Analyzing the Impact of Covid-19 on Freeway Traffic in California

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Introduction

The Covid-19 pandemic that hit the United States in March of 2020 serves as a natural experiment of sorts in many areas of study. In less than a week, Covid-19 changed the way many of us commute, work, and live. Because the impact of Covid-19 was so sudden, a difference-in-differences (DiD) model can be an effective way to estimate the impact of the pandemic. This paper uses a DiD approach to examine the initial impact of the Covid-19 pandemic on freeway dynamics in California. The dynamics this model analyzes are per hour flow (number of vehicles per hour), average speed, and station occupancy (a measure of traffic density). I expect that flow and average occupancy will decrease as a result of the lockdown, but average speed will increase.

As limiting interpersonal contact is one of the best ways to limit the spread of the virus, transportation is one of the primary areas affected by the pandemic. The impact of the lockdown on interstate traffic flows and speeds is valuable because it can be used as an instrument to study other variables of interest, as outlined in the literature review section. Furthermore, the study is interesting in its own right because it examines how flow and speed changes when only 'essential' commuting is taking place. Additionally, it can be used to gain a sense of how traffic patterns might fundamentally change as a result of the virus. Many employers in California are allowing employees to permanently work from home, so it is plausible that traffic patterns will never return to where they were pre-pandemic. These new traffic patterns may be of interest to government planners who make decisions about road use.

Literature Review

Even though the pandemic began less than a year ago, there are already many papers examining its impact on transportation. However, most of these papers deal with air traffic or other unrelated aspects of transportation. Other papers use the decrease in car travel to estimate other variables of interest. A paper by Chen et al. (2021) examines the effect of lockdown in China on air pollution. This study analyzes the impact of the lockdown on transportation in order to estimate how transportation affects air quality. The authors find that restrictions on private vehicle travel significantly alleviated air pollution in many Chinese cities.

Another working paper uses a regression discontinuity to study the effect of the lockdown on traffic accidents and mobility (Barnes et al. 2020). The authors find that traffic accidents decreased by 47%. They also report no decrease in ambulance response times, despite less traffic. A third study maps noise emissions from urban traffic in Rome during the lockdown in Italy (Aletta et al. 2020). The authors find that private trips were reduced by 65% during lockdown.

All these studies estimate the reduction in traffic in order to study some related variable, such as noise, pollution, or traffic accidents. This paper focuses on Covid-19's effect on specific aspects of freeway traffic in California. This paper does not examine the number of private trips, but instead looks at traffic flow, speed, and density along mainline freeways using a regression discontinuity analysis. We expect to see a large decrease in traffic flow, a small decrease in density, and an increase in average speed as a result of the pandemic. We anticipate that the decrease in flow will not be as large as the 65% decrease in traffic in Rome, because Rome is more densely populated and entered a more strict lockdown than California.

Data

The California Department of Transportation (Caltrans) has a system of traffic monitors on many California freeways and highways. They make the data that these monitors collect available to the public. Data from the Freeway Performance Measurement System (PeMS) was obtained for this study from pems.dot.ca.gov. Specifically the data is hourly station data for Caltrans' district 3 for the month of March 2020, as well as station metadata for the same time period, both downloaded from the data clearinghouse. (See appendix A for a map of Caltrans' district 3.) The variables in the hourly station dataset are described in Table 1.

Table 1: Variables in Hourly Station Dataset	
Timestamp	A timestamp containing a date and hour.
Station ID	A unique identifier for the station.
District	The district that the station is located in. All data in this analysis is from district 3.
Freeway	The interstate number.
Direction	The direction of travel that the station is located on (eastbound, etc).
Lane Type	The type of lane that the station measures. Only mainline freeway lanes are used in this analysis.
Station Length	The length to the next station in miles.
Samples	The number of observed data points in the March dataset for a particular station.
% Observed	The percentage of samples that were observed (some were imputed).
Total Flow	The total flow across all lanes for a particular station and hour.
Average Occupancy	The percentage of time during the hour that a vehicle was over the station sensor.
Average Speed	The average speed of vehicles for a particular station and hour.

Merging the above dataset with the station metadata dataset produced more variables, the only one of which is relevant to this project is the number of lanes at each station. The raw dataset contained roughly 940,000 observations. Each station had an observation for each hour during the month of March. After merging and cleaning the dataset, we were left with 41,500 observations.

Analysis

Chart 1 shows the median daily travel time for transits along the I-15 corridor during March. The chart only includes departures that began around 7 am. Before March 13th, the median time exhibits a lot of variability, with high values midweek due to commuter congestion, and low values on the weekends. After March 13th, the data still exhibits a weekly pattern, but with much less variance. The post-lockdown daily median travel times are comparable to the pre-lockdown weekends' median travel times.

