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If you build it, they will drive: Measuring induced demand for vehicle travel in urban areas

Kent Hymel ✉

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Highlights

- Empirical analysis of the causal effect of highway capacity expansion and vehicle-miles traveled in US urban areas.
- Develops instrumental variables based on measures of political influence to control for endogenous highway capacity.
- Aggregate vehicle miles traveled increase in exact proportion with lane-mileage.
- Congestion relief from capacity expansion vanishes within five years of capacity expansion.

Abstract

This paper examines the causal link between highway capacity and the volume of vehicle travel in US urban areas. Estimates from a dynamic panel model suggest that highway capacity expansion generates an exactly proportional increase in vehicle travel. Moreover, induced vehicle travel is expected to revert traffic speeds to pre-expansion levels in approximately five years. To address the simultaneous relationship between lane mileage and highway capacity, this paper develops an identification strategy to account for possible endogeneity bias. A set of instrumental variables measures the degree of influence that state delegations have had on key transportation committees in the US congress. The instruments strongly correlate with highway capacity and are plausibly exogenous, considering the idiosyncratic legislative process in the US. These findings cast doubt on the effectiveness of expanding highways to eliminate traffic congestion, as the speed-related benefits of new capacity tend to be short-lived.

Introduction

The distribution of federal highway funds has long been the subject of intense debate among policymakers at all levels of government, and for good reason. Abundant evidence suggests that roads have had wide-ranging effects on, among other things, productivity (Fernald, 1999), trade (Duranton et al., 2014; Allen and Arkolakis, 2014), land use within cities (Baum-Snow, 2007; Duranton and Turner, 2012), and automobile externalities (Parry et al., 2007). Highway infrastructure spending has also played an important role in countercyclical fiscal policy and was a significant part of the 2009 stimulus bill (Leduc and Wilson, 2014). Although highways generate undeniable economic benefits, they are costly to build and spawn a host of negative externalities when they are not managed efficiently. Hence, transportation planners must carefully consider the behavioral response of drivers when expanding highway capacity. How will additional highway capacity change the volume, temporal distribution, spatial distribution, and speed of vehicular travel? This paper measures one such factor: the effect of highway expansion on the volume of vehicle travel in US urban areas.

There is little dispute among transportation researchers that expanding highway capacity increases vehicle use. This phenomenon is commonly known as *induced demand*, and it demonstrates a fundamental economic principle: individuals tend to consume more of a good as the price of the good falls. In other words, wider highways increase traffic speeds and reduce the time cost of driving, thereby inducing additional vehicle travel. In the short run, when residential and employment locations are fixed, faster peak period highway

speeds attract drivers from alternate routes, modes, and times of day. Then, in the long-run, faster speeds encourage additional social and economic behavior in areas made more accessible by the new highway capacity, which further increases traffic volumes.

Research studies since the 1960s have suggested that, because of induced demand, the hoped-for benefits from highway expansion tend to be short-lived and do not provide lasting relief to traffic congestion. Early studies by Downs (1962), Smeed (1968), and Thomson (1977) go so far as to argue that, over time and without any other offsetting deterrent, rush-hour traffic speeds tend to revert to their pre-expansion levels. The finding has even been dubbed the *Fundamental Law of Road Congestion* (Downs, 1962), which asserts that the elasticity of vehicle miles traveled with respect to lane mileage is equal to one, implying that driving increases in exact proportion to highway capacity additions.

