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Easing the traffic: The effects of Indonesia's fuel subsidy reforms on toll-road travel

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Indonesia has serious traffic jams. This study uses data from 19 Indonesian toll roads over 2008–2015 to calculate the effects of Indonesia's historic recent fuel subsidy reforms on motor vehicle travel. The timing of the reforms was determined by budgetary and political factors, providing a suitable setting for estimating a causal effect. We control for a broad set of other factors potentially influencing traffic flows. Estimates using monthly data suggest an immediate fuel price elasticity of motor vehicle flows on the roads in our study of -0.1 , increasing to -0.2 when responses over a year are considered. We estimate that Indonesia's fuel subsidy reforms of 2013 and 2014 had reduced traffic pressure on these roads in the second half of 2015 by around 10% relative to the counterfactual without reform. A move to an adequate fuel excise system could contribute to more free-flowing traffic, while generating revenue for infrastructure and other investment.

Keywords: fuel subsidy, gasoline, price, elasticity, transport, Indonesia

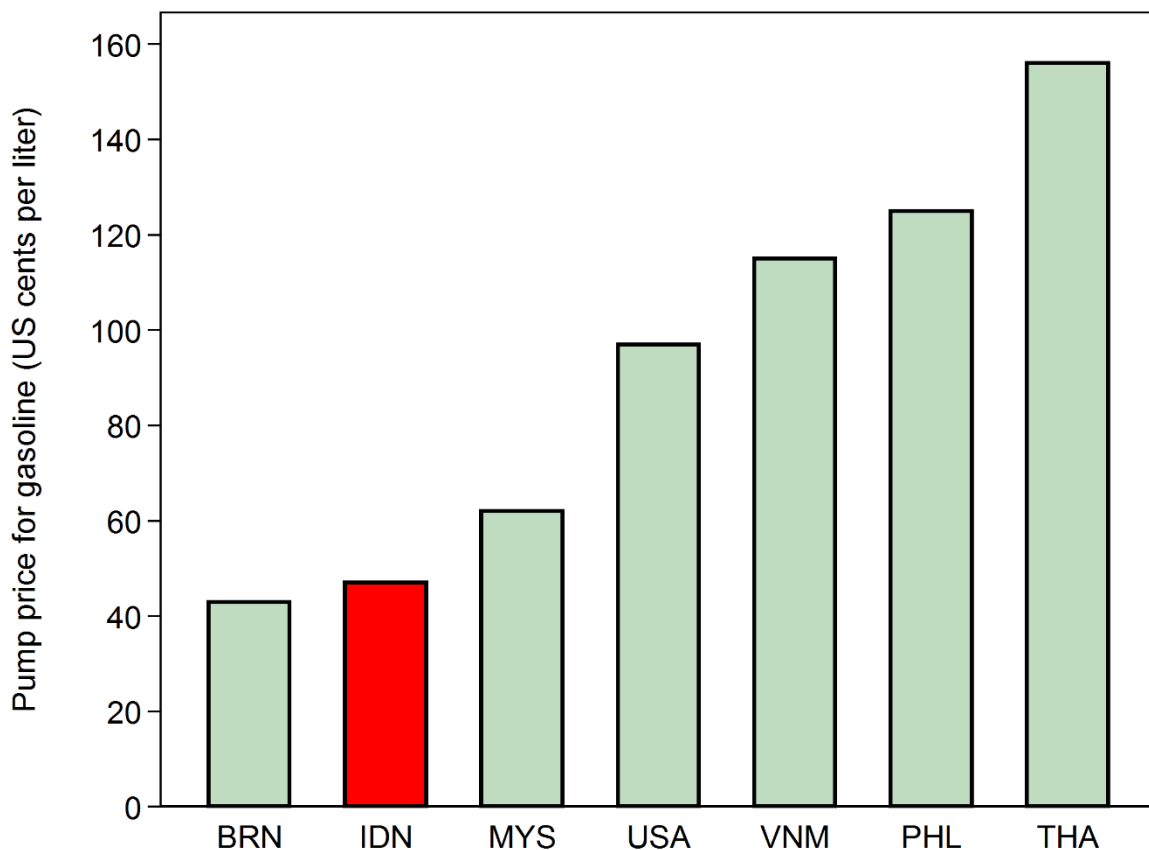
JEL classifications: R41, R48, H20

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1. Introduction

Indonesia, the world's fourth-most populous country, has for years been fiscally burdened by subsidies for oil consumption, principally for road transport. As of November 2012, Indonesia's subsidized gasoline price was only 4,500 Indonesian rupiah (IDR) per liter, or US 47 cents. This was well below even the world crude oil price of 69 cents per liter (GIZ, 2014). Losses on sales of gasoline and diesel by the state-owned oil company, Pertamina, were paid for from Indonesia's central budget. Indonesia was ranked as the world's fourth-largest subsidizer of oil use by the International Energy Agency (2015). Fig. 1 compares Indonesia's pump price for gasoline with selected neighboring countries and the United States (US).

