

The effect of fuel prices on traffic flows: Evidence from New South Wales



Tong Zhang

Australian National University

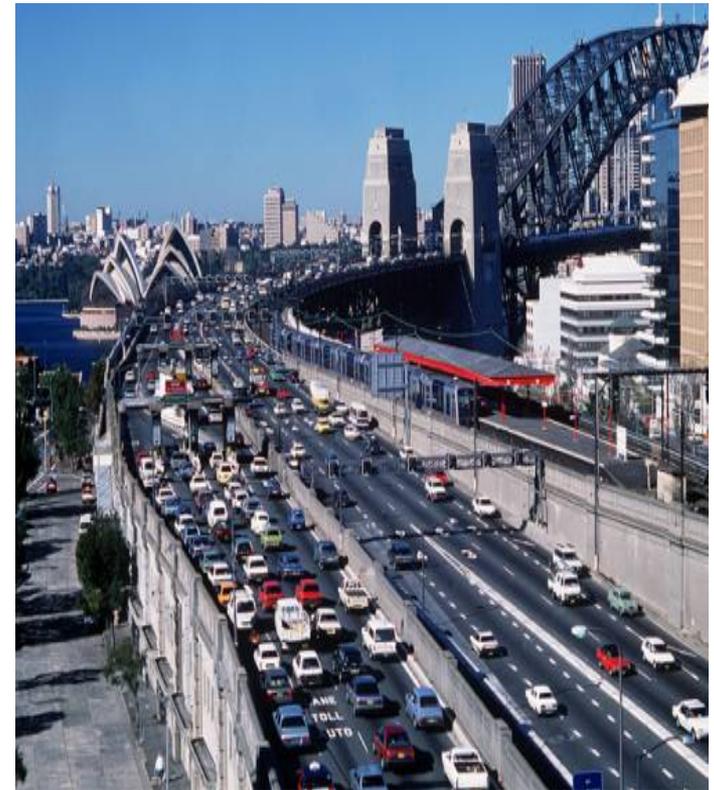
1. Introduction

Motivation:

Understanding motorist responses to price changes is crucial for plans to cope with growing road traffic.

It is possible that planners could forecast how road travel flow will change with the change of fuel prices.

Drivers' responses to changes in fuel prices can provide information on their price sensitivity and implications for road pricing.



Question

What is the effect of gasoline price changes on traffic flows in NSW?

Channels

- reduce trip frequency and distance
- change commuting modes
- change home or work locations

