Reevaluating the Broadband Bonus: Evidence from Neighborhood Access to Fiber and United States Housing Prices[1]

Gabor Molnar
University of Colorado at Boulder
Department of Economics
Campus Box 256, Boulder, CO, 80309-0256
E-mail: gabor.molnar@colorado.edu

Scott J. Savage
University of Colorado at Boulder
Department of Economics
Campus Box 256, Boulder, CO, 80309-0256
E-mail: scott.savage@colorado.edu

Douglas C. Sicker
Carnegie Mellon University
Department of Engineering and Public Policy
Institute for Software Research
129 Baker Hall, Pittsburgh, PA, 15213
E-mail: sicker@cmu.edu

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Abstract

We use the National Broadband Map and a nationwide sample of real estate transactions from 2011 to 2013 to empirically investigate the relationship between high-speed Internet service and housing prices. Estimates from a hedonic housing price model suggest that fiber-delivered Internet service may be beneficial to households in terms of increased speed and reliability of service. Single-family homes in census block groups (CBGs) with the ability to upgrade to a one gigabit per second Internet connection have a transaction price that is about 1.8 percent more than similar homes in neighborhoods where a 100 megabit per second connection is available. Controlling for speed, homes in CBGs where fiber is available have a price that is about 1.3 percent more than similar homes without fiber. When evaluated at the sample median house price, the combined effect of 3.1 percent suggests that access to fiber may be associated with about a $5,437 increase in the typical home's value. This is roughly equivalent to a fireplace or just under half the value of a bathroom.

Key words: broadband, fiber, housing prices, Internet

JEL Classification: R21, L96, L98

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1. INTRODUCTION

Numerous factors influence the value of residential real estate, including the number of bathrooms in the home, access to amenities, or the amount of crime in the neighborhood. An important consideration for some homebuyers might be access to fiber-delivered broadband Internet service (hereafter "fiber"). Fiber is traditionally supplied by the telephone company by placing direct or shared fiber all the way to the home and it has the capacity to deliver data at higher rates than any other current technology. This characteristic permits household members to smoothly access high-bandwidth video, music, and gaming services, and to productively telework from home. This paper tests empirically whether access to fiber is correlated with higher housing prices.

Broadband Internet is arguably becoming one of the most important sectors of the economy and both State and Federal policy makers have discussed proposals that would increase the deployment of broadband infrastructure. See, for example, the FCC's "National Broadband Plan" which was sent to Congress on March 17, 2010 (FCC, 2010). Formal evaluation of these proposals requires some understanding of the potential benefits from more widespread access to high-speed Internet service. However, academic studies that estimate the consumer benefits from broadband are relatively sparse and have been limited in the United States by the lack of good quality data on fiber availability, consumer choices, and Internet plan characteristics and prices. Public data on nationwide broadband presence was first made available when the National Telecommunication and Information Administration (NTIA) began publishing the National Broadband Map (NBM) in 2011 (NTIA, 2011). Updated twice a year, the NBM provides information on where broadband is available, the technology used to offer the service, the minimum and maximum speeds, and the names of the Internet service providers (ISPs).

We use the NBM and a nationwide sample of approximately half a million residential real estate transactions from 2011 to 2013 to empirically investigate the relationship between high-speed Internet service and housing prices. Estimates from a hedonic housing price model show fiber-delivered Internet service may be beneficial to households in terms of increased speed and reliability of service. Specifically, single-family homes in census block groups (CBGs) with access to a one gigabit per second (Gbps) connection have a transaction price that is about 1.8 percent more than similar homes in neighborhoods with access to a 100 megabit per second (Mbps) connection. Furthermore, controlling for speed, homes in CBGs where fiber is available have a transaction price that is about 1.3 percent more than similar homes in neighborhoods where fiber is not available. When evaluated at the sample median house price of $175,000, the combined effects suggest that access to fiber may be associated with about a $5,437 increase in the typical home's value. This is roughly equivalent to a fireplace or just under half the value of a bathroom.

Other empirical studies have quantified the consumer benefits from broadband Internet. Goolsbee and Klenow (2006) calculate consumer surplus from the Internet to be several thousand dollars per household in 2005. Greenstein and McDevitt (2009) estimate that broadband deployment, as compared to dial-up access, accounted for about $4.8 billion to $6.7 billion in new consumer surplus for the entire economy at 2006. Dutz et al. (2009) calculate that the net consumer surplus from broadband relative to dial-up increased by about 60 percent from 2005 to 2008 to $31.9 billion. Rosston et al. (2010) use choice experiments to estimate consumer utility from Internet access and find that monthly consumer surplus per household increased from $6.49 to $39.44 between 2003 and 2010. Nevo et al. (2015) estimate a model of consumer utility and evaluate welfare when consumers are offered a one Gbps plan. They estimate consumer surplus to be $160 to $236 per month and given a monthly fee of $70 to $100, suggest there is a gap between private and social benefits from investment. Ahlfeldt et al. (2014) find that upgrading from dial-up to an eight Mbps digital subscriber line (DSL) could increase the price of an average English home by 2.8 percent. An additional increase to 24 Mbps has an incremental price effect of one percent. Our paper contributes to this literature by using two new granular measures of Internet speed and access to fiber in United States neighborhoods, and by using real estate transaction data that accurately reflects the revealed preferences of homebuyers.[2]

The next section outlines the empirical model. Section three describes the data, and the results are presented in Section four. Section five concludes.

2. EMPIRICAL MODEL

We are interested in the relationship between high-speed Internet service, specifically access to fiber, and the price of homes in the United States. Panel data would be useful for testing this effect, but these data are not readily available due to the infrequent nature of repeated housing transactions. Absent panel data, one could try an instrumental variable method to better identify the relationship between access to fiber and housing prices. However, finding an excluded instrument is somewhat problematic given that many of the cost and demand determinants of fiber deployment (e.g., neighborhood demographics) also determine home values.[3] An alternative approach, similar to Heckman and Hotz (1989), Goolsbee and Petrin (2004), and Chen and Savage (2011), is to employ the control function estimator. Here, all observable variables that could be correlated with the error term are included in the housing price equation and the equation is estimated by ordinary least squares (OLS) (Cameron and Trivedi, 2005). We can then see whether, conditional on these observable variables, there is a statistically significant correlation between access to fiber in the neighborhood and housing prices.

The hedonic housing price equation for home $i = 1, 2, \ldots, n$ in neighborhood (i.e., CBG) $j = 1, 2, \ldots, J$ of county $k = 1, 2, \ldots, K$ is:

[2] Several studies use a hedonic Internet pricing model to measure the implicit price of bandwidth and various contract features, such as hourly limits, and length of contract. For example, Stranger and Greenstein (2008) show a positive relationship between speed and the Internet contract price, and Williams (2008) shows that this relationship diminishes at higher levels of speed. Similarly, Rosston et al. (2010) also find diminishing returns to speed.