Fig. 1 Gasoline pump prices, 2012, selected countries.



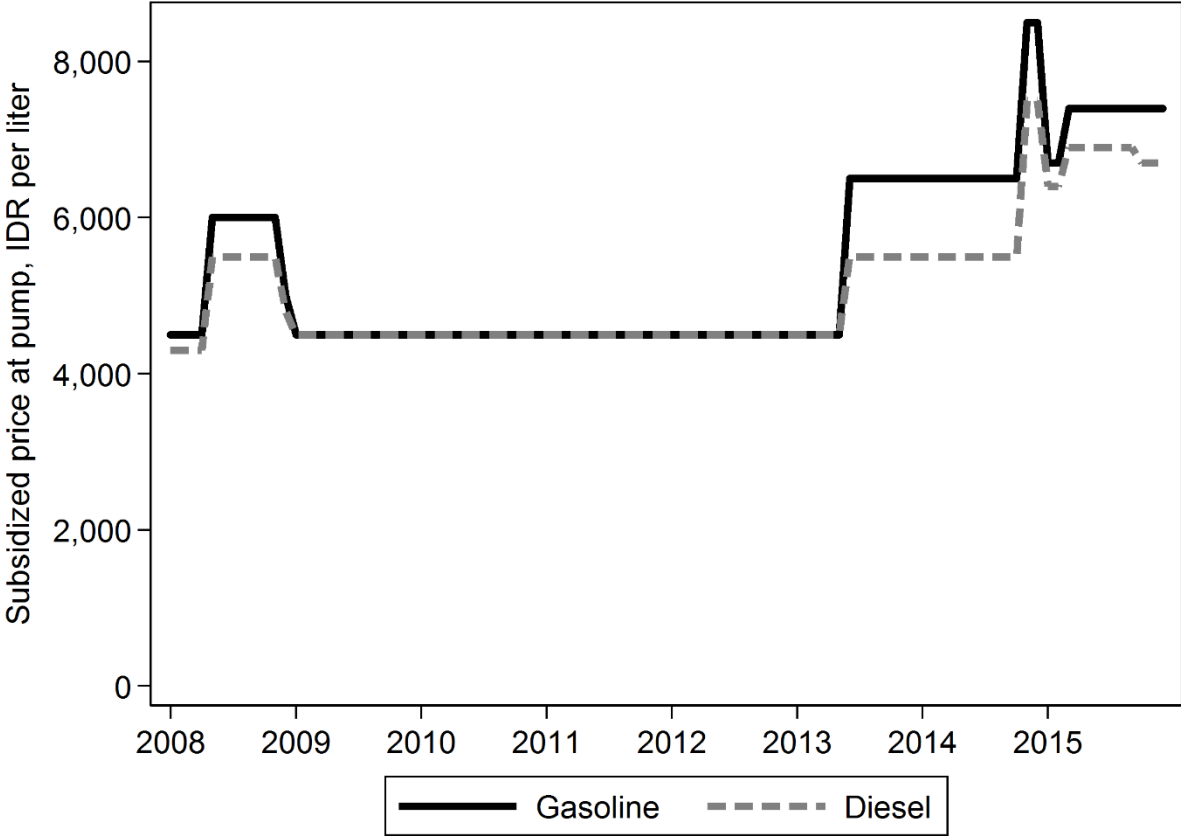
BRN = Brunei Darussalam; IDN = Indonesia; MYS = Malaysia; USA = United States; VNM = Vietnam; PHL = Philippines; THA = Thailand. Data are for November, and for the most widely sold grade of gasoline in each country. Source: World Bank (2017).

Since 2013, Indonesia has implemented ambitious reforms to its fuel subsidy arrangements. These commenced on 22 June 2013, when President Susilo Bambang Yudhoyono announced overnight increases in Indonesia's administered gasoline and diesel prices of 44% and 22%. On 18 November 2014 new President Joko Widodo increased these prices by a further 31% and

36%. This took the gasoline price to 8,500 IDR per liter. This level was short-lived, however: at the end of December 2014 the gasoline price was reduced to 6,700 IDR per liter as the world oil price fell. At this time it was also announced that the gasoline subsidy had been eliminated, although in practice some subsidies have continued. A fixed subsidy of 1,000 IDR per liter was continued for diesel (reduced to 500 IDR per liter in July 2016).