A related strand of research examines the direct effect of travel-time savings on the demand for vehicle travel. Road improvements in congested areas induce additional travel indirectly, as drivers ultimately benefit from reductions in the generalized cost of driving brought about by faster traffic speeds (For a review of the literature, see Wardman (2012).). Thus, the elasticity of vehicle mileage with respect to travel-time may serve as a better predictor of future traffic volumes, as some road improvements occur in uncongested areas and have little impact on the speed of traffic. But accurately measuring that elasticity is challenging as travel times can vary widely across the hours of the day and the days of the week. These practical difficulties have prompted many researchers to use lane mileage as a proxy for time-savings. Hence, induced demand elasticities based on capacity expansions should be correctly interpreted as average effects applying to the road types included in a given study.[1]

The existing literature on induced demand is extensive and includes case studies as well as analyses based on aggregate cross-sectional and time series data. Though rich in detail, findings from individual case studies can be hard to generalize and may have a limited ability to predict the effects of highway expansion in other metropolitan areas. Moreover, highway expansion impacts travel on a city's entire transportation network and may alter traffic on any secondary roads excluded from a case study. In contrast, studies that measure induced demand for a cross-section of metropolitan areas over many years can yield generalizable lessons that are relevant to the national highway policy debate. Nevertheless, estimates of the induced demand elasticity differ considerably across studies and depend on the time horizon, unit of measurement, and empirical model employed. Research using county or state-level panel data generate elasticity estimates that vary widely both within

and across studies (Cervero, 2002). For other reviews of the induced demand literature see Goodwin (1996), Noland and Lem (2002), and Graham and Glaister (2004).

Many of these earlier studies, however, do not provide clear identification strategies, making it difficult to uncover the causal links between highway capacity and vehicle travel. Although capacity and travel are highly correlated, it is not plausible to assume that causality flows in a single direction. Transportation planners, for example, do not randomly select which highways to widen. Instead they prioritize improving highway segments with unacceptable levels of traffic congestion or in areas expecting economic growth. Initially, a newly widened highway will attract drivers from other routes, modes of travel, and times of day. Over time, however, vehicle speeds tend to regress as traffic increases, eroding the sought-after congestion relief and encouraging further capacity expansion. Thus, it is not plausible to assume that causality flows in a single direction: highway capacity itself is endogenously determined by the volume of vehicle travel and other factors.

Failing to control for endogeneity in a travel demand model will likely generate biased estimates of the induced demand elasticity, which casts doubt on the validity of studies lacking a credible identification strategy. That said, instrumental variables (IV) has been the prevailing approach to estimating the causal effects of highway expansion. The earliest IV-based studies proposed a variety of instruments for highway capacity, which include lagged values of highway capacity growth (Fulton et al., 2000), the amount of urban land area (Noland and Cowart, 2000), and a combination of political and environmental measures (Cervero and Hansen, 2002). But, good instruments have proven difficult to find and the reliability of the induced demand estimates from these early studies is uncertain, as none tested for bias from weak or invalid instruments.

There are, however, studies that focus attention on the causal relationship between vehicle travel and highway capacity. For example, Duranton and Turner (2011) used an early plan of the US Interstate highway system from 1947 along with a set of rail and exploration routes from the 1800s to generate instruments for urban area lane mileage. Their instrumental-variable based estimates of the induced demand elasticity range from 0.92 to 1.04, which are consistent with the fundamental law. In a set of related studies, the road mileage depicted on the 1947 plan serves as an instrument in much the same way — Baum-Snow (2007) estimates the effect of highway provision on suburbanization, Michaels (2008) looks at trade barriers and labor market outcomes, and Hymel (2009) examines the effect of traffic congestion on metropolitan employment growth. In those studies, a key argument for instrument validity is the long span of time separating the 1947 highway plan from economic outcomes occurring decades later. Revisiting the map-based approach of

Duranton and Turner (2011), Hsu and Zhang (2014) generate instruments from a map of planned highways in Japan, and also find induced demand elasticity estimates that support the fundamental law of road congestion, ranging from 1.24 to 1.34. Other studies have addressed causality with Granger causality tests (Fulton et al., 2000; Melo et al., 2012), simultaneous equations models Noland (2001); Hymel et al. (2010), and propensity scores (Graham et al., 2014). Table 1 summarizes the methodologies and research findings of induced demand studies that controlled for endogeneity bias by using instrumental variables.

