**Title**
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**Publication Date**
2000-12-01

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UCI-ITS-AS-WP-00-12

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December 2000

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# New Highways, Urban Development, And Induced Travel

TRB Paper Number: 01-2996

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We examine the link between highways and urban development, by employing both hedonic analysis and multiple sales techniques to study the impact on house prices of the construction of toll roads in Orange County, California. 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 in particular, created an accessibility premium – homebuyers are willing to pay for the increased access that the new roads provided. Such willingness to pay influences both development patterns and, potentially induced traffic. 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.

## I. INTRODUCTION

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 increasingly been cited as a basis for rethinking travel demand modeling, land-use/transportation interactions, and the environmental impacts of highway projects. Yet the debate remains contentious, in part because the empirical evidence on induced travel is mostly from aggregate data that are better suited to establishing correlations than causality. As Noland and Lem (*1*) note, the studies to date, while often supportive of the hypothesis, do little to illuminate the behavioral underpinnings of the phenomenon. This paper 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 more travel. This is part of the underpinning of Downs' (*2*) "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 (see, e.g., Noland and Lem (*1*); Downs (*3*); Hills (*4*)).

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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.

The focus of this paper is on the link between highways and urban development. Specifically, this paper is a "before and after" study of the impact on house prices of the construction of toll roads in Orange County, California. Since 1993, fifty-one new centerline miles of toll road have opened in Orange County. Collectively, those roads extend the County'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 the influence of highway improvements on urban growth patterns acts 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 developed more densely. 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, development patterns, and induced travel requires first understanding those three related literatures, which we summarize below.

## II. LITERATURE REVIEW

### Induced Travel

Downs (*2*) offered one of the earliest theoretical justifications for induced travel, stating the 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 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 research of Goodwin (*5*), Hansen and Huang (*6*), and the report of the Special Advisory Commission on Truck Road Assessment (*7*). The SACTRA (*7*) report examined traffic growth in corridors that had increases in capacity, and also compared actual and forecast travel along new and improved corridors. Both pieces of evidence led SACTRA (*7*) to conclude that induced travel is a real phenomenon, concluding that, on average, traffic increased by 77% due to capacity expansion.

Hansen and Huang (*6*) used panel data for California counties to examine statistically how VMT is influenced by state highway lane miles, controlling for other factors such as county population and per capita income. They concluded that the elasticity of VMT with respect to lane miles ranged from 0.3 to 0.7 for counties and 0.5 to 0.9 for metropolitan areas. Virtually all elasticity point estimates were significant at conventional (5% or better) levels.

Noland (forthcoming) found similar results using the same methodology with data for U.S. states, and Noland and Cowart (forthcoming) also found similar results with data on metropolitan areas from the mid-Atlantic region of the United States. The results have provided support for the idea that induced travel is an important transportation phenomenon, but the issue of causality remains a point of some controversy. As Noland and Lem (*1*) 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 paper 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 (*8*), suggests that transportation infrastructure is only one of several factors that influence metropolitan decentralization, although there is debate about the relative importance of transportation versus other factors (see, e.g., the exchange between Cervero and Landis (*9*) and Giuliano, (*10*)).

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 (*12*) that examined the influence of suburban beltways on the growth of suburbs and central cities in fifty-four United States metropolitan areas. The authors conclude that beltways have little impact on overall growth of the metropolitan area, but they also conclude that the intra-metropolitan economic and land use effects that do exist are likely to be transfers from one place to another within the metropolitan area (Payne-Maxie (*12*), pp. 114-116). Yet the work by Payne-Maxie (*12*), and similar articles on the determinants of decentralization such as Bradford and Kelejian (*13*), Mills and Price (*14*), and Palumbo, Sacks, and Wasylenko (*15*), divided metropolitan areas into two components – central cities and the remaining suburban ring. This geographic focus is relatively crude and allows little analysis of 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 geographic 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 (e.g. Adkins (*16*); Mohring (*17*)). The technique of hedonic price analysis was later formalized by Rosen (*18*), and there have since been several studies of the impact of highways on house prices. Huang (*19*) reviewed the literature on hedonic price studies of the influence of highway access on house prices. He 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 (*11*), in reviewing the literature on the effect of transportation infrastructure on urban development, comes to the same conclusion – namely that later studies show a smaller impact of highway access on home values. Both Giuliano (*11*) and Huang (*16*) argue that, as the highway system was developed in many urban areas, the value of access to any particular highway was reduced because accessibility is now generally good throughout the network in most United States cities. Huang also notes that, for residential properties, noise and other disamenities will reduce the value of locating close to a highway. Langley (*20*, *21*), in a study of homes near the Washington Beltway, concluded that house prices increase with distance from the highway out to a distance of 1,125 feet, and then decrease with distance beyond 1,125 feet. Langley 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 (*10*, *11*), in reviewing both literatures, concluded that the influence of transportation on urban development patterns is growing less important. Yet most of the evidence that led Giuliano to that conclusion is based on data that are aggregated to broad geographic distinctions such as central cities and suburban rings. A more recent hedonic price study, by Voith (*22*), found that highway access (measured by travel time by highway to the 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 that are 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.