As of the start of 2015 a system of occasional price review and adjustment was also implemented, with the notional aim of ensuring that pump prices are updated to reflect changes in input costs. Under this system, fuel prices were increased in March 2015. The gasoline price was then unchanged for the remainder of 2015. Indonesia’s subsidized gasoline and diesel prices over our study period are shown in Fig. 2.

Fig. 2 Indonesia’s subsidized gasoline and diesel prices, 2008–2015.

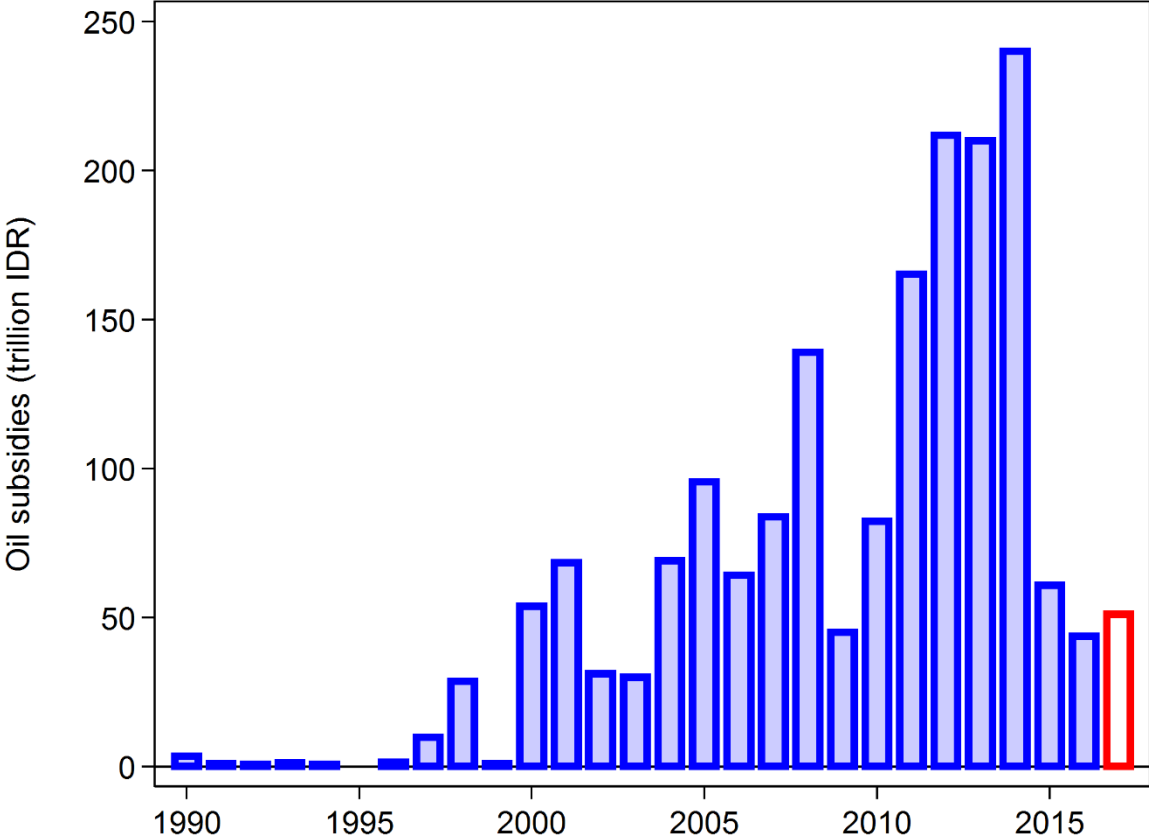


Source: CEIC (2016). Gasoline is Premium (RON 88). RON = research octane number. Data are as at the end of each month. Prices are in nominal terms. “Premium” is the name given to the fuel; it does not mean high-quality.

Indonesia’s fuel price increases since 2013, coupled with the decline in the world oil price, have allowed a large reduction in the country’s expenditure on oil subsidies (Fig. 3). Nominal

expenditure on oil subsidies in 2015 was more than 70% lower than it was in 2012. The reforms have constituted one of the most important fuel subsidy reform episodes anywhere in the world (Ross et al., 2017). Phasing out fossil fuel subsidies is a key goal of the international community, as pledged by the G20 and Asia-Pacific Economic Cooperation (APEC) in 2009.