[3] Federal subsidies for Internet infrastructure investment from the American Reinvestment and Recovery Act of 2009 may be a plausible source of exogenous variation in the neighborhood deployment of fiber.

$$\log P_{ijk} = x_i'\beta + y_j'\delta + z_k'\phi + \alpha FIBER_j + \varepsilon_{ijk} \qquad (1)$$

where P is the transaction price for the home, x is a vector of home characteristics, y is a vector of observable cost and demand characteristics that influence the ISPs decision to deploy fiber to the neighborhood, z is a vector of county characteristics, *FIBER* equals one when the home is located in a neighborhood that has access to fiber and zero otherwise, ε is an error term, and β, δ, ϕ and α are parameters to be estimated.

The important parameter of interest is α. Rejection of the null hypothesis that α equals zero provides evidence that housing prices are related to access to fiber. When $\alpha > 0$, all other things held constant, homes in CBGs where fiber is available have a transaction price that is higher than similar homes in neighborhoods where fiber is not available. Just like access to other amenities, one may conclude that access to fiber has a potential capitalization effect on housing prices. Note that the OLS estimates of equation (1) may be biased when there are unobserved factors that are correlated with access to fiber and with housing prices. For example, when housing prices are lower in neighborhoods with a "crime reputation" and ISPs are less likely to deploy fiber in these neighborhoods because of higher costs and/or lower demand, the estimate of α will have positive bias. Alternatively, when housing prices are depressed because of low economic activity and ISPs are more likely to deploy fiber in these neighborhoods because the economic, regulatory or political environment is more favorable, the estimate of α will have negative bias.[4] The vectors y and z are included in equation (1) to control for these correlations. However, a potential identification problem cannot be ruled out when there is selection on unobservables. In Section 4, we present several robustness checks to help alleviate this concern.

[4] An often-stated policy objective for more widespread high-speed Internet access is increased education and business opportunities, and economic growth. Given these objectives, some municipalities may have stronger preferences for fiber and will offer investment incentives to ISPs and/or deploy their own public infrastructure.

3. DATA

3.1 Sample

The primary sources of housing data are the transaction price and characteristics for single-family detached houses across the United States, obtained from RealtyTrac (2014). The initial random sample comprised of 1.2 million transactions drawn from 2011, 2012, and 2013. We sample this time period because the NBM, which we use to match the Internet data to the housing data, only became available in 2011, and also because 2013 was the most recent year of housing data availability from RealtyTrac. Since the initial sample included all types of housing transactions, we dropped all observations, which were not for single-family detached houses, e.g., apartments, condominiums, duplexes, etc. We also omitted all non-arm's length transactions, such as quitclaims, inter-family transfers, or partial interest sales, as these are unlikely to be transacted at true market values, as well as observations with a sales price in the bottom one percent of the distribution (i.e., \$6,000) or in the top one percent of the distribution (i.e., \$1,550,000). Finally, we dropped all observations with missing or incomplete data on home characteristics or suspicious values for these characteristics, as they are most likely reporting or recording errors. This latter group includes houses with a negative lot size and/or more than ten bathrooms. The final dataset is comprised of 520,931 real estate transactions covering all 50 states of the United States and D.C. California (78,169), Florida (60,769) and Ohio (29,943) together comprise about 32 percent of the transactions, and Alaska, Montana, New Mexico and Wyoming each have less than 30 transactions.

3.2 Variables

Equation (1) relates the transaction price for the home to the availability of fiber and a set of home, neighborhood, and county characteristics. The transaction price (P) is the agreed contract price of the home between the buyer and the seller (RealtyTrac, 2014). Note that other measures of home values include "assessor provided appraisal value" and "market value as determined by assessor" for property tax evaluations, but these assessments do not reflect true market measures as there is no buyer and seller involved in the evaluation of the properties, and the assessor's valuations are not based on real time information. Transaction data are better because they are market prices that reflect supply and demand conditions, and because they are recorded in real time at the date of the ownership transfer. Table 1 provides a detailed description of price and the other variables used in the empirical analysis.

Home characteristics. The vector of home characteristcs (*x*) are from RealtyTrac (2014) and includes: the age of the home in ten year increments (*HOUSEAGE*); the size of the lot on which the home is located in 10,000 square feet (*LOTSIZE*); the size of the home in 1,000 square feet (*HOUSESIZE*); the size of the home's garage in 1,000 square feet (*GARAGESIZE*); the number of bathrooms in the home (*BATH*); an indicator that equals one when the home has a pool, and zero otherwise (*POOL*); and an indicator that equals one when the home has a fireplace, and zero otherwise (*FIREPLACE*).[5]

Neighborhood access to fiber. The NBM defines fiber as fiber optic technology that "converts electrical signals carrying data to light and then sends the light through transparent glass fibers about the diameter of a human hair" (NBM, 2015). Because ISP decisions to offer fiber-delivered Internet service are usually made for relatively small geographical footprints, and because the availability of fiber can be measured for each CBG in the NBM, we assume each CBG to be a separate neighborhood.[6] Each CBG is comprised of one or more census blocks and

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[5] Besides information on home characteristics, the RealtyTrac (2014) data indicates for each home, the year and transaction price for an earlier sale. For a robustness test, we use these data in Section 4 to estimate a simple differences-in-differences (DID) model on a sub-sample of homes that were sold in 2002 and again in 2012.

[6] Discussions with former industry executives indicate that the decision to provide and upgrade Internet service neighborhood-by-neighborhood is common industry practice. This is consistent with CenturyLink's recent deployment of its gigabit service to selected neighborhoods within Denver (Colorado Public Radio, 2014). Similarly, Google has defined "fiberhoods" as consisting of 250 to 1,500 households, and deploy their fiber service when the demand threshold reaches five to 25 percent of these households (Lardinois, 2012). Customer reviews also indicate that certain neighborhoods often get deployed or upgraded to higher speed before others. See

a typical CBG has about 610 housing units and about 600 to 3,000 persons.[7] We define *FIBER* to equal one when the NBM reports that fiber is available in at least one of the census blocks comprising the CBG, and zero otherwise.

Neighborhood characteristics. Data from the 2010 population census (U.S. Census Bureau, 2014a) and the 2008-2012 American Community Survey (U.S. Census Bureau, 2014b) are used to construct CBG-level cost and demand controls for the ISP's decision to deploy fiber to the neighborhood (y) (Shin and Ying, 1992; FCC, 2000; Zager, 2011; Molnar and Savage, forthcoming). The demand controls are: the population of the CBG (*POP*); mean household income of the CBG (*INCOME*); mean age of the population of the CBG in years (*AGE*); and the mean number of years of schooling for the population over 25 years of age of the CBG (*EDU*). To control for ISP's costs we employ the square meters of geographical area of the CBG (*AREA*) and the total length of all roads in the CBG in miles (*ROADS*) to approximate the size of the outside plant used to connect the backbone Internet network to each subscriber's household. *BEDROCK* (the coefficient of variation of the average depth at which bedrock is first encountered across the CBG), *WETLANDS* (the percentage of total area that are wetlands in the CBG), and *INTERSECTIONS* (the number of road intersections in the CBG) control for the physical constraints that make the deployment and maintenance of equipment more difficult. Because managing a large telecom deployment is generally more cost effective than managing a smaller deployment, *HOUSES* (the number of houses in the CBG) controls for potential economies of scale.