## III. RESEARCH STRATEGY

In this research, we take advantage of the fact that a substantial network of new tolled highways was built in Orange County, California during the 1990s. This provides an opportunity to address the question of causality in ways that many other studies cannot. If the toll roads changed that pattern of accessibility in Orange County, that 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), a special purpose government agency formed in 1986 with the sole purpose of building the roads. Portions of the toll road network exist in County planning documents that date to the 1970s. Yet it was not until the TCAs developed a plan to raise money primarily through tolls, first proposed in 1988, that the prospect of 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 Corridor Backbone, was opened in 1993; the San Joaquin Hills Transportation Corridor opened in 1996, and later portions of the Foothill and Eastern Transportation corridors opened in 1999. Figure 1 shows the toll road network. Figure 1 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 that construction started and the date the construction was completed.

Even with some foresight on the part of home buyers, we expect that the market assessment of the likelihood that the roads would be built will 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 San Joaquin Hills corridor was the subject of litigation until 1993. In all, the TCAs have opened fifty-one new centerline miles of toll highway in Orange County. Of those toll roads, the two segments the opened the earliest – the Foothill Corridor Backbone and the San Joaquin Hills Corridor – are the focus of this study, as they were built and opened in essentially the middle of the span of 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. (fn – Based on Langley's results (*20*, *21*) we exclude homes that are within a 1,125 of the toll road, to avoid confounding the value of access with noise and other disamenities that are experienced close to highways.) Threshold years are chosen to reflect when the housing market most likely viewed the road as being likely to be built. Different threshold years were tested, as is discussed in Section V, below.

## IV. DATA

Dataquick, Inc. provided information about physical characteristics of houses, such as dwelling size, lot size, number of bedrooms, number of bathrooms, and street address, and information on house sales, such as year of sale, price, and loan amount. Geographic Data Technology, Inc. and California Department of Transportation provided GIS maps of Orange County's street network, which include the center lines of freeways, toll roads, and local roads, as well as the entrance and exit ramps of all grade-separated highways. Two major neighborhood characteristics are used in this study, namely crime rate and school quality. School quality was proxied by average SAT score. Crime rates were calculated based on data from California Department of Justice's Justice Statistics Center (*23*) and the California State Department of Finance Demographic Research Unit (*24*). SAT scores for Orange County were obtained from the Los Angeles Times (*25*).

There are 367,841 records of single-family detached dwelling unit sales in Orange County from 1988 to the first quarter of 2000. We used Arcview-GIS to geocode the home addresses based on the street network map mentioned earlier, and selected only those that were perfectly matched, i.e. the street number is found on a street segment with the exact same name as 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. We also used Arcview-GIS to link the locational characteristics to each house. A school district and police department jurisdiction is assigned to each house by joining the house location from the address match to the both the school district and police department jurisdiction base maps. Then, an SAT score and crime rate were assigned to each house transaction based on the year of sale and the school district or police department jurisdiction associated with the house's location.

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. We also dropped observations with inconsistent data, such as a four-bedroom house with floor area 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 sales price less than $25,000 and observations with loan amounts greater than 125% of the sale price. See Table 2 for the distribution of number of observations by year after the inappropriate data was 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.

## V. HEDONIC PRICE REGRESSIONS

We analyzed access to toll roads using a hedonic price analysis for corridors surrounding the two oldest segments of the toll road network – the Foothill Transportation Corridor Backbone (FTCBB) and the San Joaquin Hills Transportation Corridor (SJHTC).[2] The regression specification is shown below.

$$\begin{aligned} P = {} & \alpha_0 + \alpha_1 SQFT + \alpha_2 Bedroom + \alpha_3 Bath + \alpha_4 Lotsize + \alpha_5 Age + \\ & \alpha_6 SATscore + \alpha_7 CrimeRate + a_8 DtrBefore + \alpha_9 DtrAfter \\ & \sum_{i=1}^{12} \beta_i YEAR_i + \varepsilon \end{aligned} \tag{1}$$

Where P = home sales price
SQFT = size of dwelling, in square feet
Bedroom = number of bedrooms
Bath = number of bathrooms
Lotsize = size of lot, in square feet
Age = number of years since residence was constructed
SATscore = average SAT scores for the school district that contains the home
CrimeRate = total violent and property crimes per 1,000 residents in the municipality where home is located
$YEAR_i$ = Dummy variable for year of sale, ranging from 1988 (index "i" = 1) to 1999 (index "i" = 12); 2000 is the omitted year

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.[3] *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 shown below.