Fig. 3 Indonesia’s annual oil subsidies, 1990–2017.



Sources: Bank Indonesia (2016), Ministry of Finance (pers. comm.; 2017), Howes and Davies (2014), Mustami (2017). These are budget expenditures on subsidies for all oil products in nominal terms. The subsidies cover non-transport fuels such as liquefied petroleum gas (LPG). Subsidies for LPG have grown quickly in recent years. Data for 2017 are from the draft revised budget.

In this study we investigate the effects of Indonesia’s fuel subsidy reforms on road traffic. Indonesia has some of the world’s most notorious traffic jams, causing large costs for commuters and the economy more broadly. Many road trips are slowed, delayed, or forgone altogether, and many commuters spend hours per day on the road. Traffic pressure is heaviest in Greater Jakarta – the second-most populous urban area in the world, after Greater Tokyo (Demographia, 2016) – but is also serious in other cities (Castrol, 2015; Waze, 2015). Indonesia’s traffic jams are a function of high population density, underinvestment in mass transport options, and various other root causes, likely including Indonesia’s subsidization of fuel use. By reducing the incentive to

take trips of relatively low economic value, fuel subsidy reductions should provide a reasonably efficient means of reducing vehicle traffic.

Our analysis uses data on road use for a panel of 19 toll roads over 2008–2015. Aggregated monthly, the data represent 9 billion trips by motor vehicles on roads in Java, Sumatra, and Bali.¹ With the exception of Bali Mandara Toll Road, motorcycles are not permitted on the roads in our sample. We use a distributed-lag specification to investigate both immediate and delayed effects of fuel price changes, and control for a host of other factors that may have influenced observed traffic flows. The number of vehicles using a road is a key determinant of susceptibility to traffic jams (Sugiyama et al., 2008). To our knowledge this is the first study of the effects of fuel subsidy reforms on vehicle travel in Indonesia.

Our study is of international interest in that, like some other developing-country megacities, Jakarta has relatively underdeveloped public transport.² The effect of fuel price changes on road use might be expected to be relatively small when transport alternatives are limited, but we find similar estimates to those obtained in other countries. Our results are of potential use for the design of economic instruments to manage road traffic in Indonesia and elsewhere.

The paper proceeds as follows. Section 2 explains our method and discusses the expected effects of fuel subsidy reforms on road traffic. Our results are presented in Section 3. Section 4 relates our estimates to the existing literature. The final section concludes.

2. Method

2.1 Model and data

We use monthly data for 2008–2015 for 19 toll roads operated by Jasa Marga and its subsidiaries. 70% government owned, Jasa Marga is the largest toll road operator in Indonesia. 17 of the 19 roads are in Java, Indonesia’s most populated island. The sample also includes one road in North Sumatra (Belmera Toll Road) and one in Bali (Bali Mandara Toll Road). Six of the roads opened after 2008, meaning that our panel has an unbalanced structure. A list of the roads, in descending order of motor vehicle flows in December 2015, is in Table 1.

Our focus on toll roads is driven by data realities; a suitable dataset is not available for the number of trips on non-toll roads over our study period. Our sample nevertheless covers some of Indonesia’s most important and heavily-used roads, including Jakarta-Cikampek Toll Road, Jakarta Inner Ring Road, Jagorawi Toll Road, and Jakarta Outer Ring Road (JORR). Toll roads are relevant for policymakers because toll ticketing infrastructure could in principle quite easily

¹ We refer to each issued toll ticket as a “trip”. The number of actual trips is less than 9 billion, as some involve (a) being issued more than one ticket on a single road, or (b) travelling on more than one toll road.

² In 2010, only around one-fifth of trips in Greater Jakarta were by train or bus (Coordinating Ministry of Economic Affairs and Japan International Cooperation Agency, 2012). Construction of the first line of Jakarta’s mass rapid transit (MRT) system is underway.

be used for time-of-day congestion pricing. While the vehicle flow data are believed to be of reasonable quality, they are affected by some changes to ticketing arrangements, such as movements of toll booths. Our modeling will control for important changes to toll ticketing.

Table 1 Roads in the study.