Data from the NBM (2011-2013) are also used to construct two controls for Internet market structure. These variables are *ISPS* (the number of non-fiber facilities-based ISPs in the

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http://www.dslreports.com/comments/2170, http://tech.slashdot.org/story/14/03/01/0322206/how-i-cut-my-time-warner-cable-bill-by-33, and http://www.broadbandexpert.com/high-speed-internet-reviews/att/.

[7] Census blocks are statistical areas bounded by visible features, such as streets, roads, streams, and railroad tracks, and by nonvisible boundaries, such as selected property lines and city, township, school district, and county limits and short line-of-sight extensions of streets and roads (U.S. Census Bureau, 2015).

CBG) and firm-specific dummy variables corresponding to the top $b = 1, 2, 3, \ldots, 17$ ISPs that provide wireline Internet connections to the households in our sample ($BRAND^b$).

Importantly, we also use the NBM (2011-2013) to construct several measures of Internet speed. The NBM measures and classifies speed into nine categories: 0.2, 0.768, 1.5, 3, 6, 10, 25, 50 and 100 Mbps, and one Gbps. We use these data to construct *SPEED25* (equals one when the maximum advertised downstream speed of all ISPs in the CBG that provide residential wireline broadband connections is 25 Mbps or less, and zero otherwise); *SPEED50* (equals one when the maximum advertised downstream speed of all ISPs in the CBG that provide residential wireline broadband connections is 50 Mbps, and zero otherwise); *SPEED100* (equals one when the maximum advertised downstream speed of all ISPs in the CBG that provide residential wireline broadband connections is 100 Mbps, and zero otherwise; and *SPEED1024* (equals one when the maximum advertised downstream speed of all ISPs in the CBG that provide residential wireline broadband connections is one Gbps or greater, and zero otherwise. We select the first cutoff to be 25 Mbps because the FCC has recently changed the definition of broadband from a minimum download speed of four to 25 Mbps (FCC, 2015). Moreover, all ISPs can offer services in the 0.768 to 25 Mbps speed tier regardless of technology and the type of "last-mile" connection to the household (e.g. copper telephone line, coaxial cable, fiber). Cable companies can easily offer speeds between 50 and 100 Mbps over their coaxial last mile, but telephone companies with DSL technology cannot. The provision of 50 and 100 Mbps requires DOCSIS 3.0 but it can be still be offered by cable companies without a major plant upgrade. Cable companies can also provide a 100 Mbps service, but it typically requires them to split their nodes further and to allocate multiple channels for the data service. A speed of one Gbps or greater to residential customers is predominantly available today via fiber.

County characteristics. Data from the American Community Survey (U.S. Census Bureau, 2014a), County Business Pattern (U.S. Census Bureau, 2014b), and the Federal Bureau of Investigation (FBI, 2012) are used to construct county characteristics that may affect housing prices. The vector of county characteristcs is z = [*TAX*, *TURNOVER*, *ACCESS*, *ARTREC*, *POPGROWTH*, *CRIME*]. *TAX* is the nominal percentage property tax rate used in the county. *TURNOVER* is the percentage of people who lived in the same county twelve months ago, and approximates community stability. *ARTREC* (the percentage of employees in the county who work in the arts, entertainment, and recreation sector) controls for county amenities, and *ACCESS* (the average time in minutes to get to the workplace for those persons in the county who are commuting) controls for accessibility to the workplace. Following Capozza and Helsey (1989), *POPGROWTH* (the ratio of the 2010 to 2000 county populations) is included in the price equation to control for the prosperity of the area the home is located in. *CRIME* (the number of murder and rape crimes per capita in the county) approximates the crime reputation of the county.

Other controls. Because our sample of houses is nationwide and also has a time dimension, we include additional geographical and time controls in the housing price equation. The geographical controls are state-specific dummy variables corresponding to the s = 1, 2, 3, … , 51 US states and the District of Columbia ($STATES^s$). The time controls are quarter-specific dummy variables that indicate the quarter in which the home was sold (*Q1*, *Q2*, *Q3*, and *Q4*) and year-specific dummy variables that indicate the year in which the home was sold (*Y2011*, *Y2012*, and *Y2013*).

3.2 Summary Statistics

Table 2 presents summary statistics for all the variables used in our empirical analysis. The starting sample size for our analysis is 520,931 homes from 116,300 CBGs and 1,634 counties. The average transaction price for a home in our sample is \$234,573. The median sales price is \$175,000, which is reasonably close to the national average median home price over the same period of $185,862 (Parsons, 2015). The typical home is 36 years old, has an overall size of 1,839 square feet, a garage of 260 square feet, and is located on a lot size of 39,910 square feet. About 43 percent of sample homes have a fireplace and about nine percent have a pool.

Table 3 presents the sample distribution of the maximum advertised downstream speeds reported by the NBM. 13.9 percent of the homes in our sample are in neighborhoods with a maximum speed of one Gbps or greater, 52.9 percent are in neighborhoods with a maximum speed of 100 Mbps, 25.7 percent are in neighborhoods with a maximum speed of 50 Mbps, and 7.5 percent are in neighborhoods with a maximum speed of 25 Mbps or fewer. When the data are divided by access to fiber, we observe that 37.2 percent of the homes are in neighborhoods with a maximum speed of one Gbps or greater, 42.6 percent are in neighborhoods with a maximum speed of 100 Mbps, 18.6 percent are in neighborhoods with a maximum speed of 50 Mbps, and 1.61 percent are in neighborhoods with a maximum speed of 25 Mbps or fewer. In contrast, 0.2 percent of the homes in neighborhoods with no access to fiber have a maximum speed of one Gbps or greater, 59 percent are in neighborhoods with a maximum speed of 100 Mbps, 29.9 percent are in neighborhoods with a maximum speed of 50 Mbps, and close to eleven percent are in neighborhoods with a maximum speed of 25 Mbps or fewer.[8] Maximum download speeds are clearly different between fiber and non-fiber neighborhoods – a Pearson test rejected the null that there is no difference between the two distributions of speed ($\chi^2(8) = 1.5e+05$; Prob > $\chi^2 = 0.00$) – although most homes in either sub-sample can typically access a 50 or a 100 Mbps connection. Interestingly, less than 40 percent homes in neighborhoods with access to fiber can access a maximum download speed of one Gbps or

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[8] There are 617 homes in our sample that are located in neighborhoods with no access to fiber, but the NBM shows that they have a maximum speed of one Gbps. Although non-fiber technologies (e.g., DOCSIS3.0, Gigabit Ethernet to the Home) can theoretically deliver one Gbps, in practice, this speed is predominantly available to residential customers via fiber. Possible explanation for these observations in our data are is that there are certain ISPs with a technology coverage area that does not completely match their marketed coverage area, there are niche markets where Gigabit Ethernet to the home is being offered, or it is a mistake in the NBM data collection. We re-estimated the price equation without these 617 observations and the results, not reported, are almost identical to those reported in Table 6 in Section 4.

greater, and 0.02 percent of homes in neighborhoods with no access to fiber can access a speed of one Gbps. This indicates that access to fiber does not guarantee that the home can obtain a one Gbps connection and, in fact, the correlation between fiber and downstream speed in our data is about 0.52. Less than perfect correlation between fiber and speed is important in the empirical analysis below as it allows us to separately estimate the price effects from speed and access to fiber, respectively.