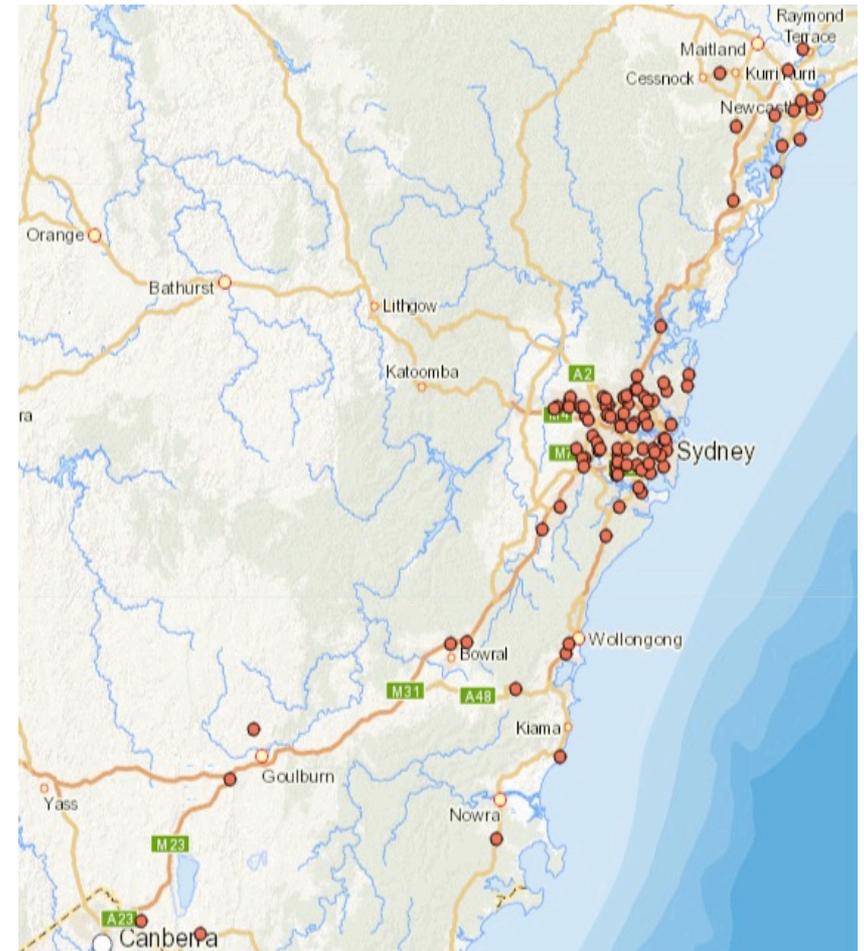


2. Data

Traffic flow (hourly):

- Source: the NSW Roads and Maritime Services.
- Count the number of vehicles via traffic collection stations
- Raw data: hourly (24 hours per day)
- Sample: 118 traffic collection stations from Jan 2010 to Dec 2017.

Figure 1 Traffic collection stations location map.



- Data issue: some missing values (when power source are compromised)
- Handle the issue: drop the day from daily data set if it contains a missing hour.
- Number of observations: **11.8 million**.

Table 1: Summary statistics for traffic flow data.

	Observations	Mean	Std.Dev.	Min	Max
Hourly data	11,776,128	770	753	1	22,690
Daily data	474,200	18,949	11,314	140	146,723
Weekly data	50,743	139,596	74,695	6,635	493,153
Monthly data	10,836	5,696,074	313,285	34,746	1,865,407

Source: NSW Roads and Maritime Services (2019). Notes: If traffic flow is 0 at a specific hour, that hour is excluded from the analysis.

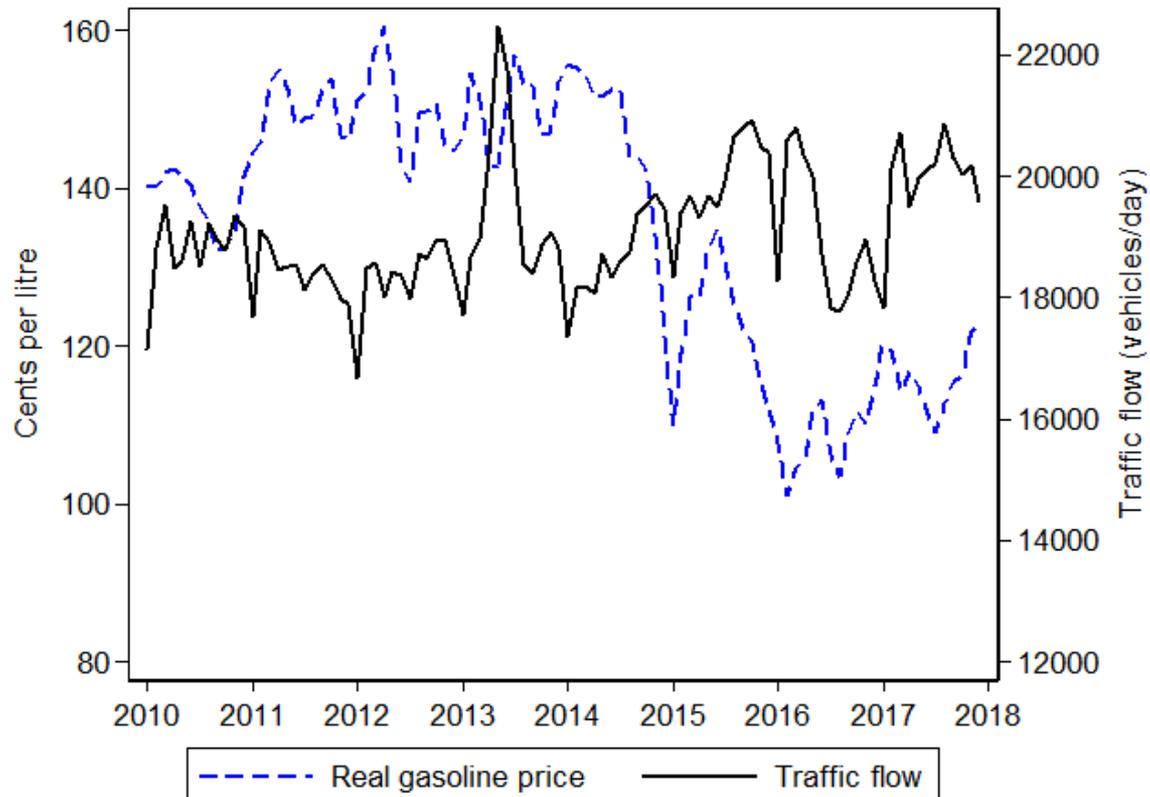
Gasoline price (daily):

Sydney's average terminal gate price (TGP) for gasoline (unleaded petrol).