Number	Road	Island	Nearest city	Number of vehicles: December 2015
1	Jakarta-Cikampek Toll Road	Java	Greater Jakarta	18,800,410
2	Jakarta Inner Ring Road	Java	Greater Jakarta	17,966,547
3	Jagorawi Toll Road	Java	Greater Jakarta	17,650,157
4	Jakarta Outer Ring Road (JORR)	Java	Greater Jakarta	13,635,526
5	Jakarta-Tangerang Toll Road	Java	Greater Jakarta	10,809,212
6	Surabaya-Gempol Toll Road	Java	Surabaya	8,139,752
7	Prof Dr Sedyatmo Toll Road	Java	Greater Jakarta	6,658,524
8	Padalarang-Cileunyi Toll Road	Java	Bandung	5,150,542
9	Semarang Toll Road	Java	Semarang	4,412,880
10	Ulujami-Pondok Aren Toll Road Section	Java	Greater Jakarta	3,723,236
11	Palikanci Toll Road	Java	Cirebon	2,488,193
12	JORR W2 North Toll Road	Java	Greater Jakarta	2,178,270
13	Belmera Toll Road	Sumatra	Medan	2,101,553
14	Semarang-Solo Toll Road	Java	Semarang	1,848,688
15	Bali Mandara Toll Road	Bali	Denpasar	1,431,174
16	Bogor Outer Ring Road	Java	Greater Jakarta	1,376,650
17	Surabaya-Mojokerto Toll Road (Section 1A)	Java	Surabaya	1,206,059
18	Cipularang Toll Road	Java	Purwakarta	527,661
19	Gempol-Pandaan Toll Road	Java	Greater Surabaya	502,723
			Total	120,607,757

Source: Jasa Marga (2016). Data for Bali Mandara Toll Road include motorcycles. The roads are “sections”. Number of vehicles is based on the number of issued tickets. In some instances, more than one ticket is issued for a trip on a road.

We use the following log-log estimation model:

$$\ln V_{r,m} = \sum_{j=1}^T \alpha_j \ln P_{m-j} + \beta_{m:y} + \beta_r + \gamma_r t + \mathbf{X}'_{r,m} \boldsymbol{\delta} + \varepsilon_{r,m} \quad (1)$$

V is the number of vehicle trips on road r in month m , measured by the number of issued tickets.³ P is the weighted average of the subsidized prices of gasoline and diesel at the end of the month.⁴ We use the first lag of the fuel price to ensure it is measured prior to month m . We also include additional lags back to $T = 12$, as it may take time to respond to fuel price changes. We thus

³ In many instances, only one ticket is issued for each unique trip on each road.

⁴ We apply weights of 0.87 for gasoline and 0.13 for diesel based on the shares of Group I vehicles (cars, small trucks, buses) versus non-Group I vehicles (trucks with two or more axles) on these roads. See the Appendix for details. We obtain similar results using alternative weighting schemes.

estimate the effect over one year of response. The long-run effect is likely larger as a result of responses such as reduced urban sprawl (Creutzig, 2014) and individuals moving closer to their workplaces.⁵ Sufficient time has yet to pass for long-run impacts to have been observed.⁶ We assume symmetric effects of price increases and price decreases.

Transport demand is seasonal. To capture this, Eq. (1) controls for the month of the year ($\beta_{m,y}$). We also include road fixed effects (β_r) to account for the different capacities and underlying demand conditions on each road. Our estimations consequently utilize the time series or *within* variation in the data. Our control set also includes a linear time trend (t) for each road, allowing vehicle flow to be subject to a road-specific underlying exponential growth or decline process.

Eq. (1)'s \mathbf{X} vector represents an extensive list of additional variables. The list includes dummies for Idul Fitri (end of Ramadan) – an event that occurs in different months from year to year. We interact the Idul Fitri dummies with the road fixed effects because some roads are likely to experience higher demand during Idul Fitri, while others experience reduced demand. The list also includes log GDP in month $m-1$, proxied by a variable constructed using quarterly GDP data and the monthly industrial production index.⁷ Our control set also includes the number of days in each month;⁸ the number of lanes on each road; the log toll tariff; a control to capture improvements in the Jabodetabek Commuterline train network from 2013; precipitation; temperature; flood dummies for Prof Dr Sedyatmo Toll Road in February 2008 and for Jakarta roads in January 2013; and dummies to account for ticketing changes on some toll roads. We include controls for a road's first month of operation if it opened during our study period; for the opening of important connecting roads and the new Medan Airport; and for extensions to existing roads. Full details of our controls and their definitions is in an Appendix.

Our regressions do not control for the consumer price index, itself in part a function of the fuel price. The road-specific time trends help to control for secular trends in other prices. Indonesia's fuel subsidy reforms freed up funds for other purposes such as infrastructure investment and cash transfers to low-income households. This expenditure is unlikely to have had noticeable short-run effects on the roads in our study, and is not controlled for. Subsidized fuel is not available in some locations in Indonesia, but this is not a substantial issue given that the 19 roads in our study are in or near major cities. We also present an estimate using the average gasoline price paid by

⁵ It is possible for the long-run effect to be smaller if people return to some of their former habits as time passes.