Table 3 also shows that about 80 percent of homes in neighborhoods with access to fiber can access a maximum download speed of 100 Mbps or more, compared to 59 percent of homes in neighborhoods with no access to fiber. While one could conclude from these data that fiber increases downstream speed, another interpretation is that ISPs deploy fiber in neighborhoods with relatively higher speeds because households in these markets have stronger preferences for bandwidth. Because this question requires further analysis, both of these effects should be considered when interpreting our empirical results in Section 4.

Table 4 compares the demographics from our sample of CBGs with the remaining population of CBGs with at least one owner occupied housing unit. A quick perusal suggests that there are some differences in the means of most of the variables between the sample and population groups. However, the mean differences for houses, age, education, and wetlands are relatively small. In contrast, CBGs in our sample have, on average, 104 more persons living in an area with 29.6 less square kilometers and earning about $6,550 more in household income per capita. This is not surprising since more homes are sold in the more populated urban and suburban areas. Nevertheless, the empirical results presented in Section 4 should be interpreted with the qualification that they pertain to markets that are located in the relatively denser populated regions of the United States.

3.3 Availability of fiber

The summary statistics above show that about 36 percent of the neighborhoods in our sample have access to fiber. This compares favorably with about 33 percent of all CBGs in the United States with a yearly breakdown of 26 percent in 2011, 33 percent in 2012, and close to 41 percent in 2013 (NBM, 2011-2013). To further investigate the determinants of access, we estimate a probit model that relates FIBER to the vector of observable cost and demand characteristics that influence the ISP's decision to fiber (y), the vector of county characteristics (z), and the region and time controls.[9]

Table 6 presents maximum likelihood estimates of the probit model. Note that the number of observations, 212,005, exceeds the number of unique CBGs, 116,330, in our data because we observe the same CBG at different points in time.[10] We observe that ISPs are more likely to offer fiber in markets with more population and with more households. Higher income, education attainment and non-white population are associated with greater likelihood of fiber access, while access is less likely in neighborhoods with a more elderly population. All other things held constant, the estimated signs on the coefficients for the road density variables suggest that the likelihood of access declines with road density but at a decreasing rate. ISPs are less likely to offer service in CBGs with more wetlands and intersections because they make deployment and maintenance more difficult and raise costs for the ISPs. Furthermore, construction and maintenance in areas with relatively more wetlands often requires additional local government approvals and more specialized engineering techniques (Zager, 2011). An increase in the number of ISPs in the market is associated with greater likelihood of fiber access.

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[9] The speed variables are excluded from the preferred probit model specification in Table 4. We also estimated an alternative specification with *SPEED* (maximum advertised downstream speed of all ISPs in the CBG that provide residential wireline broadband connections in Mbps) included as an additional explanatory variable. The results, not reported, suggest that the decision to deploy fiber is positively associated with downstream speed.

[10] We estimated the same model on the 116,330 unique CBGs and the results, not reported, are qualitatively similar to those reported in Table 6.

The impact of *AREA* and *BEDROCK* on the likelihood of fiber presence is imprecisely estimated.

Focusing on the county characteristics, we observe that all coefficients generally have the expected signs, and except for *ARTREC*, all of the coefficients are significant at the one percent level. The coefficient for *ARTREC* is significant at the ten percent level. The likelihood of access to fiber is positively associated with the county tax rate, population stability, population growth, and access to more art and recreational opportunities. In contrast, increased commuting time to work and a higher crime rate are associated with a lower likelihood of fiber access.

4. RESULTS

4.1 Baseline results

OLS estimates of the hedonic housing price model are presented in Table 6. In the first column, we report estimates from model specification (i) where we regress the logarithm of housing prices on the vector of home characteristics (x), the vector of neighborhood characteristics (y), the vector of county characteristics (z), and the region and time controls. Note that the speed and fiber variables are not included in this initial regression. The model is reasonably well specified. The adjusted R^2 is 0.614, and most of the estimated coefficients on the home and county characteristics have the expected signs, and all are statistically significant at conventional levels. The signs of the coefficients on *HOUSEAGE* and $HOUSEAGE^2$ suggest that the value of a house declines with age at a decreasing rate. The signs of the coefficients on *LOTSIZE* and $LOTSIZE^2$ suggest that the value of a house increases with lot size at a decreasing rate, while the signs on *HOUSESIZE* and $HOUSESIZE^2$ also suggest that the value of a house increases with house size at a decreasing rate. Similar relationships are also observed for garage size. The estimated coefficients on *FIREPLACE*, *POOL* and *BATH* are all positive. When evaluated at the sample median house price of $175,000, they indicate that a fireplace is associated with 3.6 percent ($6,300) higher house value, that a pool is associated with a 12.5 percent ($21,875) higher house value, and that an additional bathroom is associated with a $12,600 higher value.

The estimated coefficients on the county characteristics generally have the expected signs and they are all statistically significant. Higher county tax rates (*TAX*), population stability (*TURNOV*), population growth (*POPGROWTH*), and crime (*CRIME*) are all associated with decreasing property prices. In contrast, increased accessibility (*ACCESS*) and better access to arts and recreational opportunities (*ARTREC*) are positively correlated with property prices.

Because the neighborhood characteristics are included in the price equation to primarily control for determinants of fiber deployment, it is not clear a priori what their expected relationships with home prices are. However, the signs of the estimated coefficients on these variables seem reasonably intuitive. An increase in the population (*POP*) and the share of non-white population *(NWHITE)* are both associated with lower home prices. Increasing income (*INCOME*), population age (*AGE*), education attainment (*EDU*), and housing density (*HOUSES*) are all associated with higher home prices. All other things held constant, the coefficients on *ROAD* and $ROAD^2$ suggest that the value of a house declines with road density at a decreasing rate. Increasing *INTERSECTIONS* and *BEDROCK* are both associated with lower home prices. In contrast, a higher geographical area of the neighborhood *(AREA)*, and a higher percentage of wetlands *(WETLANDS)* are both associated with increasing property prices.