DtrBefore = Dtr*(1 – ThresholdDummy)
DtrAfter = Dtr*ThresholdDummy

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[2] The corridors now carry the names of routes of the state highway network. The San Joaquin Hills corridor is the southern extension of State Highway 73, the Foothill corridor 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 pre-existing 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.

[3] Visual examination of GIS maps confirmed that straight-line distance is strongly correlated with street network distance. This is due in part to the relatively dense network of surface streets in the corridors that 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 due to the additional computational difficulty of calculating road network distance, straight-line distance was used for this analysis.

Where Dtr = straight-line distance from each house to the nearest toll road on-ramp
ThresholdDummy = 0 for all home sales that occur 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 (*26*); Haurin and Brasington (*27*); Li and Brown (*28*)). 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.[4] The neighborhood variables, *SATscore* 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 was 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 sub-markets 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. Lastly, we expected accessibility fro the toll road to be reflected primarily in 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 whereas for other corridors we explicitly excluded homes with 1,125 feet of an on-ramp we did not exclude those few homes for the FTCBB. Unlike other corridors, we did not impose a maximum distance cutoff for the FTCBB. The FTCBB corridor is somewhat more isolated from the rest of the highway network. Of the sales within the FTCBB corridor, approximately 95% of were within three miles of an on-ramp. The corridor for the SJHTC included all homes more than 1,125 feet from a SJHTC on-ramp and less than

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

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 on that highway would confound the analysis.[5] Also, homes that were closer to an on-ramp on Interstate 5 than to a SJHTC on-ramp were excluded from the analysis, to reduce the potentially confounding influence of the parallel Interstate 5 corridor.

The literature on hedonic price analyses includes both linear and log-linear specifications. Huang (*16*) 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 in the regression. 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 (*29*) showed that MLE and 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 all years other than 1989. For the SJHTC, the linear specification is preferred in seven of thirteen years – 1991 through 1996 and 1998. (Full test results are available from the authors upon request.) Based on these results, we used 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 are 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 toll road as a certainty. The results are shown in Table 2. For the FTCBB, we chose two thresholds – one year before construction began (1989) and the year construction began (1990). The SJHTC was the subject of litigation until early 1993, and so we chose 1993 as the threshold for that corridor.

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[5] 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.

Looking first at the structure-specific variables 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 sales price, older homes sold for less near the FTCBB and for more near the SJHTC.[6] Homes in school districts with higher SAT scores sold for more in the SJHTC corridor but for less near the FTCBB. Higher crime rates had no significant impact on sales prices near the FTCBB but were associated with higher sales prices near the SJHTC. Both the SJHTC and the FTCBB corridors are in low-crime, upper income areas with good schools. The "wrong signs" on the *SATscore* and *CrimeRate* variables likely reflect the small variation in those variables in the corridors that we examined and the fact that variations in those variables are correlated with other, unmeasured aspects of geographic desirability. Lastly, distance from the coast (in feet) was included for homes in the SJHTC corridor, and as expected the effect is negative – homes sold for more than $60,000 less with each mile from the coast.

The year dummy variables show the time pattern of home prices in southern California. Home prices appreciate 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 decrease, *ceteris paribus*, by approximately $1.30 per foot (almost $7,000 per mile) from the FTCBB, and by approximately $4.50 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. This allows us to examine every possible threshold year without choosing the endpoints of our data. (fn – Choosing endpoint years would create a considerably unbalanced test, as the number of observations in the endpoint year would be substantially smaller 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 note that, given the span of the data, it is unlikely that the effect of

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[6] 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 persons familiar with the Dataquick data agreed that house prices in south 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 generally young age of homes in the area. For example, real estate experts suggested that new homes,

the toll roads would be first felt at either endpoint year. Last, note that given that the data for 2000 include only the first couple of months, we regard 1999 as the endpoint year for the data for purposes of this analysis.) 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-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.