⁶ One approach to estimating a long-run effect is to rely on forward simulations of a lagged dependent variable model. This is not a compelling approach when long-run responses such as altered urban sprawl may yet to have commenced.

⁷ We avoid controlling for log GDP in month m , as this may be affected by the fuel price. We use national GDP because gross regional product is not available on an intra-year basis for our full study period.

⁸ Leap-year Februaries have a different number of days to non-leap-year Februaries, so the month-of-year dummies do not fully control for month length. We obtain almost identical results with $\text{Ln}(\text{Average vehicle trips/day})_{r,m}$ as our dependent variable.

consumers in the nearest urban area, which includes unsubsidized gasoline.⁹ We do not control for the 2016 change to Jakarta's high-occupancy vehicle (HOV) policy, as this occurred after our study period. Hanna et al. (2017) find that this change affected Jakarta's traffic.

Our approach of using a two-dimensional road-month panel shares similarities to the approaches of Burger and Kaffine (2009), who used a freeway route-week panel from Los Angeles, and Bento et al. (2013), who employed a location-week panel also from Los Angeles. For the US there are some prior studies that have used more disaggregated data (e.g. Gillingham, 2014 used vehicle-level data from California) and also studies using more aggregated data (e.g. Small and Van Dender, 2007 utilized vehicle travel data aggregated to the US state level). Huang and Burris (2015) used monthly toll road traffic data for a sample of US toll roads, similar to our approach for Indonesia. They presented road-by-road estimates rather than estimating a panel. Relative to Khoo et al.'s (2012) study of Malaysia, ours has the advantage of using data from multiple years. This allows us to control for seasonality and ongoing trends.

2.2 Expected fuel price elasticity of motor vehicle flows

$\sum_{j=1}^T \alpha_j$ will provide our estimate of the average T -month fuel price elasticity of motor vehicle flows. It should be expected that the demand curve for motor vehicle travel is downward-sloping, meaning that this elasticity is negative. Higher fuel prices increase the monetary cost of road trips, likely inducing substitution to other travel modes, car-pooling, shorter trips, and non-travel activities such as working or eating at home. Other travel modes include train, bus, mini-bus, motorcycle, bicycle, and walking, or combinations of these options.

There are reasons, however, to think that the fuel price elasticity of vehicle flows on the roads in our study is likely to be small. Some travellers have relatively few attractive transport alternatives. Indonesia's fuel price has also been relatively low; a percentage increase in a low price may induce a small quantity response. A related point is that fuel is only one component of the cost of driving, meaning that fuel price increases may have a relatively small effect on driving decisions. Other costs include vehicle maintenance and depreciation; insurance and risk costs; toll tariffs; the cost of a paid driver (if used); and time, inconvenience, and stress costs of taking a trip. A final reason to expect a small fuel price elasticity is that many of the roads have been subject to congestion. Vehicle trips are often forgone due to concern about the traffic. Trips disincentivized by a higher fuel price may be replaced by trips by other drivers who are attracted to more free-flowing traffic. The net result might be little change in traffic flows.

⁹ As of 2014, 96% of the gasoline consumed in Indonesia's transport sector was Premium 88, the subsidized gasoline type (Ministry of Energy and Mineral Resources, 2015). Premium 88 was becoming more difficult to find in some areas in 2016, but was generally available in areas near the toll roads in our study during our sample period.

2.3 Identification

The identification assumptions required for Eq. (1) to provide a consistent, causal estimate of the fuel price elasticity of road use are that (1) decisions to change the subsidized gasoline and diesel prices have not been influenced by expectations of changes in traffic flows or related variables, (2) there are no important omitted variables that happen to be correlated with the subsidized gasoline and diesel prices and that varied due to reasons other than changes in these prices, and (3) we have adopted a suitable functional form.¹⁰ That Indonesia's fuel subsidy reform decisions were motivated by fiscal and political considerations means that the first of these assumptions is likely to be satisfied. The second is challenging. Our long list of controls does, however, help to reduce omitted variable concerns; our ability to explain most of the variation in motor vehicle flows is reflected in R^2 values of around 0.96. Identification also relies in part on the discontinuous nature of the fuel price changes; many other variables affecting vehicle flows – such as road maturity effects – are more continuous in nature. We conduct a suite of robustness checks, finding similar results across sub-groups of roads, when any single year is excluded, and in various other specifications.