4.2 Fiber and speed

Column two of Table 6 reports the estimates of model (ii) where we regress the logarithm of housing prices on home, neighborhood and county characteristics, region and time controls, and neighborhood access to fiber (*FIBER*). The adjusted R^2 is 0.614 and the results are qualitatively similar to those reported for model (i). The positive coefficient on *FIBER* implies that neighborhood access to fiber-delivered Internet service is positively associated with housing prices. All other things held constant, single-family homes in CBGs where fiber is available have a transaction price that is about 2.46 percent more than similar homes in neighborhoods where fiber is not available.

Column three of Table 6 reports the estimates of model (iii) where we regress the logarithm of housing prices on home, neighborhood and county characteristics, region and time controls, *SPEED50*, *SPEED100*, and *SPEED1024*. The adjusted R^2 is 0.614 and the results for the non-speed variables are qualitatively similar to those reported for models (i) and (ii). The positive coefficients on *SPEED50*, *SPEED100*, and *SPEED1024* imply that neighborhood access to higher Internet speeds is positively associated with housing prices. All other things held constant, single-family homes in CBGs where a maximum download speed of 50 Mbps is available have a transaction price that is about 3.3 percent more than similar homes in neighborhoods with a 25 Mbps or less connection. Homes in CBGs where 100 Mbps is available have a transaction price that is about 4.5 percent more than similar homes in neighborhoods with a 25 Mbps or less connection. Homes in CBGs where one Gbps is available have a transaction price that is about 7.1 percent more than similar homes in neighborhoods with a 25 Mbps or less connection. An F test rejects the null that the difference in price effects between access to 50 and 100 Mbps is different from zero (F(1, 520740) = 18.57; Prob > F = 0.00). Another F test rejects the null that the difference in price effects between access to 100 Mbps and one Gbps is different from zero (F(1, 520740) = 95.40; Prob > F = 0.00).[11]

Column four of Table 6 reports the estimates of model (iv) where we regress the logarithm of housing prices on home, neighborhood and county characteristics, region and time controls, *SPEED50*, *SPEED100*, *SPEED1024*, and *FIBER*. Model estimates indicate that single-

[11] Our results are qualitatively similar to Ahlfeldt et al. (2014) for the 25 to 100 Mbps speed ranges. We find that upgrading access from a 25 Mbps connection to a 50 Mbps connection could increase the price of a typical home by 3.3 percent. An additional upgrade to 100 Mbps could increase the price by a further 1.2 percent.

family homes in CBGs where 50 Mbps is available have a transaction price that is about 3.1 percent more than similar homes in neighborhoods with a 25 Mbps or fewer connection. Homes in CBGs where 100 Mbps is available have a transaction price that is about 4.2 percent more than similar homes in neighborhoods with a 25 Mbps or fewer connection. Homes in CBGs where one Gbps is available have a transaction price that is about six percent more than similar homes in neighborhoods with a 25 Mbps or fewer connection. An F test rejects the null that the difference in price effects between access to 50 and 100 Mbps is different from zero ($F(1, 520739) = 13.62$; $Prob > F = 0.00$). Another F test rejects the null that the difference in price effects between access to 100 Mbps and one Gbps is different from zero ($F(1, 520739) = 39.7$; $Prob > F = 0.00$). Controlling for speed, we also find that homes in CBGs where fiber is available have a price that is about 1.27 percent more than similar homes without fiber.

Taken together, the estimated coefficients for the speed and fiber variables in model (iv) suggest that fiber-delivered Internet service may provide benefits to households that go beyond speed, such as greater reliability of service and/or brand and marketing effects.[12] Although somewhat speculative, we can compare the estimates from model (iv) to the estimates in model (iii) to perform a simple calculation of the potential sources of the benefits that access to fiber can provide. One of the major advantages to households from access to fiber is the ability to upgrade from a 100 Mbps to a one Gbps connection. Our estimates from model (iii) indicate that such an upgrade could improve the price of a typical home by 2.6 percent. This is equivalent to $4,533 when evaluated at the sample median house price of $175,000. When we add *FIBER*, our estimates from model (iv) indicate that the same upgrade in speed could improve the price of a

[12] A survey by Render, Vanderslice & Associates (RVA) found that customer satisfaction rates are higher for Fiber to the Home (FTTH) than all other types of broadband services, and that “consumers say higher satisfaction is based on both reliability and speed.” RVA also found that “subscribers were far more satisfied with FTTH than with other types of broadband, “FTTH reliability satisfaction, at 54 percent, was 18 points higher than cable and 20 points higher than DSL," and that “FTTH users reported fewer *reboots* per month to restore service and reported less recent frustration than users of other types of broadband” (Render, 2014).

typical home by only 1.8 percent, which is equivalent to $3,213 when evaluated at the sample median house price. However, controlling for speed, homes in CBGs where fiber is available have a price that is about 1.3 percent more than similar homes without fiber, which is equivalent to $2,224 at the sample median house price. Together, the "speed effect" and the "fiber effect" are associated with an increase the typical home's value of 3.1 percent, or $5,437. This is roughly equivalent to a fireplace or just under half the value of a bathroom.

4.3 Robustness

For robustness, we first present the results from a two-step model that accounts for potential selection on unobservables by including the inverse Mills ratio (*IMR*) in model (iv). The inverse Mills ratio was calculated from the first-step probit model estimates in Table 5. Ideally, it would be nice to have an exclusion restriction, but as noted in Section 2 there are no variables in the first-step probit model that could be naturally excluded on an a priori basis. The two-step model can still perform reasonably well as long as the inverse Mills's ratio is not highly correlated with the other regressors in the second-step price equation. We checked the predicted probabilities, calculated from the probit model estimates, and they range from near zero to 0.99, with a mean of 0.364 and a standard deviation of 0.289. We conclude that there is sufficient variation in the first-step to warrant the reporting of the two-step model estimates, but note that the coefficients on *FIBER* and the speed variables should be viewed cautiously. Column five of Table 6 reports the estimates of model (v). When adding the inverse Mills ratio as an additional control variable, we note that the estimated coefficient on *FIBER* remains positive and increases from 1.3 percent to about four percent. Although, this suggests that there may be unobserved factors not accounted for in model (iv) that are biasing the price effect from fiber, it is not possible to make a definitive conclusion without an excluded instrumental variable.