TGP: the prices at which oil company terminals sell full tanker loads of fuel to wholesale customers.

- include 10% GST and fuel excise (41.6 cents/litre)
- exclude added services charges (freight, branding, wages and profit margins)

Figure 2 Average daily traffic flow across stations versus gasoline price, 2010-2017.



Source: The NSW Roads and Maritime Service (2019)

Unit root test

- Independent variable:

Table 2 Augmented Dickey-Fuller unit root test results for key independent variables.

Variables	Observations	Lags	Test statistic	<i>P</i> -value
Ln gasoline price (real)	2,086	2	-2.59	0.29
Ln S&P/ASX 200 price	2,324	1	-1.81	0.38
Rainfall (mm)	2,922	1	-39.17	0
Temperature (°C)	2,922	3	-47.93	0

Notes: Lag length are chosen by Bayesian information criterion. Data for the log real gasoline price and real gasoline price are hourly, for S&P/ASX 200 price, rainfall, and temperature are daily.

- Dependent variable (Ln hourly traffic flow):

Fisher type test: reject the null hypothesis that all panels contain unit roots at the 1% significance level.

3. Model

$$\ln TF_{i,t} = \beta_0 + \beta_1 \ln P_{i,t} + \beta_2 T + \beta_2 H_{h:d} + \beta_3 D_{d:w} + \beta_4 M_{m:y} + X'_t \varphi + S_i + \varepsilon_{i,d}$$

Traffic flow
 Real gasoline price
 Hour-of-day dummies
 Month-of-year dummies
 Station fixed effects

Time trend
 Day-of-week dummies
 Public holiday dummy;
 School holiday dummy;
 Double demerit periods dummy;
 Ln S&P ASX 200 price;
 Rainfall

Table 3 Reasons for using these explanatory variables

Variable	Reason
Time trend	account for the impact of gradual ongoing changes
Hour-of-day dummies	capture the varying level of flows throughout the day
Day-of-week dummies	capture the varying level of flows throughout the week
Month-of-year dummies	control for seasonal effects
S&P ASX 200 price	reflect expectations about the future economy
Rainfall/Weather	driving behavior could be different under weather conditions
Public holiday dummy	temporal effects
School holiday dummy	
Double demerit period dummy	drivers have different behaviour during that period

4. Results

4.1 Table 4 Basic results and IV estimates using hourly, daily, weekly and monthly data.

Dependent variable: Ln traffic flow	Hourly		Daily	
	OLS (1)	IV (2)	OLS (3)	IV (4)
Ln Real gasoline price	-0.043*** (0.016)	-0.051** (0.015)	-0.036** (0.016)	-0.042** (0.017)
Ln S&P ASX 200 price	0.019 (0.019)	0.020 (0.019)	0.020 (0.017)	0.021 (0.017)
Rainfall (mm)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)
Public holiday	-0.125*** (0.012)	-0.175*** (0.015)	-0.148*** (0.013)	-0.112*** (0.008)
School holiday	-0.015*** (0.002)	-0.017*** (0.002)	-0.025*** (0.003)	-0.025*** (0.003)
Double demerit period	-0.017*** (0.002)	-0.016*** (0.002)	-0.018*** (0.002)	-0.018*** (0.002)
Unemployment rate	No	No	No	No
Hour-of-day dummies	Yes	Yes	No	No
Day-of-week dummies	Yes	Yes	Yes	Yes
Month-of-year dummies	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes
R^2	0.90	0.92	0.98	0.98
Observations	11,624,348	11,298,675	462,816	451,800
Instrumented variable: Ln Gasoline price (real). Instrumental variable: Ln World oil price (real).				
Coefficient on instruments		0.470***		0.473***
Partial R^2 on instruments		0.80		0.82
Robust endogeneity test p value		0.000		0.000