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 the results 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 creating a negative house price gradient with distance from the toll road. Note that the magnitude of the accessibility affect is larger for a threshold year of 1993 than for threshold years of 1989 or 1990. Also note that, from Table 5, the hypothesis of an insignificant *DtrBefore* coefficient and a negative *DtrAfter* coefficient is confirmed for any threshold year on or before 1993. Construction on the FTCBB 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 that the accessibility of the FTCBB is captured in both the *DtrBefore* and *DtrAfter* variables for years after 1993. Overall, the results in Table 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 of 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 generally insignificant for thresholds before 1994, while *DtrAfter* is generally significantly negative. The exception is a significantly negative *DtrBefore* for a 1990 threshold. For 1994

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when sold in a resale market, often show price increases due to improvements such as landscaping that are not reflected in the price of the new home.

and later threshold years, the pattern is reversed, with *DtrBefore* being significantly negative while *DtrAfter* is not significant. We believe these results reflect, at least in part, the effect of substantial improvements that were 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 capacity in the interchange was increased during the mid-1990s. The Interstate 5 corridor is an alternative commute route for many residents in the SJHTC corridor. To the north and east of the SJHTC corridor, homes further 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. Lastly, 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 earlier threshold years give more reliable information on the effect of the SJHTC, and for threshold years before 1994 the results are generally consistent with what was found for the FTCBB.

Lastly, to verify our method, we use our technique to examine a corridor that had no substantial capacity improvements during this time period. We chose the State Route (SR) 22 corridor in northern Orange County. According to Caltrans, the 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 from the SR-22, but less than two miles from SR-22, defining *DtrBefore* and *DtrAfter* based on threshold years as was done for the FTCBB and SJHTC. Of course the threshold years do not reflect real changes in capacity, and so we expect there to be no meaningful difference in the coefficients on *DtrBefore* and *DtrAfter*. We examined the SR-22 to verify that the "before and after" test does not generate differences in price gradients for corridors where no difference should exist.

In Table 3, we chose 1993 as a threshold year for the SR-22, as 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.

## VI. 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 (*30*); Case, Pollakowski, and Wachter (*31*)). 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, borrowing 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 (*33*).

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. Choosing areas near and very distant from the toll road, while that clearly creates a stark difference in toll road accessibility across the two groups, 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 south Orange County. Past research has demonstrated that prices indices in different locales appreciate differently, in ways that appear to be linked to characteristics of the neighborhood (Case and Mayer (*34*); Case and Shiller (*32*); Mayer (*35*); Smith and Tesarek (*36*)). For example, preliminary analysis of our data suggested that south 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 more stark comparison, but given the development patterns in Orange County we felt that choosing homes further 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 span of our data, 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 (*33*), the regression for developing the sales price index is shown below.

$$\ln(P2_i/P1_i) = \beta_1(Y88_i) + \beta_2(Y89_i) + \ldots + \beta_3(Y00_i) + \varepsilon \qquad (2)$$

where
P1 = first sale for the same property
P2 = second sale for the same property
Y88 = dummy variable equal to –1 if first sales was in 1988,
1 if 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
$\varepsilon$ = regression error term

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. The indices for the FTCBB are graphed in Figure 2. Note that the nearby index appreciates more rapidly during the last few years of our study period. This is consistent with the toll road creating an accessibility premium that caused nearby houses to appreciate more rapidly during the study period.

The price indices in Table 6 are derived from the regression coefficients, shown in Appendix 1. Because the coefficients are point estimates, the price indices and similarly the change in price indices for the nearby and more distant corridors are also 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. 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 the more distant corridors. Note that the 90% confidence intervals for the change in year coefficients do not overlap, implying that the changes in the year coefficients, and hence house price appreciation, is 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 (1,125 feet to one mile) and more distant (two to three miles) 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 2. Note from Table 6 and Figure 3 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 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 of homes across the nearby (1,125 feet to one mile) and more distant (two to three miles) corridors around the SJHTC from 1988 to 2000.

