0.077***	0.077***	0.077***	0.077***
	(0.006)	(0.006)	(0.006)	(0.006)
square feet (100 s)	0.026***	0.026***	0.026***	0.026***
	(0.001)	(0.001)	(0.001)	(0.001)
acres	0.202***	0.202***	0.202***	0.201***
	(0.023)	(0.023)	(0.023)	(0.023)
age	−0.008***	−0.008***	−0.008***	−0.008***
	(0.001)	(0.001)	(0.001)	(0.001)
age squared	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
number of stories	0.033***	0.034***	0.034***	0.034***
	(0.006)	(0.006)	(0.006)	(0.006)
fireplace (0/1)	0.035***	0.035***	0.035***	0.034***
	(0.005)	(0.005)	(0.005)	(0.005)
air conditioning (0/1)	0.126***	0.125***	0.126***	0.126***
	(0.009)	(0.009)	(0.009)	(0.009)
basement (0/1)	0.115***	0.114***	0.114***	0.114***
	(0.009)	(0.009)	(0.009)	(0.009)
road total connections within 500 m			−0.002	
			(0.006)	
non-road total connections within 500 m			0.012*	
			(0.007)	
road bike facility within 500 m × bus stop				−0.038***
				(0.012)
road bike facility within 500 m × library				0.015
				(0.018)
road bike facility within 500 m × open space				0.025**
				(0.011)
road bike facility within 500 m × shopping				0.005
				(0.012)
road bike facility within 500 m × other/none				0.043
				(0.052)
non-road bike facility within 500 m × bus stop				0.023
				(0.017)

(continued on next page)

Table A1 (*continued*)

Variable	Specification			
	(1)	(2)	(3)	(4)
non-road bike facility within 500 m × library				0.004 (0.025)
non-road bike facility within 500 m × open space				0.013 (0.010)
non-road bike facility within 500 m × shopping				−0.001 (0.018)
non-road bike facility within 500 m × other/none				0.005 (0.021)
constant	11.367*** (0.089)	11.347*** (0.097)	11.349*** (0.096)	11.370*** (0.097)
Observations	21,133	21,133	21,133	21,133
Block Group by Year Fixed Effects	YES	YES	YES	YES
Facility Class Fixed Effects	NO	YES	YES	YES

Note: Block group by year clustered standard errors in parenthesis. *, **, and *** represent significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table A2
Reduced variable specification (dependent variable = ln(price)).

Variable	
bike facility within 100 m	0.053*** (0.013)
bike facility within 500 m	0.041*** (0.010)
bike facility within 1000 m	0.020** (0.008)
bathrooms	0.077*** (0.006)
square feet (100 s)	0.026*** (0.001)
acres	0.186*** (0.022)
age	−0.008*** (0.001)
age squared	0.000*** (0.000)
number of stories	0.033*** (0.006)
fireplace (0/1)	0.035*** (0.005)
air conditioning (0/1)	0.126*** (0.009)
basement (0/1)	0.114*** (0.009)
constant	11.012*** (0.027)
Observations	21,133
Block Group by Year Fixed Effects	YES

Note: Block group by year clustered standard errors in parenthesis. *, **, and *** represent significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table A3
Connectivity distance robustness.

Variable	Connectivity Distance		
	200 m	400 m	600 m
near road	−0.060*** (0.010)	−0.060*** (0.010)	−0.060*** (0.010)
distance to bus stop (km)	0.007 (0.011)	0.008 (0.011)	0.009 (0.011)

(*continued on next page*)

Table A3 (*continued*)

Variable	Connectivity Distance		
	200 m	400 m	600 m
distance to library (km)	−0.004	−0.004	−0.005
	(0.009)	(0.009)	(0.009)
distance to open space (km)	−0.002	−0.001	−0.002
	(0.014)	(0.014)	(0.014)
distance to shopping (km)	0.017*	0.017	0.016
	(0.010)	(0.010)	(0.011)
distance to CBD (km)	−0.038	−0.039	−0.039
	(0.026)	(0.026)	(0.026)
distance to OSU (km)	0.009	0.010	0.010
	(0.026)	(0.026)	(0.026)
distance to elementary school (km)	−0.011	−0.011	−0.011
	(0.009)	(0.009)	(0.009)
bathrooms	0.077***	0.077***	0.077***
	(0.006)	(0.006)	(0.006)
square feet (100 s)	0.026***	0.026***	0.026***
	(0.001)	(0.001)	(0.001)
acres	0.200***	0.199***	0.199***
	(0.023)	(0.022)	(0.022)
age	−0.008***	−0.008***	−0.008***
	(0.001)	(0.001)	(0.001)
age squared	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)
number of stories	0.034***	0.034***	0.034***
	(0.006)	(0.006)	(0.006)
fireplace (0/1)	0.035***	0.035***	0.035***
	(0.005)	(0.005)	(0.005)
air conditioning (0/1)	0.125***	0.125***	0.125***
	(0.009)	(0.009)	(0.009)
basement (0/1)	0.115***	0.115***	0.115***
	(0.009)	(0.009)	(0.009)
road bike facility within 500 m × bus stop	−0.028**	−0.038***	−0.029**
	(0.014)	(0.014)	(0.015)
road bike facility within 500 m × library	−0.009	−0.005	−0.007
	(0.017)	(0.018)	(0.017)
road bike facility within 500 m × open space	0.057***	0.057***	0.058***
	(0.012)	(0.011)	(0.012)
road bike facility within 500 m × shopping	−0.005	0.008	−0.003
	(0.014)	(0.014)	(0.014)
road bike facility within 500 m × other/none	0.013	0.011	0.014
	(0.012)	(0.012)	(0.012)
non-road bike facility within 500 m × bus stop	0.003	0.009	0.031*
	(0.018)	(0.016)	(0.018)
non-road bike facility within 500 m × library	0.001	0.027	−0.005
	(0.025)	(0.027)	(0.025)
non-road bike facility within 500 m × open space	0.015	0.018	0.003
	(0.012)	(0.011)	(0.013)
non-road bike facility within 500 m × shopping	0.028*	0.014	0.015
	(0.015)	(0.018)	(0.017)
non-road bike facility within 500 m × other/none	−0.020*	−0.018*	−0.020*
	(0.010)	(0.010)	(0.010)
constant	11.362***	11.368***	11.369***
	(0.098)	(0.098)	(0.098)
Observations	21,133	21,133	21,133
Block Group by Year Fixed Effects	YES	YES	YES
Facility Class Fixed Effects	YES	YES	YES

Note: Block group by year clustered standard errors in parenthesis. *, **, and *** represent significance at the 0.10, 0.05, and 0.01 levels, respectively.

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