Dependent variable: Ln traffic flow	Weekly		Monthly	
	OLS (5)	IV (6)	OLS (7)	IV (8)
Ln Real gasoline price	-0.029* (0.016)	-0.030* (0.018)	-0.042** (0.018)	-0.030 (0.020)
Ln S&P ASX 200 price	0.017 (0.018)	0.018 (0.018)	0.019 (0.023)	0.020 (0.022)
Rainfall (mm)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)
Public holiday	-0.014*** (0.004)	-0.014*** (0.004)	0.008*** (0.002)	0.007*** (0.002)
School holiday	-0.002*** (0.001)	-0.002*** (0.001)	0.000 (0.001)	0.000 (0.001)
Double demerit period	0.029*** (0.004)	0.029*** (0.004)	0.019*** (0.002)	0.018*** (0.002)
Unemployment rate	No	No	-0.000 (0.004)	-0.001 (0.004)
Hour-of-day dummies	No	No	No	No
Day-of-week dummies	No	No	No	Yes
Month-of-year dummies	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes
R^2	0.99	0.99	0.99	0.99
Observations	50,743	50,743	10,836	10,836
Instrumented variable: Ln Gasoline price (real). Instrumental variable: Ln World oil price (real).				
Coefficient on instruments		0.474***		0.460***
Partial R^2 on instruments		0.81		0.80
Robust endogeneity test p value		0.000		0.000

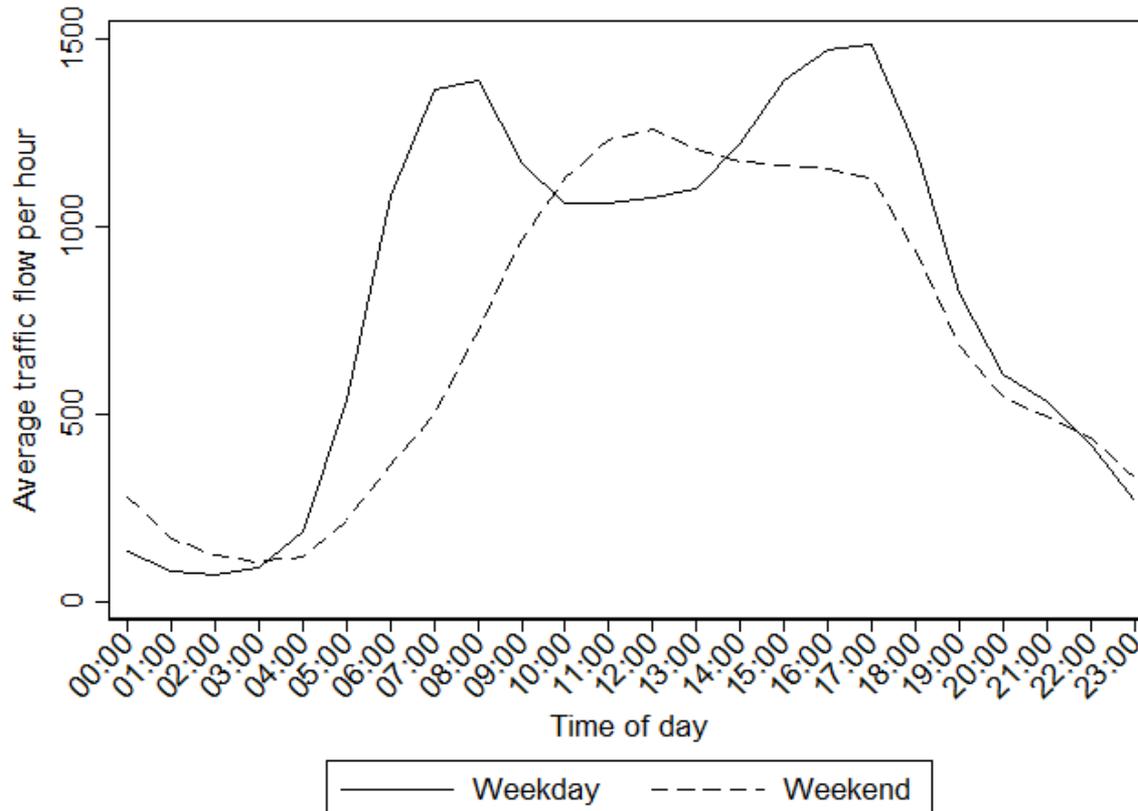
Table 5: Results using other specifications