17 of the 19 roads in our panel are part of an interconnected road system in Java, Indonesia's most populous island. Single journeys often involve travelling on more than one of the roads. For this reason, and due to time-specific shocks affecting vehicle travel across the road system, our data may exhibit a degree of cross-sectional dependence. A Breusch and Pagan (1980) Lagrange multiplier test indeed rejects the null of cross-sectional independence at the 1% level for a balanced sub-set of our panel. We consequently use the panel estimator of Driscoll and Kraay (1998), which produces standard errors non-parametrically adjusted for heteroskedasticity, autocorrelation, and potential correlation in error terms across the roads. The estimator is suited to panels with relatively long time dimensions; our sample has up to 96 observations per road. We also present estimates using monthly data for trips aggregated (a) across the 19 roads, and (b) across the 13 roads that were open throughout our full study period. These avoid the issue of panel cross-sectional dependence.

A final issue is the time-series properties of the data. To explore, we obtained the residual from a regression of our dependent variable against the month-of-year dummies, road-specific time trends, Idul Fitri dummies, and dummy variables representing changes in ticketing and other road-specific factors. We then carried out Dickey and Fuller (1979) tests on this residual. We were able to reject the null hypothesis of a unit root at the 5% significance level for 17 of the 18 roads in our sample for which we have 10 or more observations.¹¹ We are not able to reject this null for Belmera Toll Road, but obtain similar results if this road is excluded from our sample. Our log GDP proxy has a unit root, but we obtain nearly identical results if this control is

¹⁰ Bias could also enter via correlation between other explanatory variables and important omitted variables. We obtain similar estimates in a basic estimation with a reduced control set, however.

¹¹ Gempol-Pandaan Toll Road opened in June 2015, so we only have 7 observations for this road.

excluded. We also obtain a similar result from an estimation in first differences. We thus conclude that time-series econometric issues do not prevent us from obtaining accurate estimates of the fuel price elasticity of vehicle flows.

2.4 Limitations

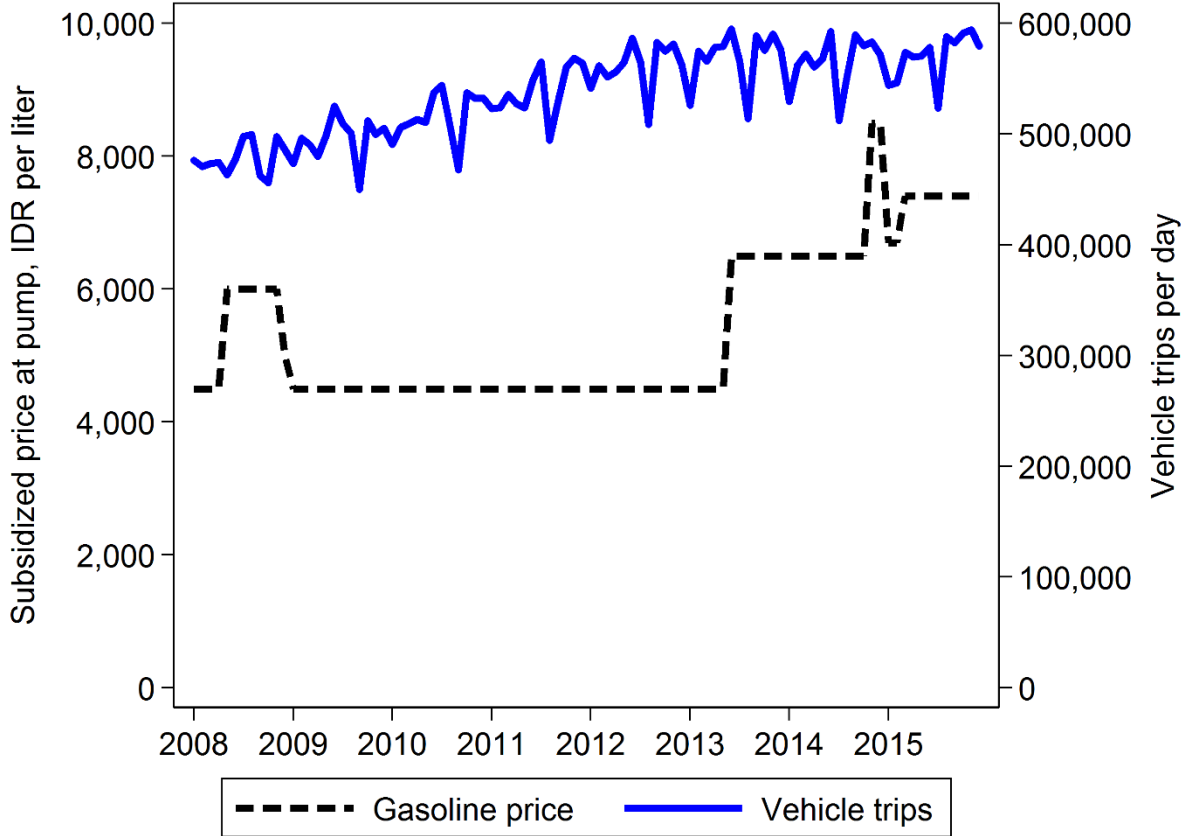
A key limitation is that our data do not cover motorcycle trips, except on the Bali-Mandara Toll Road. As of 2014 Indonesia had more than four times as many motorcycles as other motor vehicles (Badan Pusat Statistik, 2016a). Indonesia's fuel price reforms may have induced substitution to motorcycles, generally a more fuel-efficient travel option. A second limitation is that it is not possible for us to identify the effect of Indonesia's fuel subsidy reforms on non-toll roads. The effect may have been larger if users of non-toll roads are more price sensitive, or if travelers switch from non-toll roads to toll roads to conserve fuel when the fuel price increases. A smaller effect might be expected, however, if a higher fuel price induces drivers to switch to non-toll roads, perhaps due to increased use of motorcycles, or drivers no longer being able to afford the toll (Huang and Burris, 2015). A third limitation is that we do not have data on vehicle speeds or on vehicle flows at a more disaggregated time dimension, such as by hour. Researchers may in future be able to examine the effects of fuel price changes on motorcycle travel, the use of non-toll roads, intra-day effects, and/or vehicle speeds using an alternative dataset. It might also be fruitful to pursue analysis of optimal toll tariffs by time of day, and/or to apply our approach to roads in other developing countries.

