New Highways, House Prices, and Urban Development: A Case Study of Toll Roads in Orange County, CA

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Abstract

We examine the link between highways and urban development by employing both hedonic analysis and multiple sales techniques to study the impact of the construction of toll roads in Orange County, California, on house prices. Urban economic theory predicts that if highways improve accessibility, that accessibility premium will be reflected in higher land prices.

Our empirical analyses of house sales prices provide strong evidence that the toll roads, the Foothill Transportation Corridor Backbone in particular, created an accessibility premium; home buyers are willing to pay for the increased access that the new roads provide. Such willingness to pay influences both development patterns and, potentially, induced travel (the association between increases in highway capacity and increases in vehicle miles of travel). The results are consistent with the idea that induced travel is caused, in part, by changes in urban development patterns that are linked to increases in highway capacity.

Keywords: Highways; Hedonic prices; Induced travel

Introduction

House price analysis can provide a window into many current planning and urban policy questions. Economic theory predicts that land values, and, other things being equal, house prices will be higher in locations that are more accessible to employment or other desirable travel destinations. The Orange County, CA, toll-road network, built during the 1990s, provides an opportunity to test that prediction. The results have implications for understanding the often debated links between highways and urban development issues.

As an example of how hedonic price analysis can provide a window into policy questions, this research was motivated by the recent debate on induced travel.

Several recent studies have demonstrated an association between increases in highway capacity and increases in vehicle miles of travel (VMT). That phenomenon, called induced travel, has been increasingly cited as a basis for rethinking travel demand modeling, land-use/transportation interactions, and the environmental impact of highway projects. Yet the debate remains contentious, in part because the empirical evidence on induced travel is mostly from aggregate data better suited to establishing correlations than causality. As Noland and Lem (2000) note, the studies to date, while often supporting the hypothesis, do little to illuminate the behavioral underpinnings of the phenomenon. This article helps bridge that gap by providing evidence on how highway building influences house prices and, by inference, how new highways can influence development patterns and VMT.

If increases in highway capacity cause increases in VMT, the behavioral underpinnings can be divided into two broad classes. First, an increase in capacity that reduces congestion and lowers travel times reduces the full cost of travel. This lower price of travel can induce new automobile trips, irrespective of any changes in urban development. This is part of the behavioral underpinning of Downs's (1962) "law of peak hour expressway congestion."[1] Second, increases in highway capacity that lower travel times can facilitate changes in urban development that are associated with longer trips and thus more VMT (Downs 1992; Hills 1996; Noland and Lem 2000). In other words, increases in highway capacity can alter the spatial pattern of trip origins and destinations and influence VMT by affecting urban development patterns.

The focus of this article is the link between highways and urban development. Specifically, we present a before-and-after study of the impact of the construction of toll roads in Orange County, CA, on house prices. Since 1993, 51 new centerline miles of toll road have opened in Orange County. Collectively, those roads extend the area's relatively dense highway network into the rapidly growing southern part of the county. (See figure 1 for a depiction of the highway and toll-road network in the county.) We use both hedonic regression analysis and multiple sales techniques to examine how the opening of the toll-road network alters house prices in nearby corridors.

Urban economic theory posits that highway improvements influence urban growth patterns through land prices. If highways improve accessibility, that accessibility premium will be reflected in higher land prices (and *ceteris paribus*, higher house prices), and higher-priced land will be more densely developed. As a first step in better understanding the link between highways and urban development, we examine how the construction of the Orange County toll-road network altered house prices in nearby corridors. Understanding the link between house prices,

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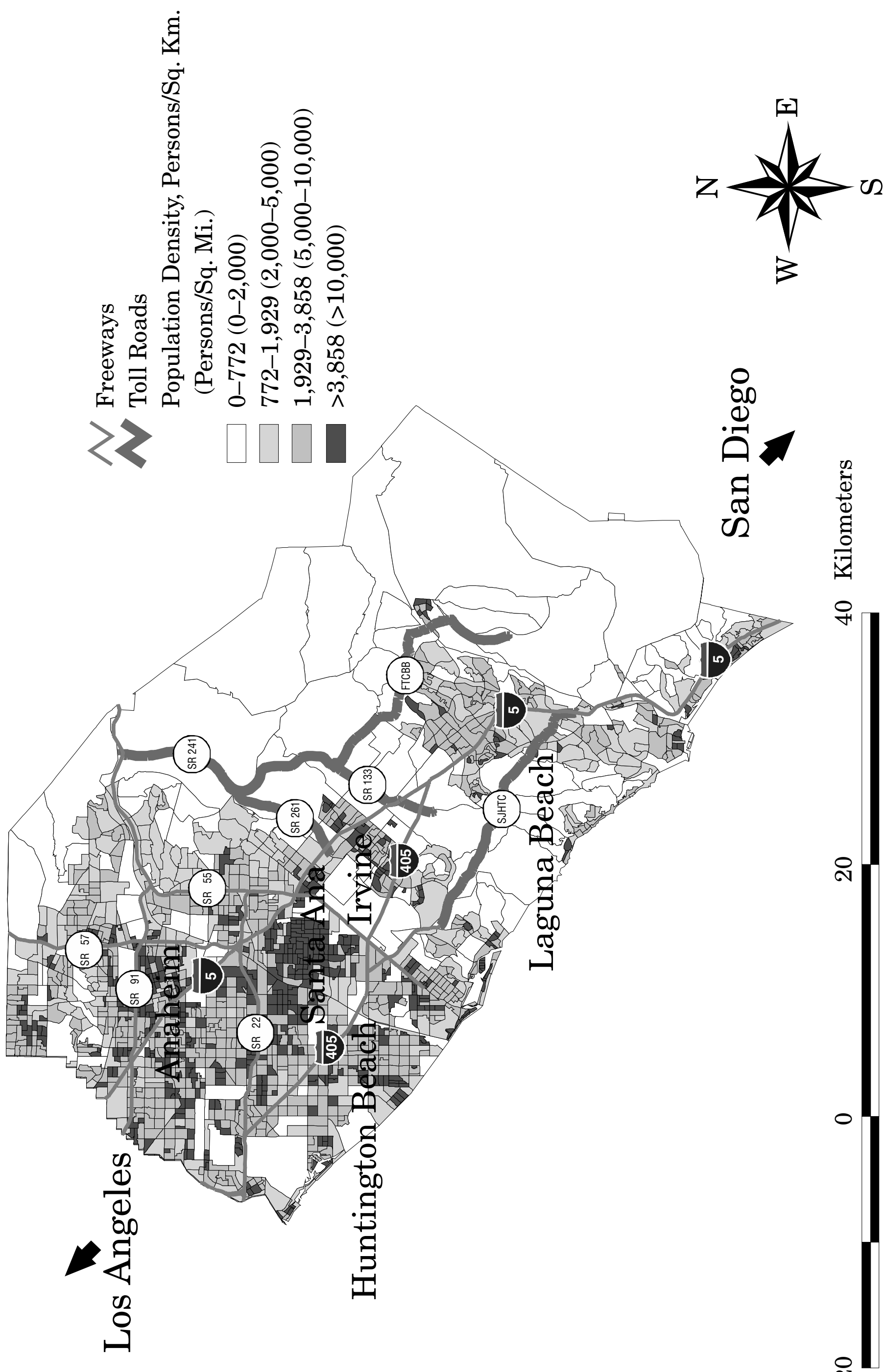
[1] Downs (1962, 1992) also discusses how increases in highway capacity can induce shifts in travel from different times of day, routes, and modes. With the exception of changes in mode, it is not clear that changes in trip scheduling or route will increase VMT, even if those shifts contribute to increases in peak-period congestion. For that reason, we follow Noland and Lem (2000), who note that the effect of highway capacity on inducing new or longer trips should be a key focus for research on the link between VMT and highway capacity.

Figure 1. **Orange County Toll Roads and Freeways**



Source: GDT, Inc.

development patterns, and induced travel requires first understanding those three related bodies of literature, which we summarize below.

Literature review

Induced travel

Downs (1962) offered one of the earliest theoretical justifications for induced travel, stating that improvements in highway capacity lower the cost of peak-hour travel and thus can create additional peak-hour traffic. More recent research has focused on the link between VMT and highway capacity, rather than on peak-hour traffic. The empirical literature, especially works that have been influential in policy circles, is quite new. Important recent empirical research on induced travel includes the work of Goodwin (1996) and Hansen and Huang (1997) and the report of the United Kingdom's Standing Advisory Committee on Truck Road Assessment (SACTRA) (1994). The SACTRA (1994) report examined traffic growth in corridors in the United Kingdom that had increases in capacity and compared actual and forecast travel along new and improved corridors. Both pieces of evidence led SACTRA (1994) to conclude that traffic increases were associated with increases in highway capacity.

Controlling for other factors such as county population and per capita income, Hansen and Huang (1997) used panel data for California counties to examine statistically how VMT is influenced by state highway lane miles. They concluded that the elasticity of VMT with respect to lane miles ranged from 0.3 to 0.7 for counties and from 0.5 to 0.9 for metropolitan areas. Virtually all elasticity point estimates were significant at conventional (5 percent or better) levels. Noland (2001) found similar results using the same methodology on state data, and Noland and Cowart (2000) also found similar results with data on 70 U.S. metropolitan areas. These results have provided support for the idea that induced travel is an important transportation phenomenon, but the causality issue remains somewhat controversial. As Noland and Lem (2000) note, the research to date provides little information on the underlying behavioral foundations of whether and how increases in highway capacity cause increases in VMT. To increase our understanding of the behavioral links between highway construction and induced travel, this article focuses on the link between highways and urban growth patterns.