Dependent variable:	Lagged dependent variable	Gasoline pump price
Ln traffic flow	(1)	(2)
Ln Real gasoline price	-0.032*** (0.007)	-0.050*** (0.018)
Ln S&P/ASX 200 price	-0.014 (0.010)	0.018 (0.023)
Rainfall (mm)	-0.000 (0.000)	-0.001*** (0.000)
Public holiday	0.008*** (0.002)	0.008*** (0.002)
School holiday	-0.000 (0.000)	0.000 (0.001)
Double demerit period	0.008*** (0.002)	0.018*** (0.002)
Unemployment rate	-0.002 (0.002)	-0.000 (0.004)
Hour-of-day dummies	No	No
Day-of-week dummies	No	No
Month-of-year dummies	Yes	Yes
Ln Traffic flow _{t-1}	0.757*** (0.029)	
Station fixed effects	Yes	Yes
Time trend	Yes	Yes
R ²	0.99	0.99
Observations	7587	10836

Notes: ***, ** and* indicate statistical significant at 1%, 5%, and 10% respectively. Both these two specifications are using monthly data. Standard errors are clustered at the station level.

4.2 Peak versus off-peak periods

Figure 3 Distribution of traffic flow



Weekday

- peak: 6am-10am & 3pm-7pm

Weekend

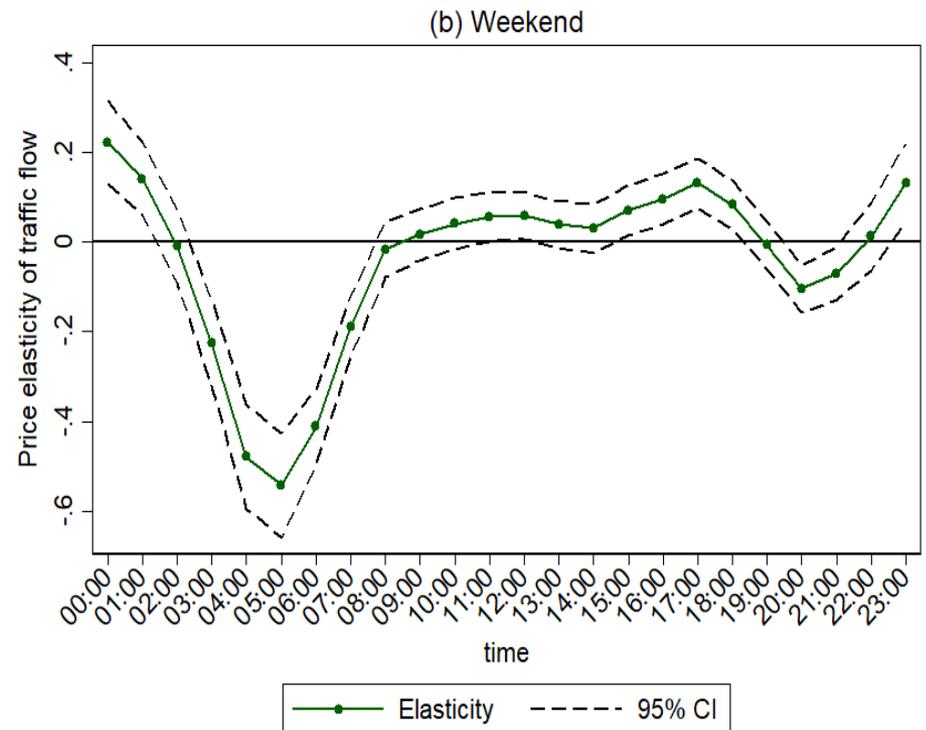
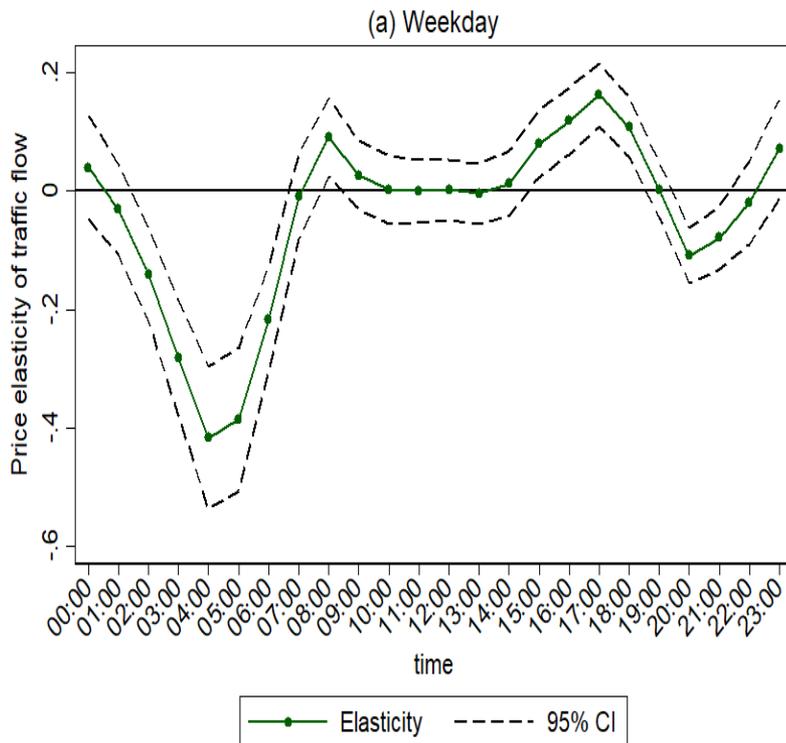
- peak: 9am-6pm