Overall, the results from the multiple sales price method show evidence that the FTCBB positively influenced the appreciation of nearby homes, but give no similar evidence for an effect of the SJHTC on home price appreciation. It is important to note that the multiple sales price method is especially limited when applied to the SJHTC corridor. The multiple sales price technique requires that the two corridors (nearby and more distant) be identical on all characteristics other than access to the toll road. For the SJHTC that assumption is problematic. The SJHTC 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 I-5 corridor, and could have benefited from the improvements in capacity on that corridor that occurred at roughly the same time that 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 more clean 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. Overall, 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.[7]

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[7] 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 the SR-22. As we expected, the price indices for the nearby and more distant corridor for the SR-22 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. The SR-22 does not have the confounding influences of coastal access and proximity to other parallel and improved corridors, and so the results of the multiple sales price technique applied to

## VII. CONCLUSION

The empirical analysis provides evidence that the construction of the first two portions of the Orange County toll road network created accessibility premia that are reflected in home sales prices analyses. The evidence is especially strong in that regard for the FTCBB, and the evidence suggests that the accessibility premium for that road shows up with increasingly large magnitudes up until the time that the first portion of the FTCBB opened. This is consistent with what standard urban and land use theory would predict. While the evidence of an accessibility premium is less strong for the SJHTC, we conclude that much of the ambiguity in the statistical results for that corridor is caused by other confounding factors that are correlated with distance from the SJHTC toll 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 thus that it is 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. Based on the evidence in this study, home buyers are willing to pay for the increased access that the new roads provided.[8] It is that willingness to pay for increased access which influences both development patterns and, potentially, induced traffic.

Overall, our results are consistent with recent research that has suggested that induced travel is a real phenomenon, and our results are consistent with the hypothesis that changes in development patterns are one cause of induced travel. Certainly, the research reported here is still an initial step. Future research should examine how the changes in house prices (and thus land prices) reported here are reflected in intra-metropolitan growth patterns, and whether and how those growth patterns changed after the toll roads were built. Yet for now 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.

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the SR-22 suggest that there is no change in accessibility premium associated with that road during the study period, as expected since that corridor had no important capacity improvements from 1988 to 2000.

[8] Given that the FTCBB and SJHTC are toll roads, travelers already pay for using the road. The evidence in this paper shows that home buyers are also willing to pay for accessibility through higher home prices.

**Acknowledgements**
This research was supported by grants from United States Environmental Protection Agency and the University of California Transportation Center. The University of California Transportation Center is funded by the United States and California Departments of Transportation. Participants at a symposium on induced travel held at UC-Berkeley in June of 2000 provided helpful comments on this research. Michael Greenwald, Lewison Lem and Robert Noland, in particular, provided helpful insights throughout the course of this research. The house price data used in this analysis were graciously provided by Dataquick, Inc., and 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.

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**TABLE 1 Date of Toll Road Construction and Completion**

| Toll Road Segments | Construction Began | Construction Complete |
|---|---|---|
| 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 Jaoquin Hills Transportation Corridor (SJHTC) | September 1993 | November 1996 |

*Source*: http://www.tcagencies.com/

**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 | 43733 | 38200 | 36716 |
| 1989 | 34430 | 29959 | 28836 |
| 1990 | 26042 | 22605 | 21481 |
| 1991 | 25157 | 22129 | 19894 |
| 1992 | 22902 | 20096 | 17251 |
| 1993 | 24388 | 21356 | 18014 |
| 1994 | 29272 | 25536 | 20791 |
| 1995 | 23822 | 20833 | 16821 |
| 1996 | 29040 | 25468 | 20345 |
| 1997 | 32763 | 27595 | 21590 |
| 1998 | 37396 | 29821 | 24244 |
| 1999 | 33237 | 28580 | 24900 |
| 2000 | 5659 | 4954 | 4302 |
| Total | 367841 | 317132 | 275185 |