Highways and urban development

The literature on highways and urban development has focused largely on the question of whether highways contribute to the decentralization of metropolitan areas. The evidence, reviewed by Boarnet and

Haughwout (2000), suggests that transportation infrastructure is only one of several factors that influence decentralization, although there is debate about the relative importance of transportation versus other factors (see the exchange between Cervero and Landis [1995] and Giuliano [1995]).

The empirical literature initially focused on how highways influence the relative growth of central cities and suburban rings. An often cited example of this work is the study by Payne-Maxie Consultants (1980) that examined the influence of suburban beltways on the growth of suburbs and central cities in 54 U.S. metropolitan areas. The authors conclude that beltways have little impact on the overall growth of the metropolitan area and that the intrametropolitan economic and land use effects that do exist are likely to be transfers from one place to another within the metropolitan area (Payne-Maxie Consultants 1980). Yet this work and similar articles on the determinants of decentralization such as Bradford and Kelejian (1973), Mills and Price (1984), and Palumbo, Sacks, and Wasylenko (1990) divided metropolitan areas into two components—central cities and the remaining suburban ring. This geographic focus is relatively crude and allows little analysis of the finer-scale impacts of highways on metropolitan growth patterns. Partly for that reason, we use data on house sales prices that are matched, via a Geographic Information System (GIS), to street addresses. This allows a more detailed study of the effect of highways on urban development.

Hedonic price studies of highway access

In the United States, studies of the impact of highways on nearby land and house values date to the beginnings of the Interstate Highway Program (Adkins 1959; Mohring 1961). The technique of hedonic price analysis was later formalized by Rosen (1974), and there have since been several studies of the impact of highways on house prices. Huang (1994) reviewed the literature on hedonic price studies of the influence of highway access on house prices and concludes that the early studies, from the 1950s and 1960s, usually showed large land price increases near major highway projects. The later studies, from the 1970s and (less often) the 1980s, typically showed smaller and often statistically insignificant land price effects from highway projects. Giuliano (1989), in reviewing the literature on the effect of transportation infrastructure on urban development, comes to the same conclusion, namely that the later studies show a smaller impact of highway access on home values. Both Giuliano (1989) and Huang (1994) argue that, as the highway system was developed in many urban areas, the value of access to any particular highway was reduced because accessibility was then generally good throughout the network in most U.S. cities. Huang (1994) also notes that for residential properties, noise and other disamenities reduce the value of locating close to a highway. Langley (1976, 1981), in a study of homes near the Washington, DC, Beltway, concluded that house prices increase with increasing distance from the highway out to a distance of 1,125 feet and then decrease with increasing distance from the highway beyond that point. Langley (1976) interprets this as evidence that the disamenities of highways dominate the value of access for distances of less than 1,125 feet.

The literature on highways and house prices echoes the broader literature on highways and urban growth. Giuliano (1989, 1995), in reviewing both literatures, concludes that the influence of transportation on urban development patterns is growing less important. However, most of the evidence that led her to that conclusion is based on data aggregated to broad geographic distinctions such as central cities and suburban rings. A more recent hedonic price study by Voith (1993) found that highway access (measured by travel time by highway to downtown) influenced house prices in the Philadelphia area and that the magnitude of that effect increased during the 1980s. Overall, the literature on house prices and highway access, like the literature on highways and urban development, has often used data aggregated to a geographic scale that can obscure fine-grained links between highways and growth patterns. Thus, the link between highways and metropolitan growth, and any ensuing link to induced travel, remains incompletely understood.

Research strategy

In this research, we take advantage of the fact that a substantial network of new tolled highways was built in Orange County, CA, during the 1990s. They provide an opportunity to address the question of causality in ways that many other studies cannot. If the toll roads changed the pattern of accessibility in Orange County, that change should be capitalized into house prices. We have data on every home sale in Orange County from 1988 through the early part of 2000. Because these data span a period that ranges from the early planning stages of the toll roads through the opening of most of the network, we expect to see house prices decrease with distance from the toll road in the later years of our data set, but not in the earlier years.

The toll roads are built and operated by the Transportation Corridor Agencies (TCAs), special-purpose government agencies formed in 1986 for the sole purpose of building the roads. Although portions of the toll-road network exist in county planning documents from the 1970s, it was not until the TCAs developed a plan to raise money primarily through tolls, first proposed in 1988, that the roads became a serious possibility. Even then, construction started on a small, 7.3-mile portion in 1990, and the rest of the network was built in stages beginning in 1993. The first part of the toll roads, the Foothill Transportation Corridor Backbone (FTCBB), was opened in 1993; the San Joaquin Hills Transportation

Corridor (SJHTC) opened in 1996 and later portions of the Foothill and Eastern Transportation corridors opened in 1999. Figure 1 not only shows the toll-road network, it also shows population density (as of 1990) for census block groups in Orange County, so that the toll-road and highway networks can be viewed alongside existing development patterns. Table 1 lists each segment with the date construction started and was completed.

Table 1. **Date of Toll-Road Construction and Completion**

Toll-Road Segments	Construction Began	Construction Completed
Eastern Transportation Corridor (SR 133)	June 1995	February 1999
Eastern Transportation Corridor (SR 241)	June 1995	February 1999
Eastern Transportation Corridor (SR 261)	June 1995	February 1999
Foothill Transportation Corridor, Backbone Segment (FTCBB)	1990	1993 and 1995
Foothill Transportation Corridor, Other Segments (SR 241)	Mid-1995	January 1999
San Joaquin Hills Transportation Corridor (SJHTC)	September 1993	November 1996

Source: Transportation Corridor Agencies 1999.

Even with some foresight on the part of home buyers, we expected that the market assessment of the likelihood that the roads would be built would rise over the early years of our data, implying that the full value of the toll roads would not be capitalized into house prices in 1988. For example, the SJHTC was the subject of litigation until 1993. In all, the TCAs have opened 51 new centerline miles of toll highway in Orange County. The two segments that opened the earliest—the FTCBB and the SJHTC—are the focus of this study, because they were built and opened in essentially the middle of the years spanned by our data, providing a good comparison of accessibility values before and after the segments opened. For those roads, we expect to see no effect of distance to the toll road before some threshold year, but declining house prices with increasing distance from the road after the threshold.[2] Threshold years are chosen to reflect when the housing market most likely incorporated a belief among buyers that a particular toll road would be built. Different threshold years were tested, as is discussed in the hedonic price regressions section of this article.

[2] Based on Langley's results (1976, 1981), we exclude homes that are within 1,125 feet of the toll road to avoid confounding the value of access with noise and other disamenities experienced close to highways.

Data

Dataquick, Inc., provided information about physical characteristics of houses, such as dwelling size, lot size, number of bedrooms and bathrooms, and street address, and information on house sales, such as year of sale, price, and loan amount. Dataquick compiles data from the Orange County Tax Assessor/Collector's and the Orange County Recorder's Offices. The Orange County Recorder keeps data on all property sales transacted in the county, and the Tax Assessor/Collector has data on the physical characteristics of every parcel. Dataquick compiles information from both data sets and sells the results, primarily to persons with real estate property appraisal interests. The information on sales characteristics (sales price and date of sale) and property characteristics can be matched via an Assessor's Parcel Number, which uniquely identifies each property. The data were made available to us for research purposes through the cooperation of Dataquick, Inc. The resulting data set is comprehensive in that it includes all property sales in Orange County from 1988 through approximately the first two months of 2000.

Two major neighborhood characteristics are used in this study: crime rate and school quality. School quality was proxied by a school district's average SAT (Scholastic Assessment Test, formerly the Scholastic Aptitude Test) score. Crime rates were calculated on the basis of data from the California Department of Justice's Justice Statistics Center (1999) and the California State Department of Finance Demographic Research Unit (1999). SAT scores for Orange County were obtained from the *Los Angeles Times* ("Orange County High School Performance" 1999).

There are 367,841 records of the sale of single-family detached dwelling units in Orange County from 1988 to the first quarter of 2000. We used Arcview-GIS to geocode the home address. Geographic Data Technology, Inc., and the California Department of Transportation provided GIS maps of Orange County's street network, which include the centerlines of freeways, toll roads, and local roads, as well as the entrance and exit ramps of all grade-separated highways. We geocoded houses using the street network map and selected only those that were perfectly matched, that is, the street number is found on a street segment with the exact name as found in the address, and the house is matched to the correct block, side of street, and approximate location within the block. We tested several address matches by comparing the GIS match to published street maps to develop the methods and criteria for an exact GIS address match. See table 2 for the distribution by year of the number of house transactions and those that were geocoded with a perfect address match.[3] We also used Arcview-GIS to link the locational characteristics

[3] The loss rate from address matching (14 percent) is low compared with typical GIS address-matching routines. We attribute this to the high-quality, commercial GIS maps and the accuracy of the address information in the Dataquick data set. We ran a test to examine the accuracy of the address-matching process by randomly selecting a substan-

Table 2. **Number of Single-Family Detached Dwelling Unit Sales in Orange County, by Year**

Year	All Observations	Observations with Perfectly Matched Address	Observations after Filtering Out Inappropriate Data
1988	43,733	38,200	36,716
1989	34,430	29,959	28,836
1990	26,042	22,605	21,481
1991	25,157	22,129	19,894
1992	22,902	20,096	17,251
1993	24,388	21,356	18,014
1994	29,272	25,536	20,791
1995	23,822	20,833	16,821
1996	29,040	25,468	20,345
1997	32,763	27,595	21,590
1998	37,396	29,821	24,244
1999	33,237	28,580	24,900
2000	5,659	4,954	4,302
Total	367,841	317,132	275,185

to each house. A school district and police department jurisdiction are assigned to each house by joining the house location from the address match to both the school district and police department jurisdiction base maps. Then, SAT score and crime rate were assigned to each transaction based on the year of sale and the school district or police department jurisdiction associated with the location of the house.