Source: The NSW Roads and Maritime Service (2019)

Table 6: Results during peak and off-peak periods.

Dependent variable: Ln traffic flow						
Period	Weekday			Weekend		
	All day (1)	Peak (2)	Off-peak (3)	All day (4)	Peak (5)	Off-peak (6)
Ln real gasoline price	-0.040** (0.017)	0.064*** (0.023)	-0.103*** (0.018) [0.000]	-0.038** (0.017) [0.814]	0.021 (0.026)	-0.074*** (0.020) [0.000]

Figure 4 Effect of gasoline prices changes on traffic flow, by time of day.



- Stock-flow relationships under crowded conditions:

In traffic flow theory, the correlation between **traffic flow (vehicles/hour)** and **traffic density (vehicles/km)** is negative when roads are congested (Keyvan-Ekbatani et al. 2012).

Higher gasoline prices \longrightarrow density decreases \longrightarrow
roadway speed increases \longrightarrow greater number of vehicles
passing through a single point ?

4.3 Heterogeneity analysis

- A: Greater Sydney (81) versus outside Greater Sydney (37);
- the NSW Roads and Maritime Severcies
- B: Sydney CBD (2) vs outside Sydney CBD (116);
- post code: 2000
- Sydney Harbour Tunnel, Cahill Expressway
- C: Toll roads (2) vs toll-free roads (116)
- Sydney Harbour Tunnel, Hills M2 Motorway
- D: Highways (29) vs non-highways (89).

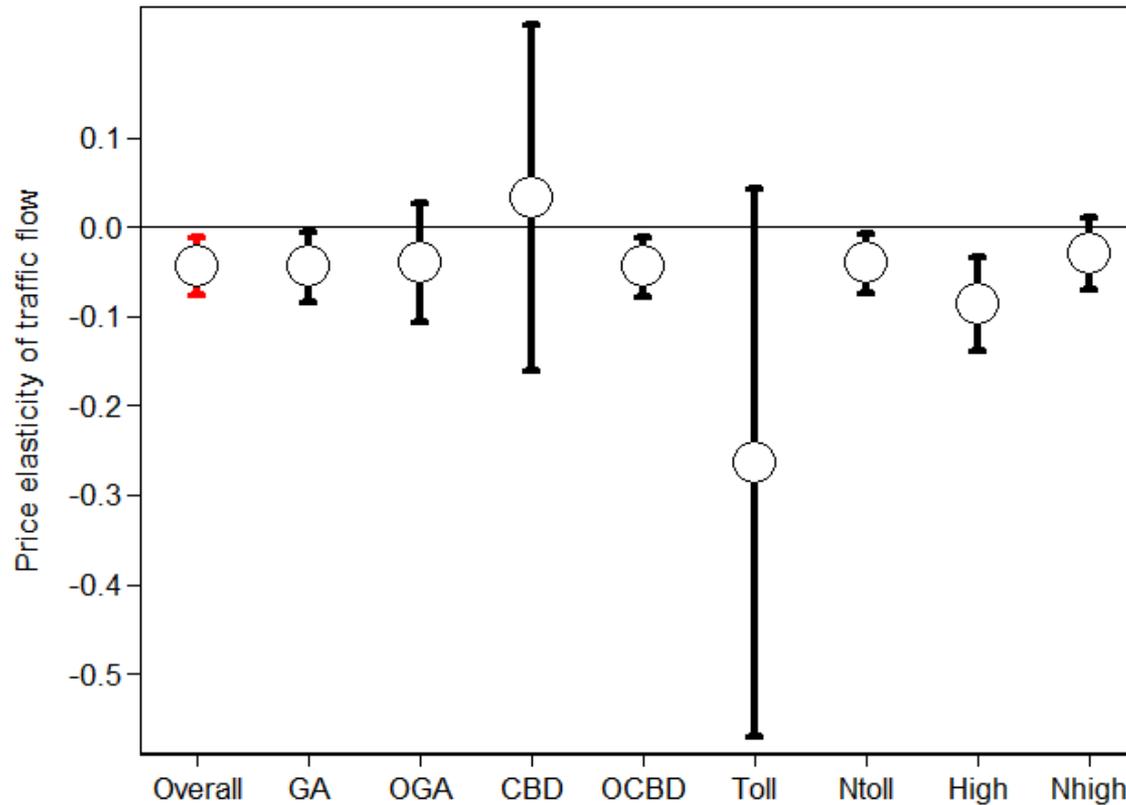
4.3 Potential station-level heterogeneity