For a second robustness check, we use the 8,130 homes in our sample that were sold in both 2002 and 2012. Because access to fiber was not available in 2002, this sub sample of data is used to estimate a differences-in-differences (DID) model where we regress the difference in the logarithm of housing prices on a constant and *FIBER*. Our underlying assumption is that the "treated" homes (i.e., single-family residential homes with access to fiber-delivered Internet) and the "non-treated" homes (i.e., single-family residential homes with no access to fiber-delivered Internet) are subject to the same time trends. This common time trend is used to control for potentially confounding factors due to a non-random assignment of fiber in the sample. Table 7 shows the OLS estimates of the DID model. The estimated coefficient on *FIBER* indicates a positive and significant relationship between the availability of fiber and home prices.[13]

5. CONCLUSIONS

This paper tests empirically whether access to fiber is correlated with higher housing prices. We use the NBM and a nationwide sample of approximately half a million residential real estate transactions from 2011 to 2013 to empirically investigate the relationship between high-speed Internet service and housing prices. Estimates from a hedonic housing price model show fiber-delivered Internet service may be beneficial to households in terms of increased speed and reliability of service. Specifically, single-family homes in census block groups (CBGs) with access to a one Gbps connection have a transaction price that is about 1.8 percent more than similar homes in neighborhoods with access to a 100 Mbps connection. Furthermore, controlling for speed, homes in CBGs where fiber is available have a transaction price that is about 1.3 percent more than similar homes in neighborhoods where fiber is not available. When evaluated at the sample median house

[13] The DID model assumes that home characteristics remain the same between 2002 and 2012, which may be unlikely. Unfortunately the RealtyTrac (2014) data has no historical information on changes in home characteristics. There could also be changes in the county and neighborhood characteristics through time that are not accounted for in the model. We are currently constructing controls for these changes with 2000 and 2010 census data.

price of $175,000, the combined effect of 3.1 percent suggests that access to fiber may be associated with about a $5,437 increase in the typical home's value. This is roughly equivalent to a fireplace or just under half the value of a bathroom.

To the best of our knowledge, this is the first paper that attempts to infer the value of fiber-delivered Internet service in the United States through the capitalization effects in housing prices. More work is required to produce robust, consistent results for policy analysis. In future research, we will group housing transactions by CBG and use a fixed effects specification to better control for unobservables at the neighborhood level. We will also explore the possibility of using Federal subsidies for Internet infrastructure investment as a plausible source of exogenous variation in the neighborhood deployment of fiber for two-step estimation. Finally, we can update the study to include the most recent year of real estate transactions data, which would include additional data for 2014, and analyze the impact of upstream speeds.

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TABLE 1

VARIABLE DESCRIPTIONS

Variable	Description and data source
P	Transaction amount for residential single-family house. Source: RealtyTrac (2014).
AGE	Age of house in ten years. Source: RealtyTrac (2014).
LOTSIZE	Lot size of house in ten thousand square feet. Source: RealtyTrac (2014).
HOUSESIZE	House size in thousand square feet. Source: RealtyTrac (2014).
GARAGESIZE	Garage size in house in thousand square feet. Source: RealtyTrac (2014).
FIREPLACE	One if house has a fireplace; zero otherwise. Source: RealtyTrac (2014).
POOL	One if house has a pool; zero otherwise. Source: RealtyTrac (2014).
NBRBATH	Number of bathrooms in the house. Source: RealtyTrac (2014).
Q1	One if transaction was in quarter one; zero otherwise. Source: RealtyTrac (2014).
Q2	One if transaction was in quarter two; zero otherwise. Source: RealtyTrac (2014).
Q3	One if transaction was in quarter three; zero otherwise. Source: RealtyTrac (2014).
Q4	One if transaction was in quarter four; zero otherwise. Source: RealtyTrac (2014).
Y2011	One if transaction was in 2011; zero otherwise. Source: RealtyTrac (2014).
Y2012	One if transaction was in 2012; zero otherwise. Source: RealtyTrac (2014).
Y2013	One if transaction was in 2013; zero otherwise. Source: RealtyTrac (2014).
$STATE^s$	One when transaction was in state or D.C. s = 1, 2, 3, … , 51, and zero otherwise.
TAX	Nominal property tax rate in the county. Source: U.S. Census Bureau (2014a).
TURNOVER	Percentage of households who lived in the same house or in the same county 12 month ago. Source: U.S. Census Bureau (2014a).
ACCESS	Weighted average of the average commuting time to work for residents located in the county. Source: U.S. Census Bureau (2014a).
ARTREC	Percentage of employees in the arts and recreation sector of the county. Source: U.S. Census Bureau (2014b).
POPGROWTH	2010 county population divided by 2000 county population. Source: U.S. Census Bureau (2000, 2010).
CRIME	The number of serious crimes (defined as murder and rape) in the county, related to the county's population. Source: FBI (2012).
POP	Number of persons in the CBG. Source: GeoLytics (2012).
HOUSES	Number of houses in the CBG. Source: GeoLytics (2012).
INCOME	Per capita income in the CBG in thousand dollars. Source: U.S. Census Bureau (2014a).
AGE	Mean age in years of the population in the CBG. Source: GeoLytics (2012).
EDU	Mean number of years of schooling of the population over 25 years of age in the CBG. Source: GeoLytics (2012).
NWHITE	The percentage of nonwhite persons in the CBG. Source: U.S. Census Bureau (2014a).
ROADS	Total length in miles of S1100 (primary), S1200 (secondary), and S1400 (local) roads in the CBG. Source: U.S. Census Bureau (2014a).
INTER-SECTIONS	Number of S1100 (primary), S1200 (secondary), and S1400 (local) road intersections in the CBG. Source: U.S. Census Bureau (2014a).
BEDROCK	Coefficient of variation of the average distance (centimeters) from the soil surface to the top of the bedrock layer in the CBG. Source: USDA (2013).
WETLANDS	Percentage of geographical area in the CBG that are wetlands. Source: GeoLytics (2012).
AREA	Geographical area (m2) of the CBG. Source: GeoLytics (2012).

TABLE 1 CONTINUED

VARIABLE DESCRIPTIONS

ISPS	Number of ISPs in the CBG that provide residential wireline broadband Internet connections, and not using fiber as the last mile. Source: NBM (2011-2013).
$BRAND^b$	One when the ISP brand in the CBG is *b* = 1, 2, 3, … , 17, and zero otherwise.
SPEED	Maximum advertised downstream speed of all ISPs in the CBG that provide residential wireline broadband connections in Mbps. Source: NBM (2011-2013).
SPEED25	One if the maximum advertised downstream speed of all ISPs in the CBG that provide wireline broadband connections is 25 Mbps or less, and zero otherwise. Source: NBM (2011-2013).
SPEED50	One if the maximum advertised downstream speed of all ISPs in the CBG that provide wireline broadband connections is 50 Mbps, and zero otherwise. Source: NBM (2011-2013).
SPEED100	One if the maximum advertised downstream speed of all ISPs in the CBG that provide wireline broadband connections is 100 Mbps, and zero otherwise. Source: NBM (2011-2013).
SPEED1024	One if the maximum advertised downstream speed of all ISPs in the CBG that provide wireline broadband connections is one Gbps, and zero otherwise. Source: NBM (2011-2013).
FIBER	One when the NBM reports that fiber is available in at least one of the census blocks comprising the CBG, and zero otherwise. Source: NBM (2011-2013).