After the GIS processing of raw data, the data set was filtered for missing data, apparent data entry errors, and non–arms length transactions. We dropped all observations with missing key variables, such as size, lot size, and number of bedrooms and bathrooms.[4] We also dropped ob-

tial number of houses and comparing the matched location with printed street maps. We found that Arcview's matching performance is highly satisfactory, with 99 percent of the cases that Arcview designated as a perfect match being correct compared with printed street maps. We assume that the 14 percent of the cases that are not address matched are random, and we have no information that would suggest otherwise.

[4] We ran a test for geographic bias for observations lost because of missing variables and found that there is a higher percentage of lost observations in the toll-road corridors that we studied than in the county as a whole. The toll-road corridors are from 1,125 feet to three miles from the centerline of the SJHTC and predominantly within three miles of the centerline of the FTCBB. (The choice of corridors is described later.) Approximately 25 percent of home sales observations were lost because of missing variables within those corridors, versus a 13 percent loss rate in all of Orange County. This difference is primarily due to higher loss rates within the toll-road corridors from 1994 through 1998. Discussions with local real estate experts led us to believe that this loss rate is due to delays in entering new home data into county databases during the mid-1990s and that the higher proportion of new homes built in the toll-road corridors is therefore responsible for the higher incidence of missing variables in those corridors. We ran the regressions that are the basis for tables 3 through 5 using only resale properties (not new homes) and found no changes in the hypothesis tests we report, suggesting that any pattern of geographic bias in missing variables does not influence our results.

servations with inconsistent data, such as a four-bedroom house with a floor area of less than 500 square feet or houses with more than 10,000 square feet and fewer than 4 bedrooms. As for non–arms length transactions, we dropped all observations with a sales price of less than $25,000 and those with loan amounts exceeding 125 percent of the sale price. See table 2 for the distribution of number of observations by year after the inappropriate data were filtered out. After address matching and filtering inappropriate data, we were left with 275,185 sales in Orange County from 1988 to the first quarter of 2000.

Hedonic price regressions

We analyzed access to toll roads using a hedonic price regression for corridors surrounding the two oldest segments of the toll-road network—the FTCBB and the SJHTC.[5] The regression specification is as follows[6]:

$$P = \alpha_0 + \alpha_1 \text{SQFT} + \alpha_2 \text{Bedroom} + \alpha_3 \text{Bath} + \alpha_4 \text{Lotsize} + \alpha_5 \text{Age} + \alpha_6 \text{SATscore} + \alpha_7 \text{CrimeRate} + \alpha_8 \text{DtrBefore} + \alpha_9 \text{DtrAfter} + \sum_{i=1}^{11} \beta_i \text{YEAR}_i + \varepsilon \quad (1)$$

Where P = home sales price deflated to 1982–84 dollars, using the housing price index for Los Angeles–Riverside–Orange County consolidated metropolitan statistical area, provided by the Bureau of Labor Statistics home page (*http://stats.bls.gov/cpihome.htm*)

SQFT = size of the dwelling, in square feet
Bedroom = number of bedrooms
Bath = number of bathrooms
Lotsize = size of the lot, in square feet
Age = number of years since the residence was constructed
SATscore = average SAT scores for the school district that contains the home

[5] The corridors now carry the names of routes of the state highway network. The SJHTC is the southern extension of State Highway 73, the FTCBB is State Highway 241, and the Eastern Corridor is a combination of an extension of State Highway 133 and portions of State Highways 241 and 261. To avoid confusion with preexisting portions of the state highway network, we refer to the corridors by name rather than number and so will use FTCBB and SJHTC to refer to those two corridors, respectively.

[6] We ran several Box-Cox tests to compare the performance of linear, log, and semi-log specifications and found that the linear specification is preferred. The Box-Cox test results are described later in this section.

CrimeRate = total violent and property crimes per 1,000 residents in the municipality where the home is located

$YEAR_i$ = dummy variable for the year of sale, ranging from 1988 (index "i" = 1) to 1998 (index "i" = 11); 1999 is the omitted year[7]

We measured the effect of distance from the toll road with two variables, DtrBefore and DtrAfter. Both variables measure the straight-line distance from each house to the nearest toll road on-ramp.[8] DtrBefore measures distance to the nearest toll road on-ramp before a threshold year that was chosen to mark when the toll roads became a serious possibility. DtrAfter measures distance to the nearest toll road on-ramp in all years during and after the threshold year. Thus, DtrBefore and DtrAfter are defined as

DtrBefore = Dtr * (1 – ThresholdDummy)

DtrAfter = Dtr * ThresholdDummy

Where Dtr = straight-line distance from each house to the nearest toll road on-ramp

ThresholdDummy = 0 for all home sales that occured before the threshold year; 1 for sales in the threshold year and in subsequent years.

Threshold years are defined both on an a priori basis and by analyzing which definitions of threshold years yielded regressions with a maximum log-likelihood value.

The variables in the hedonic regression include structure-specific characteristics (SQFT, Bedroom, Bath, Lotsize, and Age), neighborhood characteristics (SATscore, CrimeRate), year dummy variables to control for the real estate cycle, and the toll-road distance variables that are the focus of this analysis. The structure-specific and neighborhood characteristics are similar to those used in other hedonic studies (e.g., Dipasquale and Wheaton 1996; Haurin and Brasington 1996; Li and Brown 1980). The structure-specific variables include all variables in the Dataquick data set that were reported with a frequency and reliability that allowed them to be used in this study.[9] The neighborhood variables, SATscore

[7] Data for 2000 were omitted because they included only the first two months of the year. The results in tables 3 and 5 do not change if 2000 data are included in the regression.

[8] Visual examination of GIS maps confirmed that straight-line distance is strongly correlated with street-network distance, due in part to the relatively dense network of surface streets in the corridors we studied. Because we are testing the hypothesis that distance from the toll road is reflected in house values, a good proxy for driving distance will suffice if the hypothesis test is accepted. For that reason, and because of the additional computational difficulty of calculating road-network distance, straight-line distance was used for this analysis.

[9] For example, the variables that denote swimming pools, view properties, and garages were missing in well over half of the observations.

and CrimeRate, were included to control for two local characteristics that can affect house prices. Homes were address matched to school districts and municipalities, and then the SATscore and CrimeRate data for the appropriate year were matched to each sale.

We analyzed sales prices in corridors around the FTCBB and SJHTC both to isolate property markets that were internally homogenous and to focus on areas that would be most likely to experience improvements in accessibility from the toll roads. Initial analyses on the full Orange County data set suggested that the hedonics for different submarkets behaved differently. For example, the price of properties within several miles of the coast is strongly affected by distance from the coast. Also, the markets in the northern and southern half of the county behaved differently both in relation to the time-series properties and in relation to specific hedonic characteristics. Last, we expected accessibility from the toll road to be reflected primarily in the prices of homes along the toll-road corridors.

The corridor around the FTCBB was chosen to include all homes that were closer to a FTCBB on-ramp than to any other toll road or highway on-ramp. There were only 123 home sales within 1,125 feet of the FTCBB, out of 29,197 sales in the FTCBB corridor, and so we did not exclude those few homes for the FTCBB as we did for the other analyses. Nor did we impose a maximum distance cutoff for the FTCBB corridor. Compared with other Orange County highways, the FTCBB is somewhat isolated from the rest of the highway network, since it is in the southeastern quadrant of the county, near foothills and a national forest to the north and east. Of the sales within the FTCBB corridor, approximately 95 percent were within three miles of an FTCBB on-ramp.

The corridor for the SJHTC included all homes more than 1,125 feet from a SJHTC on-ramp and less than two miles from a SJHTC on-ramp. The two-mile limit was imposed to isolate areas near the SJHTC and to avoid places that might be close enough to the parallel Interstate 5 that improvements to that highway would confound the analysis.[10] Also, homes that were closer to an Interstate 5 on-ramp than to a SJHTC on-ramp were excluded from the analysis to reduce the potentially confounding influence of the parallel Interstate 5 corridor.

As we explain later in this section, we also analyzed house prices near an Orange County highway (State Route [SR] 22) that had no important improvements or capacity increases during our study period to verify that our method, when applied to a highway with no improvements,

[10] The Interstate 5 corridor parallel to the SJHTC was improved substantially in the mid-1990s, and thus we wish to attempt to isolate areas where the effect of the SJHTC is likely to dominate the effect of improved accessibility on Interstate 5.

gives no evidence of a change in the distance gradient (or accessibility premium). This provides some assurance that changes in the distance gradient (the coefficients on the DtrBefore and DtrAfter variables), if observed for the toll-road corridors, are due to the opening of the roads.

The literature on hedonic price analyses includes both linear and log-linear specifications. Huang (1994) concludes that there is no single dominant hedonic price specification, and we followed common practice by using a Box-Cox test to examine the relative performance of linear and log-linear specifications of the regression in equation (1). In the log-linear specification, the log of all variables was used. Because the year dummy variables take on a value of zero, the Box-Cox regressions were run separately for each year. Homes with Age equal to zero were dropped from the log-linear specifications and thus from the Box-Cox tests.