Table 7: Heterogeneity analysis: by station group.

	Number of stations	Gasoline price-traffic flow elasticity
A. Greater Sydney vs others		
Greater Sydney	81	-0.044**
Outside Greater Sydney	37	-0.040 [0.907]
B. Sydney CBD vs others		
Sydney CBD	2	0.032
Outside Sydney CBD	116	-0.045*** [0.449]
C. Toll roads vs others		
Toll roads	2	-0.264*
Toll-free roads	116	-0.040** [0.158]
D. Highway vs others		
Highway	29	-0.086***
Non-highway	89	-0.030 [0.110]

Notes: All regressions use hourly data. Group is controlled for separately. Figures in square bracket are p-value for test of equality to the coefficient for the other group in the same panel.

Figure 6: Gasoline price elasticity of traffic flow and 95% confidence intervals.



4.3 Medium-run elasticities

Dependent variable: Ln traffic flow					
	(1)	(2)	(3)	(4)	(5)
Ln Real gasoline price	-0.033** (0.016)	0.003 (0.015)	0.001 (0.015)	0.012 (0.016)	0.012 (0.016)
Ln Real gasoline price t_{-30}		-0.039*** (0.015)	-0.025*** (0.010)	-0.053*** (0.010)	-0.069*** (0.010)
Ln Real gasoline price t_{-60}			-0.010 (0.016)	0.043*** (0.011)	0.058*** (0.012)
Ln Real gasoline price t_{-90}				-0.043** (0.015)	-0.038*** (0.010)
Ln Real gasoline price t_{-120}					0.001 (0.014)
Station fixed effects	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes
Adjusted R ²	0.98	0.98	0.98	0.98	0.98
Observations	469,196	409,349	357,560	314,085	276,942
Medium-run elasticity	-0.033**	-0.035**	-0.035*	-0.041**	-0.037*

Notes: The medium-run elasticity is the sum of the coefficients for each price term.

5. In line with prior studies

Gasoline price-traffic flow elasticity

- Elasticity obtained: -0.04

Bento et al. (2012): -0.083 for highways in Los Angeles.

Burke et al. (2017) : -0.1 in the short-run; -0.2 in the long-run (Indonesian toll roads).

Siddique (2008): -0.09 to 0 in Perth, Australia.

Gasoline price-public transit ridership elasticity

Congressional Budget Office (2008) : higher gasoline prices lead to greater ridership on transit rail systems (the U.S.).

Wallis and Kennedy (2007) : Australian public transport elasticities with respect to petrol prices generally range from 0 to 0.2.

Data: monthly data from July 2016 to December 2018.

$$\ln PT_t = \beta_0 + \beta_1 \ln P_t + \beta_2 U_t + \beta_3 C_t + D_{m:y} + \varepsilon_t$$

↓ ↙ ↓ ↓ ↓

Utilization figures using Opal card Real gasoline price Unemployment rate CCI Month-of-year dummies

Table 9: Gasoline price-public transit ridership elasticity.