TABLE 2
SAMPLE SUMMARY STATISTICS

Variable	Obs.	Mean	s.d.	Min	Max
Home Characteristics					
P	520,931	234,573	210,127	6,001	1,549,000
AGE	520,931	3.642	2.831	0	100.3
LOTSIZE	520,931	3.991	236.4	0	100,000
HOUSESIZE	520,931	1.839	1.521	0.001	900.1
GARAGESIZE	520,931	0.260	0.287	0	31.2
FIREPLACE	520,931	0.428	0.495	0	1
POOL	520,931	0.094	0.292	0	1
BATH	520,931	2.006	1.114	0	10.5
Q1	520,931	0.198	0.399	0	1
Q2	520,931	0.268	0.443	0	1
Q3	520,931	0.282	0.450	0	1
Q4	520,931	0.252	0.434	0	1
Y2011	520,931	0.312	0.463	0	1
Y2012	520,931	0.332	0.471	0	1
Y2013	520,931	0.356	0.479	0	1
County Characteristics					
TAX	1,164	0.011	0.006	0.002	0.034
TURNOVER	1,164	0.933	0.027	0.645	0.979
ACCESS	1,164	24.34	4.708	13	43
ARTREC	1,164	0.014	0.015	0	0.185
POPGROWTH	1,164	1.118	0.140	0.812	2.091
CRIME	1,164	3.1E-04	1.8E-04	0	0.002
Neighborhood (CBG) Characteristics					
POP	116,330	1.529	0.855	0.010	29.677
HOUSES	116,330	638.1	352.7	6	21,535.000
INCOME	116,330	62,943	32,106	2,499	250,001.000
AGE	116,330	38.358	5.620	17	77.94
EDU	116,330	13.076	1.498	2	20
NWHITE	116,330	0.248	0.254	0	1
ROADS	116,330	16.099	50.144	0.026	4,854
INTERSECTIONS	116,330	60.908	71.859	1	4,073
BEDROCK	116,330	0.042	0.141	1.7E-04	10.905
WETLANDS	116,330	0.028	0.094	5.4E-08	0.988
AREA	116,330	1.4E+07	1.2E+08	21,568	1.7E+10
ISPS	116,330	3.806	1.866	1	17
SPEED	116,330	203.4	318.8	0.768	1,000
SPEED25	116,330	0.082	0.275	0	1
SPEED50	116,330	0.252	0.434	0	1
SPEED100	116,330	0.525	0.499	0	1
SPEED1024	116,330	0.141	0.348	0	1
FIBER	116,330	0.362	0.481	0	1

NOTES. The median house price (*P*) is $175,000. Obs. is number of observations. s.d. is standard deviation.

TABLE 3
SAMPLE DISTRIBUTION OF THE
MAXIMUM ADVERTISED DOWNSTREAM SPEED TO THE HOME

	Full sample			Access to fiber			No access to fiber		
Mbps	Frequency	Percent	Cumulative	Frequency	Percent	Cumulative	Frequency	Percent	Cumulative
0.768	110	0.02	0.02	0	0	0	110	0.03	0.03
1.5	318	0.06	0.08	1	0	0	317	0.1	0.13
3	1,071	0.21	0.29	16	0.01	0.01	1,055	0.32	0.45
6	2,012	0.39	0.67	89	0.05	0.05	1,923	0.59	1.04
10	21,362	4.1	4.77	1,507	0.78	0.84	19,855	6.05	7.09
25	14,163	2.72	7.49	1,485	0.77	1.61	12,678	3.86	10.95
50	133,956	25.71	33.21	35,898	18.62	20.22	98,058	29.89	40.84
100	275,531	52.89	86.1	82,055	42.55	62.77	193,476	58.97	99.81
1,024	72,408	13.9	100	71,791	37.23	100	617	0.19	100
Total	*520,931*	*100*		*192,842*	*100*		*328,089*	*100*	

Source: NBM (2011-2013).

TABLE 4

POPULATION AND SAMPLE CHARACTERISTICS

	Population		Sample		
Variable	Obs.	Mean	Obs.	Mean	Diff.
POP	215,017	1.425	116,330	1.529	-0.104
		(0.796)		(0.855)	
HOUSES	215,017	609.5	116,330	638.1	-28.58
		(329.4)		(352.7)	
INCOME	215,017	56,392	116,330	62,943	-6,550
		(30,590)		(32,106)	
AGE	215,017	38.06	116,330	38.36	-0.296
		(5.801)		(5.620)	
EDU	215,017	12.96	116,330	13.08	-0.121
		(1.517)		(1.498)	
NWHITE	215,017	0.272	116,330	0.248	0.024
		(0.262)		(0.254)	
ROADS	215,017	27.53	116,330	16.10	11.43
		(110.5)		(50.14)	
INTERSECTIONS	215,017	72.46	116,330	60.91	11.56
		(121.3)		(71.86)	
BEDROCK	215,017	0.046	116,330	0.042	0.005
		(0.155)		(0.141)	
WETLANDS	215,017	0.027	116,330	0.028	-0.002
		(0.090)		(0.094)	
AREA	215,017	4.4E+07	116,330	1.4E+07	3.0E+07
		(6.5E+08)		(1.2E+08)	

NOTES. Diff. is the population mean less the sample mean. Obs. is number of observations. Standard deviation of mean in parenthesis. Standard error of diff. in parenthesis.

TABLE 5
PROBIT MODEL ESTIMATES OF ACCESS TO FIBER

	Estimate	s.e.
TAX	10.82***	1.306
TURNOVER	0.720***	0.210
ACCESS	-0.004***	0.001
ARTREC	0.600*	0.341
POPGROWTH	0.322***	0.033
CRIME	-384.4***	29.10
POP	0.107***	0.011
HOUSES	6.3E-05**	3.1E-05
INCOME	3.6E-06***	1.3E-07
AGE	-0.005***	0.001
EDUC	0.013***	0.002
NWHITE	0.309***	0.017
ROADS	-0.319**	0.160
$ROADS^2$	0.136***	0.041
INTERSECTIONS	-0.001***	1.0E-04
WETLANDS	-0.362***	0.038
AREA	3.9E-11	7.9E-11
BEDROCK	-0.037	0.028
Y2012	0.286***	0.008
Y2013	0.571***	0.008
ISPS	0.183***	0.002
CONSTANT	-7.051***	0.329
Likelihood	-96,209	
Observations	212,005	

NOTES. Dependent variable is *FIBER*. s.e. denotes robust standard errors. ***significant at the 0.01 level; **significant at the 0.05 level; *significant at the 0.1 level. Estimates of state dummy variables ($STATE^s$), ISP dummy variables ($BRAND^b$), and seasonal dummy variables (*Q1*, *Q2*, *Q3*) are not reported.