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

| Corridor | FTCBB | | | | SJHTC | | SR-22 | |
|---|---|---|---|---|---|---|---|---|
| Threshold year | 1989 | | 1990 | | 1993 | | 1993 | |
| Variables | Coefficient | t-stat. | Coefficient | t-stat. | Coefficient | t-stat. | Coefficient | t-stat. |
| SQFT | 122.67 | 48.19 | 122.66 | 48.17 | 165.82 | 29.34 | 73.22 | 35.57 |
| Bedroom | -14070.26 | -7.28 | -14068.06 | -7.28 | -12372.67 | -2.91 | 12688.88 | 12.29 |
| Bath | 11118.79 | 3.17 | 11138.74 | 3.17 | 24448.70 | 3.42 | -4163.51 | -2.41 |
| Lotsize | 0.47 | 11.00 | 0.47 | 11.00 | 1.25 | 4.62 | 2.56 | 14.40 |
| Age | -1043.73 | -3.72 | -1039.95 | -3.70 | 2338.20 | 4.15 | 593.72 | 4.47 |
| SATscore | -967.09 | -6.39 | -965.64 | -6.38 | 859.48 | 7.51 | 118.67 | 8.40 |
| CrimeRate | -101.98 | -1.79 | -101.37 | -1.77 | 510.40 | 11.34 | -260.95 | -23.17 |
| DtrBefore | -0.81 | -1.11 | -1.02 | -1.79 | -3.31 | -1.69 | 0.14 | 0.42 |
| DtrAfter | -1.32 | -3.78 | -1.32 | -3.63 | -4.53 | -2.47 | 0.23 | 0.78 |
| Coast | - | - | - | - | -12.80 | -26.59 | - | - |
| Year88 | -268752.70 | -8.82 | -266480.20 | -8.86 | -129849.50 | -3.88 | 14719.43 | 2.27 |
| Year89 | -182782.70 | -6.87 | -185631.20 | -6.85 | -33244.10 | -1.00 | 51633.07 | 7.93 |
| Year90 | -199708.50 | -7.40 | -199495.50 | -7.39 | -29834.67 | -0.91 | 55550.17 | 8.41 |
| Year91 | -200329.30 | -7.41 | -200120.50 | -7.40 | -68924.24 | -2.11 | 47166.38 | 7.15 |
| Year92 | -201497.50 | -8.07 | -201302.80 | -8.06 | -108805.50 | -3.36 | 43638.77 | 6.66 |
| Year93 | -212713.10 | -8.55 | -212526.60 | -8.54 | -106896.90 | -3.80 | 23596.69 | 3.87 |
| Year94 | -214119.00 | -9.27 | -213949.70 | -9.26 | -105496.30 | -3.78 | 5466.12 | 0.91 |
| Year95 | -192638.10 | -9.51 | -192491.10 | -9.50 | -131949.30 | -4.86 | -5584.48 | -0.95 |
| Year96 | -108785.00 | -9.88 | -108757.10 | -9.88 | -203992.80 | -7.99 | -28271.62 | -4.99 |
| Year97 | -91689.36 | -8.58 | -91670.11 | -8.58 | -163779.10 | -6.55 | -32868.49 | -5.81 |
| Year98 | -48203.56 | -4.58 | -48179.41 | -4.57 | -87745.68 | -3.52 | -20496.63 | -3.70 |
| Year99 | -14238.57 | -1.36 | -14235.68 | -1.36 | -57875.85 | -2.32 | -5039.04 | -0.92 |
| Constant | 1207062.00 | 7.13 | 1205333.00 | 7.12 | -606506.90 | -4.84 | -46378.24 | -2.66 |
| Number of Obs. | 10218 | | 10218 | | 5329 | | 4141 | |
| R-Squared | 0.4167 | | 0.4166 | | 0.5738 | | 0.6085 | |
| Adj. R-Squared | 0.4155 | | 0.4154 | | 0.5720 | | 0.6065 | |
| ML | -133224.6 | | -133224.7 | | -72292.269 | | -49748.252 | |

**TABLE 4 Log-likelihood values for threshold years**

| Threshold | Log-likelihood values for threshold years | |
|---|---|---|
| Year | FTCBB | SJHTC |
| 1989 | -133224.56 | -72292.25 |
| 1990 | -133224.67 | -72292.03 |
| 1991 | -133224.19 | -72292.36 |
| 1992 | -133223.21 | -72292.37 |
| 1993 | **-133223.06** | -72292.27 |
| 1994 | -133224.79 | -72292.08 |
| 1995 | -133224.69 | -72290.59 |
| 1996 | -133224.74 | -72287.27 |
| 1997 | -133224.77 | **-72285.57** |
| 1998 | -133224.72 | -72285.76 |