Dependent variable: Ln total utilization	Public transit utilization
Ln real gasoline price	0.278*** (0.058)
Unemployment rate	-0.066*** (0.021)
Consumer confidence index	0.001 (0.002)
Month-of-year dummies	Yes
Time trend	No
R^2	0.91
Observations	30

6. Conclusion

- Higher gasoline prices do reduce traffic flows, but the effect is very inelastic in NSW.
- The elasticities depend on the time of day.
 - The elasticity during off-peak periods is particularly pronounced, both on weekdays (-0.10) and weekends (-0.07).
 - Interestingly, a positive effect of fuel prices on traffic flows is observed for peak periods on weekdays ($+0.06$).
- Not much heterogeneity between different station groups.
- Higher fuel prices encourage people to use public transport.

Implications:

- The results can be useful for predicting traffic flows.
 - Traffic flows are relatively unresponsive to changes in fuel prices. However, even if the effect is small, fuel price swings can still lead to quite large changes in the number of vehicles using the roads in absolute terms.
- The results could provide some suggestions for road pricing, which is often flagged as a priority economic reform for Australia (Productivity Commission 2006).

Thank you!

Q & A

Tables: OLS results using weighted average fuel prices

Dependent variable: Ln traffic flow	hourly	daily	weekly	monthly
Ln average gasoline and diesel price	-0.040** (0.016)	-0.034** (0.016)	-0.029* (0.016)	-0.042** (0.017)
Ln S&P/ASX 200 price	0.019 (0.019)	0.020 (0.017)	0.018 (0.018)	0.020 (0.022)
Rainfall (mm)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)	-0.001*** (0.000)
Public holiday	-0.125*** (0.012)	-0.148*** (0.013)	-0.014*** (0.004)	0.008*** (0.002)
School holiday	-0.015*** (0.002)	-0.025*** (0.003)	-0.002*** (0.001)	0.000 (0.001)
Double demerit period	-0.017*** (0.002)	-0.018*** (0.002)	0.029*** (0.004)	0.018*** (0.002)
Unemployment rate	No	No	No	-0.000 (0.004)
Hour of day dummies	Yes	No	No	No
Day of week dummies	Yes	Yes	No	No
Month of year dummies	Yes	Yes	Yes	Yes
Station fixed effects	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes
R^2	0.90	0.98	0.99	0.07
Observations	11,624,348	412,816	50,743	10,836

Notes: coefficients for constants are not reported. ***, ** and* indicate statistical significant at 1%, 5%, and 10% respectively. Standard errors are clustered at the station level. All regressions use hourly data.

Variable Definition and data sources:

Traffic flows: the number of vehicles for each traffic collection station for each hour of each day. Source: NSW Roads and Maritime Services (2019).

Gasoline price (real): terminal gate price is in Australian cents and inclusive of GST and excise. TGP Nominal TGP is taken from the Australian Institute of petroleum, calculated based on information provided by BP Australia, Caltex, Shell Australia and ExxonMobil. I use consumer price index deflators for all goods in Sydney to adjust the price on 2017 base. Source of CPI: Australian Bureau of Statistics (2018).

Gasoline pump price (real): pump price for gasoline (unleaded petrol) in Australian cents. Source: Fueltrac (2018).

Time trend: In the hourly and daily estimates, I use daily time trend, which is equal to 1 in 1st January 2010 and increases by 1 in each subsequent day. In the weekly estimate, this is equal to 1 in the first week of 2010 and increases by 1 in each subsequent week. In the monthly estimate, this is equal to 1 in January 2010 and increases by 1 in each subsequent month.

Public holiday dummy: Equals 1 if the day is a public holiday; 0 otherwise.

School holiday dummy: Equals 1 if the day is a school holiday; 0 otherwise.

S&P/ASX 200 price (AXJO): a market-capitalization weighted and float adjusted stock market index of stocks listed on the Australian Securities Exchange. Source: Investing.com

Rainfall: rainfall in millimetre (mm). Source: The Australian Bureau of Meteorology (2019).

World crude oil price (real): Cushing, OK WTI Spot price FOB (US\$ per barrel). Source: the U.S. Energy Information Administration (2018). I deflated using the US CPI from the St Louis Fred (2017).

Exchange rate: AUD/USD exchange rate. A\$1=USD. Source: Reserve Bank of Australia.

Unemployment rate (%): Department of Jobs and Small Business (2019).

Consumer confidence index: ANZ-Roy Morgan (2018) Australian consumer confidence index.