To help disentangle causality, this paper examines how scarce highway funds are allocated across competing projects. Policymakers at the federal, state, and local level all exert influence over the distribution of highway funds. A key funding mechanism in the US is the Federal-Aid Highway Program, which redistributes motor-fuel tax revenue put into the Highway Trust Fund. Using a statutory formula, the program apportions federal funds among states to help pay for a variety of surface transportation programs. Key factors in the formula include the size of each state's road network, the amount of vehicle travel, fuel tax revenues, and air pollution levels.[2] Ultimately state and local transportation departments decide where to spend their own portion of the funds.

Do these formulas, written by Congress, accurately reflect highway transportation needs? If so, the funding formulas present further evidence that road building is not exogenous to vehicle travel. However, legislative politics can also create inefficiencies if the formulas redirect funds towards places with influential members of congress and away from places with high priority road projects. To answer that question, this paper develops a set of instrumental variables that measure the degree of influence each state's congressional delegation has had in the US House of Representatives and US Senate.

The remainder of this paper is organized as follows. Section 2 provides background information about highway finance and its relation to politics in the US. Section 3 describes this paper's identification strategy and provides evidence demonstrating the exogeneity and predictive strength of the instrumental variables. To estimate the induced demand elasticity, Section 4 develops a dynamic panel model of urban travel demand across US states between 1981 and 2015. The model addresses important statistical issues including unobserved heterogeneity, endogenous highway capacity, and the dynamic response of vehicle travel to highway capacity expansions. Section 5 presents a robust set of estimates which suggests that, over the long run, highway expansions generate an almost one-for one increase in vehicle travel. That is, the most trustworthy estimates of the induced demand

elasticity are very close to one and add further support for the fundamental law of road congestion.

Section snippets

Background

Surface-transportation spending bills have historically been contentious, and there is little doubt that members of Congress have strong incentives to secure federal funds for their constituents and to oblige campaign contributors (Levitt and Poterba, 1999; Knight, 2005). Highways are tangible, long-lived, and conspicuous. Because of those features, members can, without much difficulty, point to a popular highway improvement and claim credit for securing the federal funds that helped finance it

Research design

To help motivate the empirical model and identify an appropriate set of explanatory variables, this section develops a conceptual framework to illustrate the relationships between highway capacity, vehicle miles traveled, and other relevant factors. Fig. 1 presents a directed graph depicting the hypothesized causal linkages between vehicle miles traveled and its determinants. Each of the diagram's arrows indicate the presence and direction of a first-order causal link between two variables. The

Empirical model and estimation

The main goal of this research is to estimate the induced demand elasticity, but doing so is made difficult by three primary factors. First, including highway capacity or another endogenous variable in a travel demand regression model generates biased coefficient estimates. So, to account for endogeneity bias, this paper employs an instrumental variables approach as described in Section 3.

Second, unobservable factors that influence travel demand are likely to exist, and if not controlled for,

Results

This section presents regression results and induced demand elasticities generated by the dynamic model using both least-squares and GMM based estimators. Across all models, urban vehicle miles traveled and urban lane mileage are in logarithmic form and measured per-capita. The set of control variables includes the state unemployment level, log income per-capita, and log real gas price. Some specifications also include year dummies, a linear time trend, or a set of state-specific time trends.

Conclusion

These findings offer persuasive evidence supporting the fundamental law of traffic congestion, and indicate that capacity expansion is not a viable long-term solution to urban traffic congestion. Across specifications of the dynamic model that controlled for endogenous lane-mileage and state fixed effects, the within-group estimator generated long-run induced demand elasticities ranging between 0.892 and 1.063, all with very small standard errors. These elasticities, along with the other

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> ...Finally, this paper has not considered the environmental and social problems inherent in the transport system in Australia and many other countries. These include but are not limited to the construction of new motorways etc. inducing demand [110], the loss of public space for parking and subsequent urban heating, and poor health outcomes from the lack of active transport [111]. Health outcomes in Australia would be improved by increasing public and active transport [93]....

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