TABLE 6

OLS ESTIMATES OF HOME PRICES

	Model (i)	Model (ii)	Model (iii)	Model (iv)	Model (v)
AGE	-0.058***	-0.058***	-0.058***	-0.058***	-0.058***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
AGE^2	0.001***	0.001***	0.001***	0.001	0.001***
	(3.9E-04)	(4.0E-04)	(4.0E-04)	(4.0E-04)	(4.0E-04)
LOTSIZE	1.5E-05**	1.5E-05**	1.6E-05**	1.5E-05**	1.5E-05**
	(7.2E-06)	(7.2E-06)	(7.3E-06)	(7.3E-06)	(7.3E-06)
LOTSIZE^2	-2.4E-10**	-2.4E-10**	-2.4E-10**	-2.4E-10**	-2.4E-10**
	(1.1E-10)	(1.1E-10)	(1.1E-10)	(1.1E-10)	(1.1E-10)
HOUSESIZE	0.275***	0.275***	0.275***	0.275***	0.275***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
HOUSESIZE^2	-3.1E-04***	-3.1E-04***	-3.1E-04***	-3.1E-04***	-3.1E-04***
	(1.7E-05)	(1.7E-05)	(1.7E-05)	(1.7E-05)	(1.7E-05)
GARAGESIZE	0.074***	0.074***	0.075***	0.074***	0.074***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
GARAGESIZE^2	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***
	(3.0E-04)	(2.9E-04)	(3.1E-04)	(3.0E-04)	(3.0E-04)
FIREPLACE	0.036***	0.036***	0.036***	0.036***	0.036***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
POOL	1.2E-01***	1.2E-01***	1.2E-01***	1.2E-01***	1.2E-01***
	(5.5E-03)	(5.5E-03)	(5.5E-03)	(5.5E-03)	(5.5E-03)
BATH	0.072***	0.072***	0.072***	0.072***	0.072***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Q1	-0.074***	-0.073***	-0.073***	-0.073***	-0.073***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Q2	-0.011***	-0.011***	-0.011***	-0.011***	-0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Q3	0.012***	0.012***	0.012***	0.012***	0.012***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Y2012	0.024***	0.022***	0.020***	0.019***	0.017***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Y2013	0.123***	0.119***	0.113***	0.113***	0.109***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
TAX	-36.86***	-36.98***	-37.10***	-37.13***	-37.24***
	(0.426)	(0.427)	(0.426)	(0.426)	(0.427)
TURNOVER	-2.1E+00***	-2.1E+00***	-2.1E+00***	-2.1E+00***	-2.1E+00***
	(5.2E-02)	(5.2E-02)	(5.2E-02)	(5.2E-02)	(5.2E-02)
ACCESS	0.014***	0.014***	0.014***	0.014***	0.014***
	(2.9E-04)	(2.9E-04)	(2.9E-04)	(2.9E-04)	(2.9E-04)
ARTREC	0.532***	0.515***	0.514***	0.507***	0.502***
	(0.076)	(0.076)	(0.076)	(0.076)	(0.076)
POPGROWTH	-0.563***	-0.564***	-0.565***	-0.565***	-0.568***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
CRIME	-238.459***	-236.552***	-236.521***	-235.952***	-233.283***
	(7.609)	(7.618)	(7.616)	(7.619)	(7.722)

NOTES. Dependent variable is log *P*. s.e. denotes robust standard errors. ***significant at the 0.01 level; **significant at the 0.05 level; *significant at the 0.1 level.

TABLE 6 CONTINUED

OLS ESTIMATES OF HOME PRICES

	Model (i)	Model (ii)	Model (iii)	Model (iv)	Model (v)
POP	-0.036***	-0.037***	-0.036***	-0.037***	-0.037***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
HOUSES	1.1E-04***	1.1E-04***	1.1E-04***	1.1E-04***	1.1E-04***
	(2.9E-06)	(2.9E-06)	(2.9E-06)	2.9E-06)	(3.2E-06)
INCOME	7.7E-06***	7.7E-06***	7.7E-06***	7.7E-06***	7.6E-06***
	(1.0E-07)	(1.0E-07)	(1.0E-07)	(1.0E-07)	(1.0E-07)
AGE	0.011***	0.011***	0.011***	0.011***	0.011***
	(2.0E-04)	(2.0E-04)	(2.0E-04)	(2.0E-04)	(2.0E-04)
EDU	0.035***	0.035***	0.035***	0.035***	0.035***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
NWHITE	-0.454***	-0.456***	-0.455***	-0.456***	-0.459***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
ROADS	-0.515***	-0.512***	-0.496***	-0.496***	-0.493***
	(0.087)	(0.087)	(0.087)	(0.086)	(0.087)
$ROADS^2$	0.184***	0.183***	0.177***	0.177***	0.176***
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
INTERSECTIONS	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(3.1E-05)	(3.1E-05)	(3.1E-05)	(3.1E-05)	(3.1E-05)
BEDROCK	-0.114***	-0.114***	-0.113***	-0.113***	-0.112***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
WETLANDS	0.288***	0.290***	0.289***	0.290***	0.293***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
AREA	1.3E-10***	1.3E-10***	1.4E-10***	1.4E-10***	1.4E-10***
	(3.6E-11)	(3.6E-11)	(3.6E-11)	(3.6E-11)	(3.6E-11)
FIBER		0.025***		0.013***	0.043***
		(0.002)		(0.002)	(0.014)
ISPS	0.060***	0.059***	0.058***	0.058***	0.057***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
SPEED50			0.033***	0.031***	0.031***
			(0.004)	(0.004)	(0.004)
SPEED100			0.045***	0.042***	0.042***
			(0.004)	(0.004)	(0.004)
SPEED1000			0.071***	0.060***	0.061***
			(0.005)	(0.005)	(0.005)
IMR					-0.018***
					(0.008)
CONSTANT	12.91***	12.92***	12.93***	12.93***	12.94***
	(0.214)	(0.213)	(0.218)	(0.218)	(0.217)
Observations	520,844	520,844	520,844	520,844	520,835
R-squared	0.6142	0.6143	0.6144	0.6144	0.6144

NOTES. Dependent variable is log *P*. s.e. denotes robust standard errors. ***significant at the 0.01 level; **significant at the 0.05 level; *significant at the 0.1 level. Estimates of state dummy variables ($STATE^s$), ISP dummy variables ($BRAND^b$), and seasonal dummy variables (*Q1*, *Q2*, *Q3*) are not reported. Model (v) has fewer observations because New Mexico and Wyoming are dropped from the first-step probit model because they predict no access to fiber perfectly.

TABLE 7
DIFFERENCES-IN-DIFFERENCES MODEL ESTIMATES OF HOME PRICES 2002 AND 2012

		Estimate	s.e.
FIBER		0.052***	0.015
CONSTANT		0.079***	0.010
R-squared	0.014		
Observations	8,130		

NOTES. Dependent variable is $\Delta log\ P$. s.e. denotes robust standard errors. ***significant at the 0.01 level. Observations are from 2002 and 2012.