To compare the performance of linear and log-linear specifications, we normalized the original data by their geometric means. Pindyck and Rubinfeld (1991) showed that maximum likelihood estimation (MLE) and ordinary least squares (OLS) yield the same results with normalized data. The OLS results of the normalized data for linear and log linear forms can therefore be compared directly, and the best-fitting model with the highest adjusted R^2 is chosen as the preferred specification. For the FTCBB, the linear specification is preferred in every year except 1989. For the SJHTC, the linear specification is preferred in 7 of 13 years—1991 through 1996 and 1998. (Full test results are available from the authors on request.) These results led us to use linear specifications for both the FTCBB and the SJHTC. Because the log-linear specification requires excluding new homes (which have Age equal to zero)—and because new homes constitute approximately one-fifth of all sales in the SJHTC corridor—we felt that the linear specification should be preferred even in the case of the SJHTC, for which the Box-Cox test gave more ambiguous results about the appropriate specification.

We first chose threshold years to reflect the time when the housing market was most likely to view the completion of the two segments of the toll road as a certainty. The results are shown in table 3. For the FTCBB, we chose two thresholds: one year before construction began (1989) and the year it began (1990). The SJHTC was the subject of litigation until early 1993, and so we chose 1993 as the threshold for that corridor.

Looking first at the structure-specific variables, table 3 shows that larger homes sold for a higher price, homes with more bedrooms sold for less in both the FTCBB and SJHTC corridors, more bathrooms increased the sales price in both the FTCBB and SJHTC corridors, and older homes sold for less near the FTCBB and for more near the

Table 3. **Hedonic Regressions for Toll Roads and Freeway Corridors in Orange County**

Corridor	FTCBB		FTCBB		SJHTC		SR 22	
Threshold Year	1989		1990		1993		1993	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
SQFT	79.25	47.60	79.24	47.58	111.57	29.75	46.68	34.67
Bedroom	–9,147.09	–7.24	–9,144.97	–7.24	–9,953.85	–3.54	8,208.17	12.14
Bath	6,289.57	2.73	6,313.33	2.74	13,321.01	2.81	–2,748.86	–2.43
Lotsize	0.29	10.54	0.29	10.55	0.68	3.82	1.67	14.00
Age	–630.81	–3.43	–626.32	–3.40	1,330.69	3.57	374.30	4.31
SATscore	–636.57	–6.42	–635.25	–6.41	706.65	9.28	72.89	7.88
CrimeRate	–83.14	–2.23	–83.52	–2.23	331.04	11.18	–174.00	–23.70
DtrBefore	–0.41	–0.87	–0.56	–1.50	–1.90	–1.47	0.05	0.24
DtrAfter	–0.87	–3.79	–0.88	–3.70	–4.49	–3.68	0.21	1.09
Coast	—	—	—	—	–8.07	–25.37	—	—
Year88	–117,347.50	–6.17	–115,756.60	–6.18	43,398.01	2.51	48,844.72	17.24
Year89	–65,101.13	–3.98	–68,104.03	–4.08	100,242.50	5.90	68,924.61	24.10
Year90	–88,674.52	–5.33	–88,409.07	–5.32	82,295.02	4.92	62,539.14	21.23
Year91	–95,520.78	–5.73	–95,257.12	–5.71	46,260.35	2.78	52,224.63	17.72
Year92	–100,306.40	–6.59	–100,072.10	–6.58	12,169.65	0.75	46,839.39	16.12
Year93	–108,816.10	–7.18	–108,583.20	–7.16	19,643.80	1.58	32,220.19	13.13
Year94	–110,029.30	–7.91	–109,825.20	–7.90	21,250.43	1.74	20,314.01	8.75
Year95	–97,137.43	–8.19	–96,963.47	–8.17	–4,050.22	–0.36	12,635.69	5.67
Year96	–44,415.20	–10.57	–44,378.10	–10.56	–65,332.83	–7.28	–3,444.62	–1.70
Year97	–36,488.80	–9.51	–36,467.50	–9.50	–42,508.31	–5.06	–8,261.37	–4.09
Year98	–15,181.00	–4.13	–15,162.76	–4.13	–6,187.38	–0.74	–5,061.28	–2.71
Constant	761,763.90	6.88	760,367.80	6.87	–629,060.00	–7.59	–45,212.64	–4.18
Number of Observations	10,086		10,086		5,263		4,080	
R^2	0.4117		0.4117		0.5555		0.6217	
Adjusted R^2	0.4105		0.4105		0.5537		0.6198	

Note: The dashes indicate that Coast was not in the model in that column.

SJHTC.[11] Homes in school districts with higher SAT scores sold for more in the SJHTC corridor but for less near the FTCBB. Higher crime rates reduced sales prices near the FTCBB but were associated with higher sales prices near the SJHTC. Both the SJHTC and the FTCBB are in low-crime, upper-income areas with good schools. The “wrong signs” on the SATscore variable for the FTCBB and the CrimeRate variable for the SJHTC likely reflect the small variation in those variables in the corridors we examined and the fact that these variations are correlated with other, unmeasured aspects of geographic desirability. Finally, distance from the coast (in feet) was included for homes in the SJHTC corridor, and, as expected, the effect is negative—homes sold for approximately $42,000 less with each mile from the coast.

The year dummy variables show the time pattern of home prices in Southern California. Home prices appreciated rapidly in the late 1980s, lost value in the recession years of the early 1990s, and began to appreciate again in 1995 for the FTCBB corridor and 1997 for the SJHTC corridor.

The distance variables show the expected pattern: A negative gradient appears after the threshold year for both the FTCBB and the SJHTC. Specifically, the coefficients on DtrBefore are insignificant, and the coefficients on DtrAfter are significantly negative in all three regressions. After the threshold year, home prices in the FTCBB corridor decrease, *ceteris paribus*, by approximately $0.88 per foot, a gradient of approximately $4,600 less in price per mile from the FTCBB. Home prices decrease, *ceteris paribus*, and by approximately $4.49 per foot (or almost $24,000 per mile) from the SJHTC.

While the results in table 3 suggest that the toll roads created an accessibility premium and by inference could have contributed to changing development patterns, we prefer to also analyze different threshold years. We defined threshold years for both the FTCBB and SJHTC that ranged from 1989 to 1998 to examine every possible threshold year without choosing the end points of our data.[12] We ran the regression in equation (1), allowing the threshold year to take on values from 1989 through 1998 and then chose the threshold year that yielded the largest log-

[11] The negative coefficient on Bedroom is indicative of a higher-priced, luxury home market, with larger homes that have relatively few bedrooms. Local real estate experts and people familiar with the Dataquick data agreed that house prices in southern Orange County are more influenced by dwelling size than by the number of bedrooms and that the negative coefficient on Bedroom was not surprising. The positive effect of Age near the SJHTC was likely due to the general newness of homes in the area. For example, real estate experts suggested that new homes, when sold in a resale market, often show price increases because of improvements such as landscaping that are not reflected in the original price.

[12] Choosing end point years as thresholds would create a considerably unbalanced test, since the number of observations in the end point year would be substantially smaller

likelihood value. This allows the data to suggest which threshold year gives the best explanatory power. Log-likelihood values for threshold years for the corridors are shown in table 4.

Table 4. **Log-Likelihood Values for Threshold Years**

Threshold Year	FTCBB	SJHTC
1989	–127,174.87	–69,188.25
1990	–127,174.97	–69,188.27
1991	–127,174.31	–69,187.97
1992	–127,173.17	–69,187.41
1993	**–127,173.12**	–69,186.99
1994	–127,175.30	–69,188.23
1995	–127,175.29	–69,187.99
1996	–127,175.31	–69,186.02
1997	–127,175.25	**–69,185.03**
1998	–127,175.27	–69,185.27

Note: Maximum log-likelihood values are shown in bold.

The log-likelihood surface is quite flat, suggesting that the choice of threshold year has little impact on the overall explanatory power of the hedonic regression. Of course, the choice of threshold year can matter somewhat more for hypothesis tests on the DtrBefore and DtrAfter variables, and so it is reassuring that the maximum likelihood technique gives results that are generally consistent with those in table 3.

For the FTCBB, the maximum log-likelihood value is attained when the threshold year is 1993. Table 5 shows the coefficients and t-statistics for the DtrBefore and DtrAfter variables for each threshold year, so that one can see how the hypothesis tests are affected by the choice of threshold year. For a threshold year of 1993, the coefficient on DtrBefore is insignificant and the coefficient on DtrAfter is significantly negative, consistent with the FTCBB's creating a negative house price gradient with distance from the toll road. The magnitude of the accessibility effect is larger for a threshold year of 1993 than for 1989 or 1990. Also in table 5, the hypothesis of an insignificant DtrBefore coefficient and a negative DtrAfter coefficient is confirmed for any threshold year on or before 1993. FTCBB construction began in 1990, and the first segment of that portion of toll road opened in 1993, so the significantly negative coefficient on DtrBefore for later threshold years likely reflects the fact that the accessibility of the FTCBB is captured in both the DtrBefore and DtrAfter variables for years after 1993. Overall, the results in table

than the number of observations in all other years, creating some concern that statistical results could be driven by those differences in the number of observations. Also, given the span of the data, it is unlikely that the effect of the toll roads would be first felt at either end point year. Last, given that the data for 2000 include only the first two months of that year, we regard 1999 as the end point for purposes of this analysis.