**TABLE 5 Coefficients and t-statistics for DtrBefore and DtrAfter**

| Threshold | FTCBB | | SJHTC | | SR-22 | |
|---|---|---|---|---|---|---|
| Year | Coefficient | t-statistics | Coefficient | t-statistics | Coefficient | t-statistics |
| 1989 | | | | | | |
| DtrBefore | -0.8087 | -1.111 | -5.3990 | -1.761 | -0.2562 | -0.420 |
| DtrAfter | **-1.3177** | **-3.775** | **-3.6822** | **-2.383** | 0.2553 | 1.054 |
| 1990 | | | | | | |
| DtrBefore | -1.0201 | -1.786 | **-5.7407** | **-2.271** | -0.3460 | -0.785 |
| DtrAfter | **-1.3230** | **-3.632** | **-3.3551** | **-2.077** | 0.3666 | 1.413 |
| 1991 | | | | | | |
| DtrBefore | -0.8346 | -1.642 | -4.4374 | -1.952 | -0.0367 | -0.096 |
| DtrAfter | **-1.4444** | **-3.811** | **-3.7431** | **-2.228** | 0.2995 | 1.098 |
| 1992 | | | | | | |
| DtrBefore | -0.6892 | -1.493 | -3.6863 | -1.781 | 0.0683 | 0.195 |
| DtrAfter | **-1.6306** | **-4.101** | **-4.1642** | **-2.364** | 0.2663 | 0.937 |
| 1993 | | | | | | |
| DtrBefore | -0.7365 | -1.692 | -3.3127 | -1.688 | 0.1377 | 0.422 |
| DtrAfter | **-1.6972** | **-4.116** | **-4.5307** | **-2.470** | 0.2318 | 0.777 |
| 1994 | | | | | | |
| DtrBefore | **-1.2778** | **-3.104** | **-4.9003** | **-2.625** | 0.2464 | 0.802 |
| DtrAfter | **-1.2220** | **-2.815** | -2.9703 | -1.543 | 0.1289 | 0.409 |
| 1995 | | | | | | |
| DtrBefore | **-1.3475** | **-3.421** | **-5.9079** | **-3.338** | 0.2400 | 0.838 |
| DtrAfter | **-1.1050** | **-2.393** | -1.1725 | -0.567 | 0.1142 | 0.332 |
| 1996 | | | | | | |
| DtrBefore | **-1.3094** | **-3.428** | **-6.9359** | **-4.041** | 0.3533 | 1.292 |
| DtrAfter | **-1.1393** | **-2.324** | 1.4222 | 0.640 | -0.1303 | -0.349 |
| 1997 | | | | | | |
| DtrBefore | **-1.2162** | **-3.303** | **-6.8933** | **-4.187** | 0.4066 | 1.561 |
| DtrAfter | **-1.3524** | **-2.492** | 3.4418 | 1.391 | -0.4132 | -0.984 |
| 1998 | | | | | | |
| DtrBefore | **-1.2982** | **-3.625** | **-6.2316** | **-3.965** | 0.3966 | 1.583 |
| DtrAfter | -1.0558 | -1.686 | 5.3831 | 1.825 | -0.6428 | -1.336 |

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

**TABLE 6 House Price Indices in Toll Road Corridors by Year**

| | FTCBB | | SJHTC | |
|---|---|---|---|---|
| Year | 1125 ft. to 1 mi. | 2 to 3 mi. | 1125 ft. to 1 mi. | 2 to 3 mi. |
| 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.

**TABLE 7 Changes in Coefficients for Determining Home Price Indices in Toll Road Corridors**

| Toll Road Corridors | Treatment/Control Corridors | Changes in Coeff. | Standard Errors | 90% C.I. Lower | 90% C.I. Upper | 95% C.I. Lower | 95% C.I. Upper |
|---|---|---|---|---|---|---|---|
| FTCBB | 1125 ft. to 1 mi. | 0.3823 | 0.0186 | 0.3517 | 0.4129 | 0.3451 | 0.4195 |
| | 2 to 3 mi. | 0.3057 | 0.0230 | 0.2679 | 0.3434 | 0.2597 | 0.3516 |
| SJHTC | 1125 ft. to 1 mi. | 0.3533 | 0.0173 | 0.3249 | 0.3817 | 0.3188 | 0.3879 |
| | 2 to 3 mi. | 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.

## APPENDIX 1 Regression Results for the Multiple Sales Price Analysis for FTCBB

| | 1125 ft. to 1 mi. | | 2 to 3 mi. | |
|---|---|---|---|---|
| Variables | Coeff. | t-stat. | Coeff. | t-stat. |
| 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 |
| No. of obs. | 2016 | | 1594 | |
| R-squared | 0.6901 | | 0.5899 | |
| Adj. R-squared. | 0.6882 | | 0.5868 | |

## APPENDIX 2 Regression results for the Multiple Sales Price Analysis for SJHTC

| | 1125 ft. to 1 mi. | | 2 to 3 mi. | |
|---|---|---|---|---|
| Variables | Coeff. | t-stat. | Coeff. | t-stat. |
| 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) | |
| No. of obs. | 2016 | | 1594 | |
| R-squared | 0.6901 | | 0.5899 | |
| Adj. R-squared. | 0.6882 | | 0.5868 | |

