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Crossing the bridge: The effects of time-varying tolls on curbing congestion

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ABSTRACT

This paper estimates the traffic volume and travel time effects of the road congestion pricing implemented on the San Francisco-Oakland Bay Bridge. I employ both difference-in-differences and regression discontinuity approaches to analyze previously unexploited data for the two years spanning the price change and obtain causal estimates of the hourly average treatment effects of the policy. I find evidence of peak spreading in traffic volume and decreases in travel time during peak hours. I also find suggestive evidence of substitution to a nearby bridge and decreases in travel time variability. In addition, I calculate own- and cross-price elasticities.

1. Introduction

In 2010, urban road congestion cost the United States $101 billion, including nearly two billion gallons of wasted fuel and 4.8 billion hours of travel delay.[1] To address the problem, the US Department of Transportation has called for measures such as road congestion pricing to be implemented to help alleviate the problem. While theory suggests that congestion pricing should work, and empirical studies exist on the effects of toll changes, there is little empirical evidence as to the magnitude of change we should expect from and the effectiveness of time-varying pricing programs. In this paper, I use previously unexploited data and a more robust econometric approach to provide point estimates of the causal effects on traffic volume and travel time from the recent implementation of time-varying congestion pricing on one of the main toll bridges in the San Francisco Bay Area. I also show reductions in travel time variability and calculate the ranges for price elasticities.

Pricing traffic congestion is based on the economic theory of negative externalities: the driver of a vehicle imposes costs on all the other drivers on the road and, due to the open-access nature of government-funded roads, the driver does not internalize those costs; this results in an inefficiently high number of drivers using the road. In theory, the optimal corrective policy is a tax equal to the marginal social cost imposed by the additional driver, which makes drivers internalize the external costs. The optimal fee should therefore be a time-varying fee that depends on real time traffic conditions. The pricing increase on the San Francisco Bay Bridge (Bay Bridge) was primarily implemented to raise funds to pay for bridge

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[1] Schrank et al. (2011) and USDOT (2008b).

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maintenance and seismic retro-fitting, but it is in fact a peak time pricing program. While it falls short of being an optimal fee, the time-varying congestion pricing on the bridge studied in this paper does reflect the higher marginal social damage during times of heavier traffic, and it is one of the few attempts to implement time-varying congestion pricing on roads in the United States. A wide body of literature focuses on the theory of externalities and congestion, but existing empirical studies of road congestion are scarce due partially to limited instances of actual implementation.

In this paper, I test the hypothesis that congestion pricing decreases traffic volume and results in a shorter travel time during peak hours on the bridge. In addition, I investigate the possibility that marginal drivers switch to traveling during off-peak times or substitute to an alternate route that lacks congestion pricing, and that travel time variability on the Bay Bridge during peak hours decreases. If the pricing plan is successful in altering behavior, it could have important consequences for use in policy-making to stem the costs associated with road congestion. Furthermore, because road use is linked to other outcomes (e.g. air and noise pollution, traffic accidents, and petroleum use and importation), policies that affect driver behavior could have consequences in other areas.[2]

This paper is organized as follows: Section 2 provides some background on existing work; Section 3 explains the empirical design; Section 4 describes the data; Section 5 shows my results; Section 6 discusses the policy implications and welfare impacts; and Section 7 suggests directions for future work and concludes.

2. Background

The economic literature is rich with theory on congestion pricing that dates back to at least Vickrey (1963) who originated the theory of policies to handle road congestion and pointed out the need for different prices during peak and off-peak hours. Small et al. (2005) have noted the open-access problem inherent in our publicly-provided (and underpriced) road systems, and suggest that charging an optimal fee to access the roads could encourage a more efficient allocation. Baumol and Oates (1988) suggest that the optimal solution to congestion is to impose a Pigouvian tax (equal to marginal damage) on the drivers, who are the producers of congestion externalities. Small (1983) investigates the distributional impacts of congestion tolls using a modal choice equilibrium model and survey data, and concludes that "in almost all cases, the net result is benefits for all income groups." Boardman and Lave (1977) model the speed and flow relationship of traffic and test the model using data from a limited access highway. They conclude that congestion prices must vary by time of day to encapsulate the time-dependent private and social costs of driving. Using numerical simulations of a spatial general equilibrium model, Anas and Rhee (2006) compare congestion pricing and urban boundaries, essentially comparing a price regulation to a standard, as a means of reducing congestion and urban sprawl, and find that congesting pricing is first best and that using urban boundaries actually reduces welfare. Pricing negative congestion externalities is going to become more important with the introduction of increasingly stringent Corporate Average Fuel Economy (CAFE) standards, which will likely decrease the private per mile cost of driving, and consequently increase congestion.

McFadden (1974) emphasizes the importance of proper planning and policy in developing urban transportation systems, and he notes that travel decisions have many dimensions, including purpose, timing, and mode, all of which are important considerations for pricing road congestion. McFadden (1974) also provides evidence that travel time is valued linearly and increasing in the wage rate; additionally, he presents suggestive evidence that more salient costs associated with driving, such as tolls, appear to be weighted more heavily than less salient driving costs, such as mileage and maintenance costs. Subsequent work by Finkelstein (2009) shows that collecting tolls electronically can have the effect of rendering tolls less salient, and that the adoption of electronic toll collection makes the short run toll price elasticity of driving smaller.

Elsewhere in the economics literature, non-pecuniary attempts to decrease traffic and congestion have been shown to be ineffective. For example, Davis (2008) shows that a one-day-a-week ban on driving a vehicle in Mexico City, which was a policy aimed at reducing air pollution that has been introduced in several locations in South America, did not decrease air pollution, and resulted in more, and disproportionately higher-emissions, vehicles being driven. Davis concludes that the restrictions were unsuccessful in prompting drivers to reduce usage of private vehicles, which suggests that if such a policy were implemented to curb congestion, it would be equally unsuccessful. Additionally, expanding road capacity is found to be an ineffective way to reduce congestion, as found by Duranton and Turner (2011), who echo previous findings that peak traffic grows to fill the maximum available capacity, in short: if you build it, they will come.

Time-varying congestion pricing on roads had previously been implemented in only four other locations in the US (see Table 1): in 1995 in Orange County, California; in 1998 in San Diego, California; in 1998 in Lee County, Florida; and in 2006 a short test run in Oregon. In San Diego, non-HOV drivers can use the HOV lanes of Interstate 15 for a price that varies dynamically with traffic demand with the goal of keeping the HOV lanes flowing at full speed, and the time saved is estimated to be about one hour for each round trip made by a vehicle. In Orange County, lanes running parallel to State Route 91 for 10 miles can be used by drivers by paying a predetermined price by time of day and day of week, the amount of which is adjusted every 3 months and is based on previous demand. The reports on the effectiveness of this program maintain that

[2] For example, Currie and Walker (2011) demonstrate that road congestion contributes to poor infant health, and easing road congestion can reduce prematurity and low birth weight. Levy et al. (2010) estimate that the value of small particulate matter related mortality attributable to congestion is $31 billion annually. Schrage (2006) shows the incident and costs of accidents are higher with higher congestion. Dickerson et al. (2000) show that the accident externality increases substantially with high traffic volumes. Treiber and Kesting (2008) show that traffic congestion can increase fuel consumption by 80% and travel time by up to a factor of 4.