Table 5. **Coefficients and *t*-Statistics for DtrBefore and DtrAfter**

Threshold Year	FTCBB		SJHTC		SR 22	
	Coefficients	t-Statistics	Coefficients	t-Statistics	Coefficients	t-Statistics
1989						
DtrBefore	–0.411	–0.867	–2.909	–1.443	–0.043	–0.107
DtrAfter	**–0.866**	**–3.789**	**–3.358**	**–3.280**	0.167	1.052
1990						
DtrBefore	–0.559	–1.502	–3.184	–1.916	–0.246	–0.859
DtrAfter	**–0.884**	**–3.702**	**–3.316**	**–3.096**	0.270	1.586
1991						
DtrBefore	–0.455	–1.375	–2.393	–1.601	–0.056	–0.224
DtrAfter	**–0.971**	**–3.908**	**–3.724**	**–3.341**	0.237	1.323
1992						
DtrBefore	–0.382	–1.269	–2.010	–1.477	0.007	0.031
DtrAfter	**–1.098**	**–4.207**	**–4.166**	**–3.561**	0.226	1.210
1993						
DtrBefore	–0.430	–1.514	–1.898	–1.471	0.051	0.241
DtrAfter	**–1.139**	**–4.205**	**–4.489**	**–3.681**	0.215	1.092
1994						
DtrBefore	**–0.784**	**–2.919**	**–3.050**	**–2.484**	0.115	0.577
DtrAfter	**–0.834**	**–2.920**	**–3.537**	**–2.760**	0.166	0.798
1995						
DtrBefore	**–0.836**	**–3.254**	**–3.780**	**–3.246**	0.121	0.649
DtrAfter	**–0.761**	**–2.500**	–2.535	–1.838	0.168	0.739
1996						
DtrBefore	**–0.817**	**–3.280**	**–4.558**	**–4.034**	0.197	1.105
DtrAfter	**–0.785**	**–2.425**	–0.865	–0.581	0.023	0.094
1997						
DtrBefore	**–0.770**	**–3.207**	**–4.582**	**–4.227**	0.230	1.356
DtrAfter	**–0.913**	**–2.536**	0.188	0.113	–0.125	–0.447
1998						
DtrBefore	**–0.831**	**–3.555**	**–4.252**	**–4.108**	0.227	1.394
DtrAfter	–0.699	–1.668	1.039	0.517	–0.240	–0.739

Note: Significant coefficients (95 percent two-tailed test) are shown in bold.

5 strongly support the hypothesis that the FTCBB created an accessibility premium that previously did not exist in that corridor.

For the SJHTC, the results in table 4 show that 1997 is the threshold year that maximizes the regression log-likelihood value. The SJHTC opened in November 1996. Looking at the results in table 5, the coefficients on DtrBefore and DtrAfter are the opposite of our hypothesis for a 1997 threshold: DtrBefore is significantly negative in that year, and DtrAfter is not significant. Looking at how the coefficients and hypothesis tests vary with different threshold years, the coefficient on DtrBefore is insignificant for thresholds before 1994, while DtrAfter is significantly negative for thresholds before 1994. For the threshold year 1994, both DtrBefore and DtrAfter are significantly negative, and for later threshold years DtrBefore is significantly negative and DtrAfter is not significant. We believe that these results reflect, at least in part, the effect of substantial improvements completed in the nearby Interstate 5 corridor in the mid-1990s.

The interchange between Interstates 5 and 405—a major peak-hour traffic bottleneck in this region—was substantially improved, and the capacity of the interchange was increased during the mid-1990s. The Interstate 5 corridor is an alternative commuter route for many residents near the SJHTC. To the north and east of the SJHTC, homes farther from the SJHTC are closer to Interstate 5. Thus, one explanation for the insignificant coefficient on DtrAfter for later threshold years is that the expected negative price gradient with distance from the SJHTC is confounded with the negative price gradient, in the opposite direction, from the improved Interstate 5 corridor. Overall, the approximately contemporaneous improvements in the parallel Interstate 5 corridor make it more difficult to isolate an accessibility premium associated with the SJHTC than with the FTCBB. Also, the improvements in the Interstate 5 corridor suggest that earlier threshold years, before the Interstate 5 improvements were completed, might better isolate the premium from the SJHTC. Last, if home buyers anticipated the completion of the SJHTC, a threshold as late as 1997 could include some portion of the accessibility premium in the DtrBefore coefficient. For all these reasons, we believe that earlier threshold years give more reliable information on the effect of the SJHTC, and for threshold years before 1994, the results are consistent with what was found for the FTCBB.

To verify our method, we used our technique to examine a corridor that had no substantial capacity improvements during this time period. We chose the SR 22 corridor in northern Orange County. According to the California Department of Transportation, SR 22 had no important increases in capacity during the study period. We ran the regression in equation (1) on sales farther than 1,125 feet, but less than two miles from SR 22, defining DtrBefore and DtrAfter based on threshold years as was done for the FTCBB and SJHTC. In this case, the threshold years do not reflect real changes in capacity, and so we expect no meaningful difference in the coefficients on DtrBefore and DtrAfter.

In table 3, we chose 1993 as a threshold year for SR 22, since that year is approximately in the middle of the data. The coefficients on DtrBefore and DtrAfter are both insignificant, implying no difference in the effect of distance from the highway before and after the admittedly arbitrarily chosen threshold year. In table 5, we show the coefficients and t-statistics for DtrBefore and DtrAfter for threshold years that range from 1989 through 1998. The coefficients on both distance variables are insignificant for all threshold years, providing robust evidence that the before-and-after test gives no evidence of a change in price gradient for an unimproved corridor. This provides some reassurance that the changes in price gradient for the FTCBB and the SJHTC are associated with the construction of those toll-road segments, and not with any statistical artifact of the analytical technique.

Finally, we examined the validity of running one regression on pooled data for 1988 through 1999.[13] We tested regressions with interaction terms for all independent variables and all year dummy variables. The overwhelming majority of the interaction terms were statistically insignificant, with the exception of the interaction terms for SQFT and LotSize. Given that, we estimated the regressions for tables 3 and 5 with SQFT and LotSize interacted with the year dummy variables, as shown:

$$P = \alpha_0 + \alpha_1\text{SQFT} + \sum_{i=1}^{11}\delta_i\text{SQFT} * \text{YEAR}_i + \alpha_2\text{Bedroom} + \alpha_3\text{Bath} + \alpha_4\text{Lotsize} + \sum_{i=1}^{11}\gamma_i\text{Lotsize} * \text{YEAR}_i + \alpha_5\text{Age} + \alpha_6\text{SATscore} + \alpha_7\text{CrimeRate} + \alpha_8\text{DtrBefore} + \alpha_9\text{DtrAfter} + \sum_{i=1}^{11}\beta_i\text{YEAR}_i + \varepsilon \quad (2)$$

In the above regression, SQFT * YEAR_i is an interaction variable for SQFT and the 11 year dummy variables, and Lotsize * YEAR_i is similarly defined.

Compared with the results in table 3, the only change from estimating the regression shown above is that the coefficient on DtrAfter is significantly negative at the 10 percent level, rather than the 5 percent level, for a threshold year of 1990. The results for the SJHTC from tables 3 and 5 are unchanged when regression (2) is run. For the FTCBB, the pattern reported in table 5 also persists when regression (2) is used. Overall, there are essentially no changes to the pattern of hypothesis tests on DtrBefore and DtrAfter around reasonable threshold years if the regression in equation (2) is used, suggesting that the results reported in tables 3 and 5 are robust when more flexible specifications that allow variation in coefficients across years are used. We conclude that

[13] Because we expect the coefficients on the DtrBefore and DtrAfter variables to vary during the time period we study, a Chow test implemented on the regression in equation (1) should, and does, reject the hypothesis of equal coefficient vectors for comparisons of data sets that are split at or near the preferred threshold years. Eliminating the toll-road distance variables from the regression for purposes of a Chow test is also problematic, since other structure-specific or location-specific variables can be correlated with distance from the toll roads and hence could pick up the effect of a changing accessibility premium. For those reasons, we examined the issue of structural equivalence across different years by running a regression with interaction terms for the independent variables and year dummy variables, as discussed later.

any structural equivalence issues across the years in our data set do not affect our hypothesis tests on DtrBefore and DtrAfter.

Overall, the evidence for an accessibility premium is strong for both corridors. In the case of the FTCBB, the hypothesis tests are consistent with our expectations for any threshold year up to and including the year the toll road opened, 1993. For the SJHTC, the hypothesis tests similarly give evidence of a land-price gradient appearing for threshold years up to and including the year the litigation for that road was settled, also 1993. For threshold years after 1993, both DtrBefore and DtrAfter are significantly negative for the FTCBB, which is expected since for threshold years after 1993 the road was open during both the "before" and "after" periods tested by the regression. For the SJHTC, the DtrAfter variable is insignificant for threshold years 1995 or later, which we believe reflects the improvements to the parallel Interstate 5 corridor during the mid-1990s.

Multiple sales price analysis

An alternative method of analyzing house price changes is to develop indices based on multiple sales of the same property (e.g., Bailey, Muth, and Nourse 1963; Case, Pollakowski, and Wachter 1991). The advantage of this technique is that it controls for any time-invariant characteristics of the property or location, including characteristics that cannot be measured in the data set. When applied to an event study such as the construction of the toll roads, it is typical to develop multiple sales price indices for two areas, an area near the toll road (a treatment group, to borrow terminology from standard research design literatures) and an area more distant from the toll road (a control group). For an example of this technique applied to the Miami rail transit system, see Gatzlaff and Smith (1993).