Map 1: Orange County Toll Roads and Highways

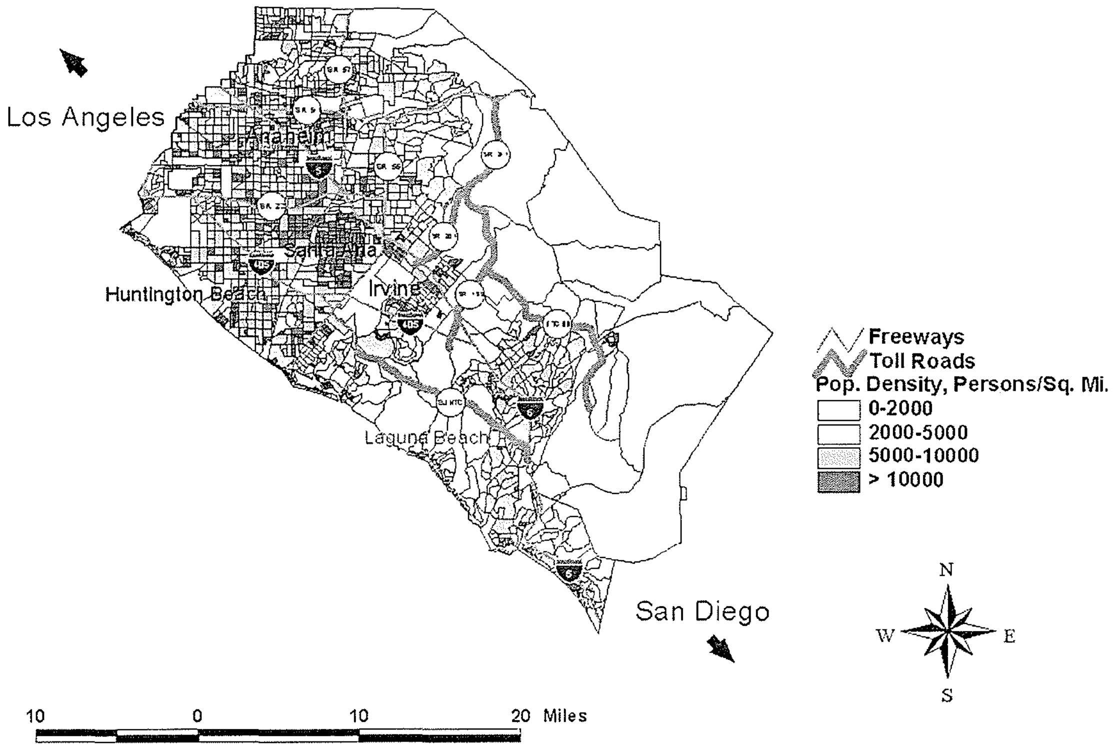

**FIGURE 2 House Price Indices in FTCBB Corridors**

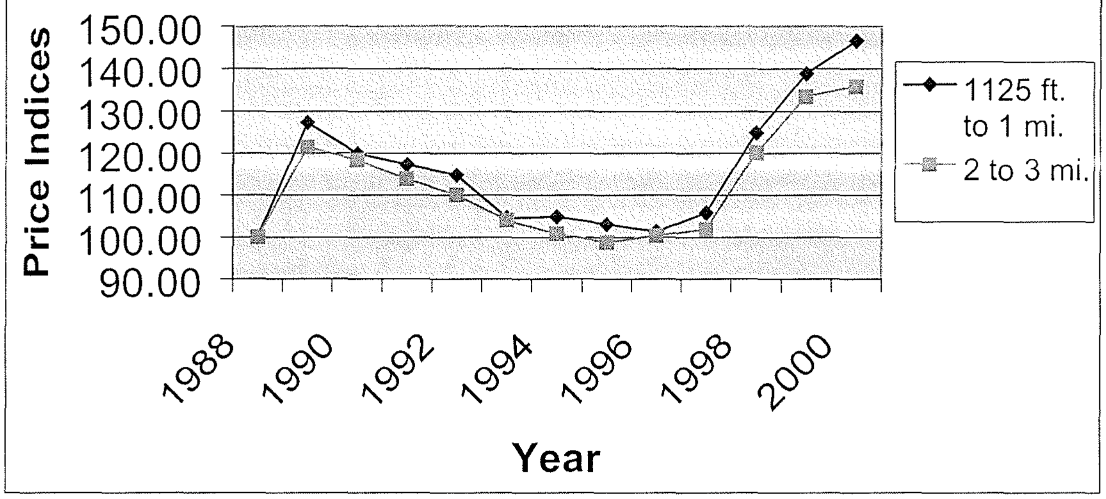

**FIGURE 3 House Price Indices in SJHTC Corridors**