Chart 1: Median Daily Travel Time for 7 am Departures along I-15 during March

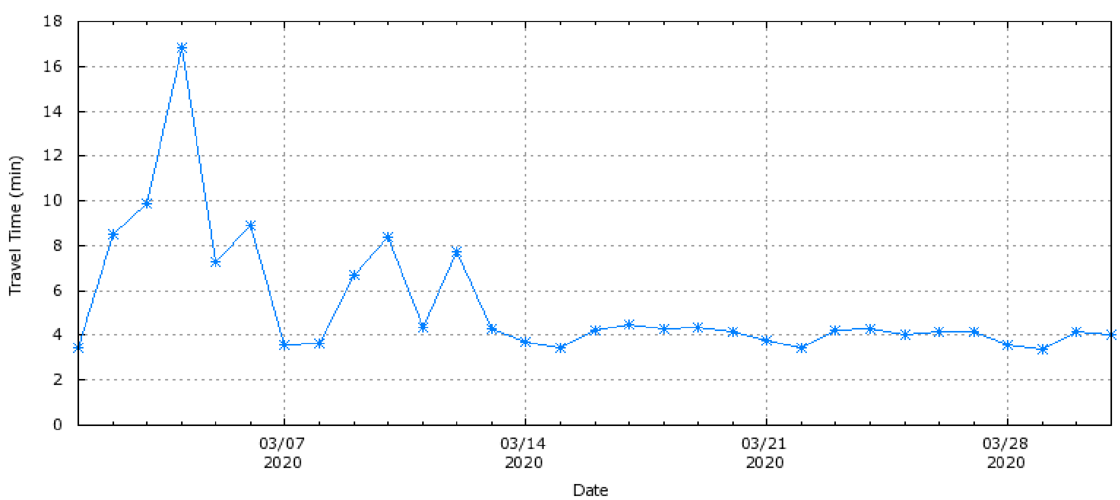


Chart from pems.dot.ca.gov

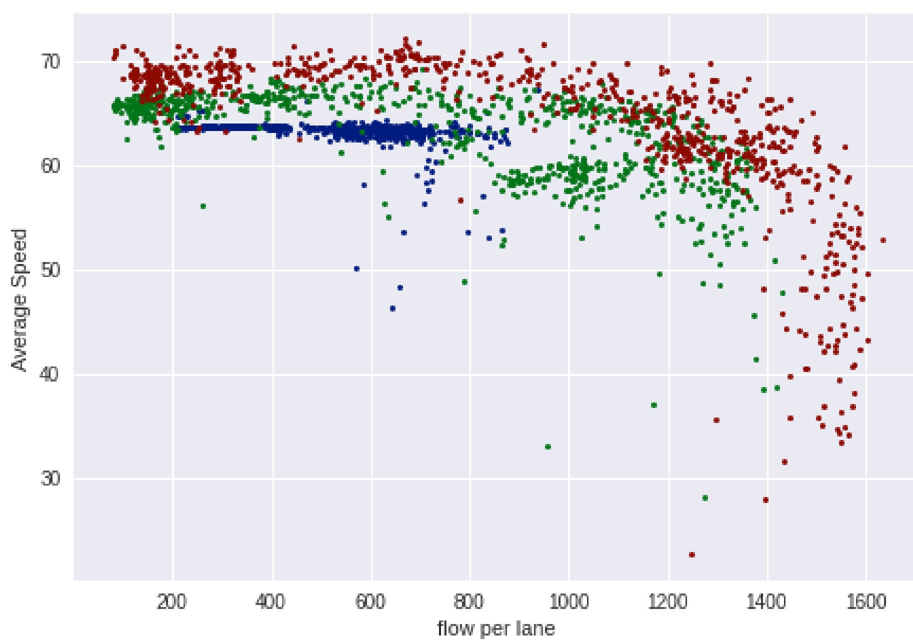
In California, panic buying began in the week that ended on March 14th. On March 13th, San Joaquin county declared a state of emergency and closed schools. The last day of school for Sacramento was March 13th. For these reasons, as well as features like those exhibited in Chart

1, the regression analyses in this paper classify dates before March 13th as ‘pre-pandemic’ and dates on or after the 13th as ‘post-pandemic’.

This paper estimates the effect of the March 13 lockdown on three fundamental aspects of interstate transportation. These are:

1) Percentage change in flow: The percentage change in flow answers a fundamental question: “How much did traffic decrease as a result of the lockdown?”. Graph 2 presents speed as a function of flow for three sample stations in the dataset. For the red and green stations especially, speed decreases as flow increases. This is caused by congestion. The blue station does not exhibit much congestion. This is reflective of the nature of freeways, where some locations are often congested and other locations rarely are.

Chart 2: Speed-Volume Curve for Three Sample Stations



We expect that flow will decrease as a result of the pandemic. As a result, congestion should also fall. In this paper the percentage change in per lane flow is approximated using the natural log of per lane flow.