The treatment and control groups must be chosen by the researcher and should be as similar as possible for all characteristics other than the event being examined. For our purposes, this implies choosing areas near the toll-road corridor and more distant from the corridor that are otherwise similar. While choosing areas near and very distant from the toll road clearly creates a stark difference in toll-road accessibility across the two groups, it also risks comparing areas that are not otherwise similar. In particular, the toll-road corridors generally run through middle- and upper-income areas in the rapidly growing suburban fringe of southern Orange County. Past research has demonstrated that price indices in different locales appreciate differently, in ways that appear to be linked to neighborhood characteristics (Case and Mayer 1996; Case and Shiller 1994; Mayer 1993; Smith and Tesarek 1991). For example, preliminary analysis of our data suggested that southern Orange County emerged earlier and more strongly from the depressed real estate market of the early and mid-1990s. For those and other reasons, we chose control and treatment groups that are relatively close to each other, so that the two groups would likely differ only in access to the toll roads.

For both the FTCBB and the SJHTC, the treatment group is homes between 1,125 feet and one mile from the nearest toll road on-ramp. The control group is homes between two and three miles from the nearest toll road on-ramp. More dramatic variation in distance from the toll road, and thus toll-road access, would have allowed a starker comparison, but given the development patterns in Orange County, we felt that choosing homes farther than three miles from the toll road risked comparing control and treatment groups that were not sufficiently similar.

For both the FTCBB and SJHTC, we developed multiple sales price indices for homes in the nearby (1,125 feet to one mile) and more distant (two to three miles) corridors. Given that the FTCBB and SJHTC were constructed and opened during the time our data spanned, we expect nearby homes to get a larger accessibility premium and thus appreciate faster than homes in the more distant corridor.

Following Gatzlaff and Smith (1993), the regression for developing the sales price index is

$$\ln(P2_i/P1_i) = \beta_1(Y88_i) + \beta_2(Y89_i) + \ldots + \beta_{13}(Y00_i) + \varepsilon \qquad (3)$$

where P1 = first sale for the same property
P2 = second sale for the same property
Y88 = dummy variable equal to –1 if first sale was in 1988, 1 if the second sale was in 1988, 0 otherwise
dummy variables for Y89 through Y00 correspond to the years 1989 through 2000, and are defined similarly to Y88
ε = regression error term

The estimated coefficients from equation (3) can be used to calculate price indices. As an example, for a house that sold once in 1988 and again in 1992, equation (3) becomes

$$P2_i/P1_i = \exp(\beta_5 - \beta_1)$$

Thus, for any two years, the ratio of home sales prices in those years is the difference in the corresponding estimated regression coefficients for the latter year minus the initial year. Using that relationship, home sales price indices were calculated for each year, normalizing the index for 1988 at 100.

Sales price indices for the nearby (1,125 feet to one mile) and more distant (two to three miles) corridors around the FTCBB are shown in table 6. These indices for the FTCBB are derived from the regression

Table 6. **House Price Indices in Toll Road Corridors by Year**

	FTCBB		SJHTC	
Year	1,125 feet to 1 mile	2 to 3 miles	1,125 feet to 1 mile	2 to 3 miles
1988	100.00	100.00	100.00	100.00
1989	127.23	121.37	125.86	115.75
1990	119.90	118.40	127.00	120.83
1991	117.30	113.84	120.00	117.92
1992	114.82	110.04	115.69	113.18
1993	104.55	104.03	107.33	103.71
1994	104.81	100.81	105.84	103.84
1995	**103.04**	98.75	**104.47**	103.23
1996	101.28	**100.32**	103.10	110.35
1997	105.81	101.89	112.32	116.79
1998	124.84	120.06	129.17	133.05
1999	138.78	133.43	142.38	145.91
2000	146.56	135.75	—	—

Note: Interpolated indices are shown in bold. The dashes indicate that the index was not developed for the year 2000 in that column.

coefficients shown in appendix A and are graphed in figure 2. Note that the nearby index appreciates more rapidly during the last few years of our study period, consistent with the toll road's creating an accessibility premium that caused nearby houses to appreciate more rapidly.

Because the price indices in table 6 are derived from regression coefficients that are point estimates, the price indices and, similarly, the change in price indices for the nearby and more distant corridors are estimated from the data. We examined whether the change in the regression coefficients from 1988 through 2000 was significantly different across the two corridors. In table 7, we show the change in the regression coefficient from 1988 to 2000 (the coefficient on the 2000 dummy variable minus the coefficient on the 1988 dummy variable) and the standard error of that change for both the nearby and more distant FTCBB corridors. We also show the 90 percent and 95 percent confidence intervals for the change in coefficients from 1988 to 2000 for both the nearby and more distant corridors. Note that the 90 percent confidence intervals for the change in year coefficients do not overlap, implying that the changes in the year coefficients, and hence house price appreciation, are significantly different for the nearby and more distant FTCBB corridors at the 90 percent confidence level.

Also in table 6, we show the price indices for the nearby and more distant corridors around the SJHTC toll road. A graph of those price indices is shown in figure 3, and the coefficients from the estimating equation for the nearby and more distant SJHTC corridors are shown in appendix B. Table 6 and figure 3 indicate that the index for the nearby corridor is higher than the index for the more distant corridor until 1996. In 1996 and later years, the more distant corridor has a higher

Figure 2. **House Price Indices in the FTCBB Corridors**

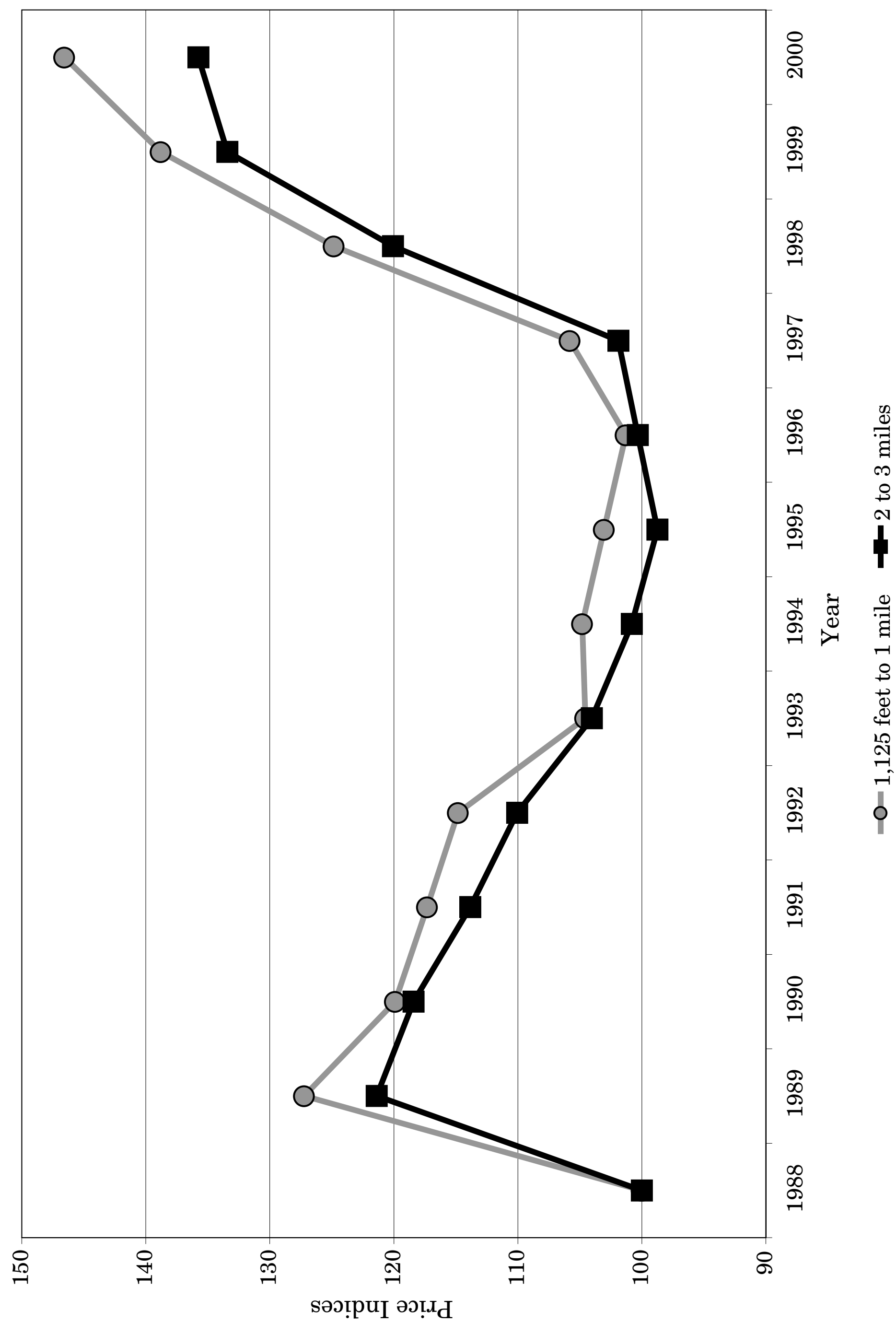


Table 7. **Changes in Coefficients for Determining House Price Indices in Toll-Road Corridors**

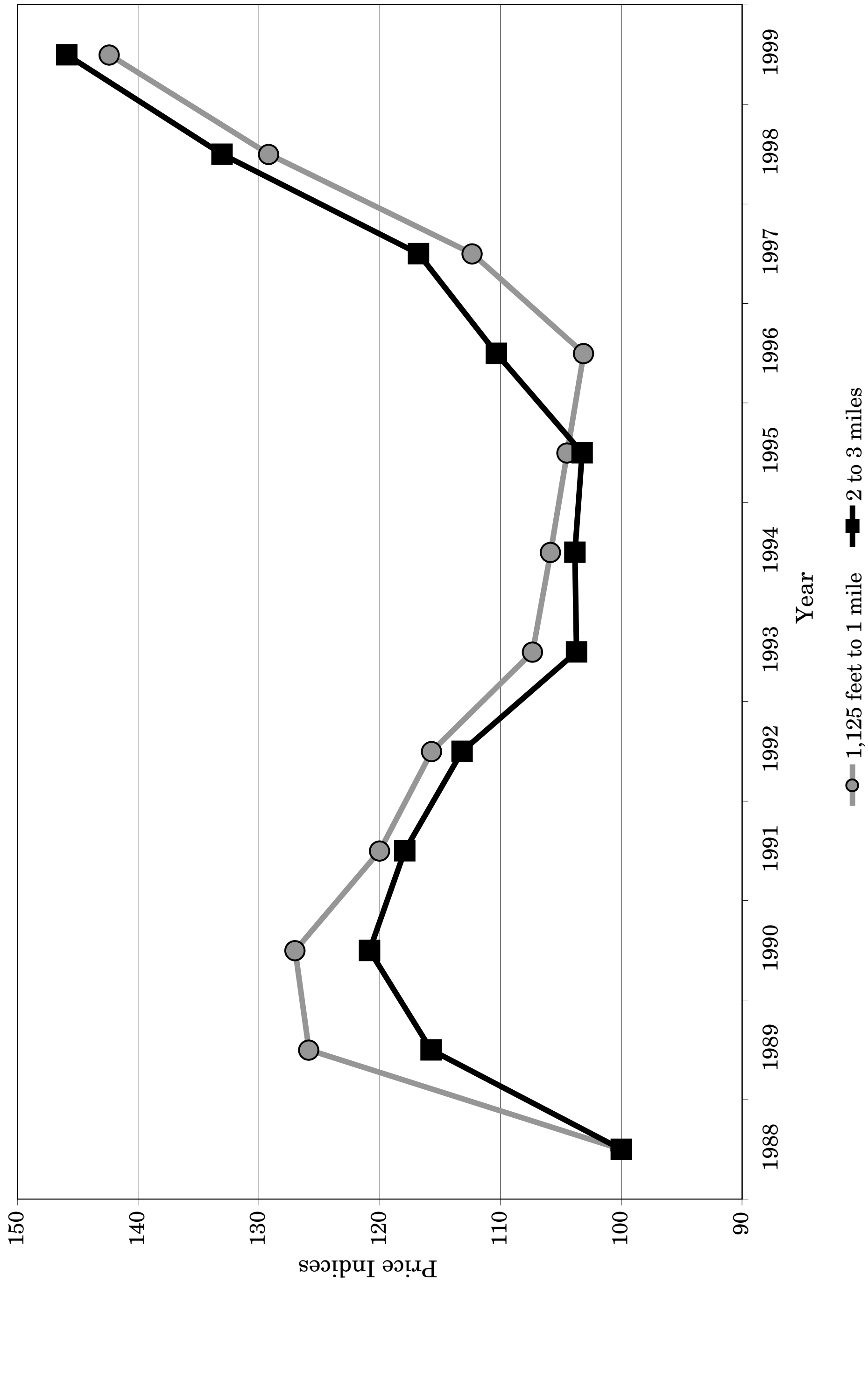
Toll-Road Corridors	Treatment/Control Corridors	Changes in Coefficient	Standard Errors	90% Confidence Intervals		95% Confidence Intervals	
				Lower	Upper	Lower	Upper
FTCBB	1,125 feet to 1 mile	0.3823	0.0186	0.3517	0.4129	0.3451	0.4195
	2 to 3 miles	0.3057	0.0230	0.2679	0.3434	0.2597	0.3516
SJHTC	1,125 feet to 1 mile	0.3533	0.0173	0.3249	0.3817	0.3188	0.3879
	2 to 3 miles	0.3778	0.0574	0.2835	0.4721	0.2631	0.4925

Note: Changes in coefficients are from 1988 to 2000 for FTCBB and from 1988 to 1999 for SJHTC.

price index. In table 7, we show the change in the regression coefficient from 1988 to 2000 for both the nearby and more distant corridors, the standard error of that change, and the 90 and 95 percent confidence intervals for the change in year coefficients over the study period. The 90 percent confidence intervals for the nearby and more distant corridors for the SJHTC overlap, implying that there is no statistically significant difference in appreciation across the nearby and more distant corridors from 1988 to 2000.

Overall, the results from the multiple sales price method indicate that the FTCBB positively influenced the appreciation of nearby homes, but give no evidence for a similar effect on home price appreciation for the SJHTC. It is important to note that the multiple sales price method is especially limited when applied to the SJHTC corridor. This technique requires that the two corridors (nearby and more distant) be identical in all characteristics other than access to the toll road. For the SJHTC, that assumption is problematic because it is approximately four to five miles from the coast, such that homes south of the SJHTC are almost certainly influenced by the desirability of coastal locations. Similarly, homes in the more distant corridor to the north of the SJHTC are within a few miles of the Interstate 5 corridor and could have benefited from the improvements in capacity on that corridor that occurred at roughly the same time the SJHTC opened. Overall, we find it very difficult to believe that the nearby and more distant corridors around the SJHTC provide a good controlled experiment that holds factors other than toll-road access constant. In that regard, the FTCBB provides a cleaner experiment, and we also prefer to give more weight to the hedonic regressions for both the FTCBB and the SJHTC, since the hedonic analysis allows some ability to control for potentially confounding factors. Therefore, we conclude that the multiple sales price technique for the SJHTC illustrates the difficulty of finding good control and experimental corridors around that toll road, and we are persuaded by the evidence from the cross-sectional regressions and the multiple sales price technique for the FTCBB that the toll roads created an accessibility premium that is reflected in home sales prices beginning approximately in the mid-1990s.[14]

Figure 3. **House Price Indices in the SJHTC Corridors**



Conclusion

The empirical analysis provides evidence that the construction of the first two portions of the Orange County toll-road network created accessibility premiums that are reflected in home sales prices. The evidence is especially strong in that regard for the FTCBB and suggests that the accessibility premium for that road shows up with increasing magnitude until the time the first portion of the FTCBB opened. This finding is consistent with what standard urban and land use theory would predict. While the evidence of an accessibility premium is not as strong for the SJHTC, we conclude that much of the ambiguity in the statistical results for that corridor is caused by other confounding factors correlated with distance from the road. It is encouraging that the hedonic regressions, which allow some ability to control for confounding influences, give evidence of the appearance of an accessibility premium after the litigation over the SJHTC had concluded.

The implication for induced travel is that the evidence from Orange County suggests rather strongly that new highways change the geographic pattern of accessibility, that those changes are reflected in home sales prices, and that it is thus reasonable to conclude that new highways will also create changes in development patterns. Another conclusion from this study is that both the FTCBB and the SJHTC improved accessibility near the corridors in ways that home buyers valued. The evidence in this study indicates that home buyers are willing to pay for the increased access the new roads provided.[15] It is that willingness to pay for increased access that influences both development patterns and, potentially, induced traffic.

Overall, our results are consistent with recent research suggesting that induced travel is a real phenomenon and consistent with the hypothesis that changes in development patterns are one cause of induced travel. Certainly, our research is still an initial step. Future research should

[14] As in the cross-sectional regression analysis, we also used the multiple sales price technique to examine price indices in nearby (1,125 feet to one mile) and more distant (two to three mile) corridors around SR 22. As we expected, the price indices tracked each other very closely, and the change in the year dummy variables for the nearby and more distant corridors were not statistically significantly different from each other. SR 22 does not have the confounding influences of coastal access and proximity to other parallel and improved corridors that made interpreting the SJHTC results problematic, so the results of the multiple sales price technique applied to SR 22 suggest that there is no change in accessibility premium associated with that road during the study period. That was expected, since SR 22 had no important capacity improvements from 1988 to 2000.

[15] Given that the FTCBB and SJHTC are toll roads, travelers already pay for using them. The evidence in this article shows that home buyers are also willing to pay for the accessibility created by those roads through higher home prices.

examine how the changes in house prices (and thus land prices) reported here are reflected in intrametropolitan growth patterns and whether and how those growth patterns changed after the toll roads were built. For now, the results are consistent with the idea that induced travel is caused, in part, by changes in urban development patterns linked to increases in highway capacity.