2) Average station occupancy: Average occupancy is the percentage of time that a car is above the station sensor during the hour. We expect average occupancy to fall as a result of the pandemic because fewer vehicles are on the roads.
3) Average speed: Average speed is calculated by averaging the speed of all vehicles that passed the station in a given hour. Average speed is closely related to congestion. As seen in table 1, when too many people are on the road, speed decreases, and eventually flow decreases as well. Flow decreases under congestion because drivers slow down to compensate for the higher densities. We expect that the lockdown will increase average speeds. This hypothesis is due to the fact that the lockdown should limit traffic, which will in turn reduce congestion and allow drivers to speed up.

For each of these aspects of transportation, we run a linear regression to estimate the effect of the pandemic lockdown on the aspect. For each regression we control for hour, county, number of lanes, and freeway number. As the lockdown ('Post Covid') is represented as a simple binary variable, the coefficient can be directly interpreted as the effect of the lockdown on the aspect of interest.

Results

The results of the regressions are shown in table 2. According to OLS 1, the lockdown decreased flow by 43%. Average occupancy decreased as well by 2.1%, and average speed increased by about 1.2 mph.

Table 2: Initial Impact of Covid-19 on Mainline Flow, Speed, and Occupancy			
Regression number:	**OLS 1**	**OLS 2**	**OLS 3**
Dependent variables:	Log of Flow per Lane	Average Occupancy	Average Speed

Post Covid	-0.433	-0.021	1.197
SE	(0.00)	(0.00)	(0.00)
Constant	3.553	-0.035	67.697
SE	(0.01)	(0.00)	(0.00)
R squared	0.673	0.440	0.163

All coefficients are significant at the p<0.001 level. Standard Errors in parenthesis.
Each model includes controls for hour, county, number of lanes, and freeway number.

The coefficients for OLS 2 and OLS 3 are smaller than expected, especially compared to the coefficient for OLS 1. Traffic flow decreased by 43%, yet average occupancy decreased by only 2.1%. Yet average occupancy was already a low value, so perhaps this result is not too surprising. Initially a 1.197 mph average increase does not sound like a lot. However, the constant for OLS 3 shows that the average speed pre-pandemic was 67.7 mph. Hence the 1.197 mph increase reflects a 1.77% increase in speed after the lockdown.

The coefficient of determination R^2 of the prediction is especially low for OLS 2 and OLS 3 even though all the coefficients are statistically significant. This indicates that average occupancy and average speed are highly correlated with the lockdown, but that the lockdown does not explain much of the variability in these variables.

This potentially could also indicate that these models have omitted variable bias, because much of the variance is not explained by the model. This variance probably could be controlled for with variables like weather, vehicle types, presence of road work or lane closures, etc. The models in this paper do not control for those things. They only control for the time of day, the freeway, the number of lanes, and the county.

Conclusion

Ultimately, the results of the regressions confirm our hypothesis that flow and occupancy decreased and average speed increased when lockdown began. They also confirm the prediction that flow would decrease less than 65%, the percent that traffic decreased in Rome, Italy, as reported by Aletta et al.

The implications of this study are at least twofold. First, this study shows that average speeds increased by 1.2 mph (or 1.77%) with a 43% reduction in flow. This implies that most freeways in district 3 were not too heavily congested before the pandemic. A 1.77% speed increase saves drivers countless hours over time, but a 43% reduction in flow is a heavy penalty to pay.

Secondly, this study implies that roughly 43% of pre-pandemic interstate travel was either discretionary or was a commute that is no longer taking place. The breakdown of commuting vs. discretionary travel could be inferred by examining how traffic patterns changed during commuting times vs. other times. This is a promising area for future research.

Citations

Aletta, Francesco, Stefano Brinchi, Stefano Carrese, Andrea Gemma, Claudia Guattari, Livia Mannini, and Sergio Maria Patella. 2020. "Analysing urban traffic volumes and mapping noise emissions in Rome (Italy) in the context of containment measures for the COVID-19 disease." *Noise Mapping,* 7, no. 1 (3 August 2020): 114-122. https://doi.org/10.1515/noise-2020-0010

Barnes, Stephen R., Louis-Philippe Beland, Jason Huh, and Dongwoo Kim. 2020. "The Effect of COVID-19 Lockdown on Mobility and Traffic Accidents: Evidence from Louisiana." *Global Labor Organization Discussion Paper.* No. 616. Working Paper. http://hdl.handle.net/10419/222470

Chen, Zhongfei, Xinyue Hao, Xiaoyu Zhang, Fanglin Chen. 2021. "Have traffic restrictions improved air quality? A shock from COVID-19." *Journal of Cleaner Production*, 279, no. 10 (10 January 2021) 123622. https://doi.org/10.1016/j.jclepro.2020.123622.

Appendix A

Chart 3: Caltrans' District 3 (Marysville/ Sacramento) Within California

Map from dot.ca.gov/caltrans-near-me