Appendix

Table A.1. **Regression Results for the Multiple Sales Price Analysis for FTCBB**

	1,125 feet to 1 mile		2 to 3 miles	
Variables	Coefficient	t-Statistic	Coefficient	t-Statistic
Y88	–0.0176	–2.1160	0.0286	2.7430
Y89	0.2232	27.4040	0.2223	19.8160
Y90	0.1639	18.2810	0.1975	17.5240
Y91	0.1420	16.0150	0.1582	13.4770
Y92	0.1206	13.5740	0.1243	10.6340
Y93	0.0270	2.9760	0.0681	5.7170
Y94	0.0294	3.2310	0.0366	3.0790
Y95	(dropped)	—	0.0159	1.3040
Y96	–0.0048	–0.5250	(dropped)	—
Y97	0.0389	4.3570	0.0473	4.0730
Y98	0.2043	23.4800	0.2114	19.0520
Y99	0.3102	34.5120	0.3170	27.5590
Y00	0.3647	21.8940	0.3342	16.3360
Number of observations	2,016		1,594	
R^2	0.6901		0.5899	
Adjusted R^2	0.6882		0.5868	

Table A.2. **Regression Results for the Multiple Sales Price Analysis for SJHTC**

	1,125 feet to 1 mile		2 to 3 miles	
Variables	Coefficient	t-Statistic	Coefficient	t-Statistic
Y88	–0.0477	–4.1150	–0.4473	–11.1570
Y89	0.1823	15.8240	–0.3011	–7.3210
Y90	0.1913	15.5370	–0.2581	–6.2950
Y91	0.1346	10.6240	–0.2824	–6.8100
Y92	0.0981	7.4890	–0.3235	–7.4590
Y93	0.0231	1.6980	–0.4109	–9.8240
Y94	0.0091	0.7110	–0.4097	–10.2590
Y95	(dropped)	—	–0.4155	–9.9790
Y96	–0.0172	–1.2950	–0.3489	–8.3490
Y97	0.0685	5.6740	–0.2921	–7.2800
Y98	0.2083	16.4830	–0.1617	–4.0110
Y99	0.3057	23.8900	–0.0695	–1.6950
Y00	0.3459	14.0850	(dropped)	—
Number of observations	1,644		479	
R^2	0.5784		0.5303	
Adjusted R^2	0.5753		0.5182	

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This research was supported by grants from the U.S. Environmental Protection Agency and the University of California Transportation Center. The University of California Transportation Center is funded by the U.S. and California Departments of Transportation. Participants at a symposium on induced travel held at the University of California at Berkeley in June 2000, at the 2000 Association of Collegiate Schools of Planning meetings, and at the 2001 Transportation Research Board annual meetings all provided helpful comments on this research. Michael Greenwald, Lewison Lem, and Robert Noland, in particular, provided helpful insights throughout the course of this research, and we are grateful for the comments of the anonymous referees. The house price data used in this analysis were graciously provided by Dataquick, Inc., and we thank John Karevoll of Dataquick for his assistance in obtaining them. The California Department of Transportation and Geographic Data Technology, Inc., provided GIS maps for the highway and toll-road network. The authors alone are responsible for the analysis and interpretations.

References

Adkins, William G. 1959. Land Value Impacts of Expressways in Dallas, Houston, and San Antonio, Texas. Bulletin 227. Washington, DC: Highway Research Board.

Bailey, Marin J., Richard Muth, and Hugh O. Nourse. 1963. A Regression Method for Real Estate Price Index Construction. *Journal of the American Statistics Association* 4:933–42.

Boarnet, Marlon G., and Andrew F. Haughwout. 2000. Do Highways Matter? Evidence and Policy Implications of Highways' Influence on Metropolitan Development. Washington, DC: Brookings Institution Center on Urban and Metropolitan Policy. Also available at <http://www.brookings.edu/es/urban/boarnet.pdf> (last modified August 2000).

Bradford, David F., and Harry H. Kelejian. 1973. An Econometric Model of the Flight to the Suburbs. *Journal of Political Economy* 81(3):566–89.

California Department of Finance. 1999. California Demographic Research Unit Reports. World Wide Web page <http://www.dof.ca.gov/html/Demograp/repndat.htm> (accessed November 1999).

California Department of Justice, Justice Statistics Center. 1999. *California and FBI Crime Index Statewide by Jurisdiction.* World Wide Web page <http://caag.state.ca.us/cjsc/datatabs.htm> (accessed November 1999).

Case, Bradford, Henry O. Pollakowski, and Susan Wachter. 1991. On Choosing among House Price Index Methodologies. *AREUEA Journal* 19(3):286–307.

Case, Karl E., and Christopher J. Mayer. 1996. Housing Price Dynamics within a Metropolitan Area. *Regional Science and Urban Economics* 26(4):387–407.

Case, Karl E., and Robert J. Shiller. 1994. A Decade of Boom and Bust in the Prices of Single-Family Homes: Boston and Los Angeles, 1983 to 1993. *New England Economic Review*, March-April 1994, pp. 40–51.

Cervero, Robert, and John Landis. 1995. The Transportation–Land Use Connection Still Matters. *ACCESS*, No. 7. Berkeley, CA: University of California Transportation Center.

Dipasquale, Denise, and William C. Wheaton. 1996. *Urban Economics and Real Estate Markets.* Englewood Cliffs, NJ: Prentice Hall.

Downs, Anthony. 1962. The Law of Peak-Hour Expressway Congestion. *Traffic Quarterly* 16(3):393–409.

Downs, Anthony. 1992. *Stuck in Traffic: Coping with Peak-Hour Traffic Congestion.* Washington, DC: Brookings Institution.

Gatzlaff, Dean H., and Marc T. Smith. 1993. The Impact of the Miami Metrorail on the Value of Residences near Station Locations. *Land Economics* 69(1):54–66.

Giuliano, Genevieve. 1989. Research and Policy Review 27: New Directions for Understanding Transportation and Land Use. *Environment and Planning A* 21:145–59.

Giuliano, Genevieve. 1995. The Weakening Transportation–Land Use Connection. *ACCESS*, No. 7. Berkeley, CA: University of California Transportation Center.

Goodwin, Phil B. 1996. Empirical Evidence on Induced Traffic. *Transportation* 23(1):35–54.

Hansen, Mark, and Yuanlin Huang. 1997. Road Supply and Traffic in California Urban Areas. *Transportation Research A* 31(3):205–18.

Haurin, Donald R., and David Brasington. 1996. School Quality and Real House Prices: Inter- and Intrametropolitan Effects. *Journal of Housing Economics* 5(4):351–68.

Hills, Peter J. 1996. What Is Induced Traffic? *Transportation* 23(1):5–16.

Huang, William. 1994. The Effects of Transportation Infrastructure on Nearby Property Values: A Review of the Literature. Institute of Urban and Regional Development (IURD) Working Paper No. 620. Berkeley, CA: University of California.

Langley, C. John Jr. 1976. Time-Series Effects of a Limited-Access Highway on Residential Property Values. *Transportation Research Record* 583:36–44.

Langley, C. John Jr. 1981. Highways and Property Values: The Washington Beltway Revisited. *Transportation Research Record* 812:16–20.

Li, Mingche M., and H. James Brown. 1980. Micro-Neighborhood Externalities and Hedonic Housing Prices. *Land Economics* 56(2):125–41.

Mayer, Christopher J. 1993. Taxes, Income Distribution, and the Real Estate Cycle: Why All Houses Do Not Appreciate at the Same Rate. *New England Economic Review,* May-June, 1993, pp. 39–50.

Mills, Edwin S., and Richard Price. 1984. Metropolitan Suburbanization and Central City Problems. *Journal of Urban Economics* 15(1):1–17.

Mohring, Herbert. 1961. Land Values and the Measurement of Highway Benefits. *Journal of Political Economy* 69(3):236–49.

Noland, Robert B. 2001. Relationships between Highway Capacity and Induced Travel. *Transportation Research A* 35(1):47–72.

Noland, Robert B., and William A. Cowart. 2000. Analysis of Metropolitan Highway Capacity and the Growth in Vehicle Miles of Travel. *Transportation* 27(4):263–90.

Noland, Robert B., and Lewison L. Lem. 2000. Induced Travel: A Review of the Recent Literature and the Implications for Transportation and Environmental Policy. Paper presented at the European Transport Conference, Cambridge, England, September 2000 and the Conference of the Association of Collegiate Schools of Planning, Atlanta, November 2000.

Orange County High School Performance Report. 1999. *Los Angeles Times* On-line Archive, Orange County Edition, Metro Section, 1989 to 1999. World Wide Web page <http://latimes.com/archives/> (accessed December 1999).

Palumbo, George, Seymour Sacks, and Michael Wasylenko. 1990. Population Decentralization within Metropolitan Areas: 1970–1980. *Journal of Urban Economics* 27(2):151–67.

Payne-Maxie Consultants. 1980. *The Land Use and Urban Development Impacts of Beltways, Final Report.* Prepared for the U.S. Department of Transportation and the U.S. Department of Housing and Urban Development. Washington, DC: U.S. Government Printing Office.

Pindyck, Robert S., and Daniel L. Rubinfeld. 1991. *Econometric Models and Economic Forecasts.* New York: McGraw-Hill.

Rosen, Sherwin. 1974. Hedonic Prices and Implicit Markets—Product Differentiation in Pure Competition. *Journal of Political Economy* 82(1):34–55.

Smith, Barton A., and William P. Tesarek. 1991. House Prices and Regional Real Estate Cycles: Market Adjustments in Houston. *AREUEA Journal* 3(3):396–416.

Standing Advisory Committee on Trunk Road Assessment. 1994. *Trunk Roads and the Generation of Traffic.* London: U.K. Department of Transport.

Transportation Corridor Agencies. 1999. World Wide Web page <http://www.tcagencies.com> (accessed November 1999).

Voith, Richard. 1993. Changing Capitalization of CBD-Oriented Transportation Systems—Evidence from Philadelphia, 1970–1988. *Journal of Urban Economics* 33(3):361–76.