2.5 A look at the data

Before proceeding to our econometric results, Fig. 4 presents a look at monthly daily-average vehicle flows for the Jakarta Inner Ring Road against the price of one liter of Premium gasoline (the subsidized gasoline type). The Jakarta Inner Ring Road is the second-most utilized road in our sample (Table 1).¹² It can be seen that vehicle trip numbers exhibit relatively slow growth after the fuel price increases of 2008, 2013, and 2014. Substantial seasonality, and an underlying upward trend, can also be observed. These will be controlled for in our econometric estimates, to which we now turn.

¹² We opted for Jakarta Inner Ring Road instead of Jakarta-Cikampek Toll Road because there was a change to ticketing on the Jakarta-Cikampek in 2011 that affected its data series. This is controlled for in our econometric modelling.

Fig. 4 Vehicle trips versus gasoline price, Jakarta Inner Ring Road.



Note: Data are monthly. Sources: CEIC (2016), Jasa Marga (2016). Gasoline price is the nominal Premium (RON 88) price as at the end of the month. RON = research octane number. “Premium” is the name given to the fuel; it does not mean high-quality.

3. Results

3.1 Regression estimates

Our distributed lag estimates are presented in Table 2. Column 1 includes one lag of the log fuel price, with an additional lag added in each subsequent column. The estimates suggest that the immediate fuel price elasticity of vehicle flows is -0.1 , significantly different from zero at the 1% level. This elasticity increases as time passes, reaching -0.2 twelve months after an initial price shock. The effect is highly inelastic. The estimates nevertheless suggest that Indonesia’s fuel subsidy reductions contributed to easing traffic flows on the roads in our sample.

Table 3 presents alternative specifications, focusing on the immediate fuel price elasticity. The first is a specification excluding the GDP, precipitation, temperature, tariff, and election controls. The result is similar. We also obtain a similar estimate for the balanced sample of the 13 roads that opened before January 2008 (column 2). Column 3 uses the average gasoline price paid by consumers in the nearest urban area, which includes purchases of unsubsidized gasoline. Data for

this variable are not available for 2011 and 2015. We obtain a slightly smaller immediate price elasticity of -0.08 , again significantly different from zero at the 1% level. Columns 4 and 5 use the log subsidized gasoline price and log subsidized diesel price, respectively. A larger elasticity is obtained for the diesel price.

One concern is that growth in vehicle flows may have slowed anyway in recent years because some of the roads are at or near peak capacity. Road maturity effects of this type might confound our estimates. The issue is primarily relevant to the congested roads of Greater Jakarta. To explore, Column 6 of Table 3 includes an interaction between the log fuel price and a dummy for roads outside Greater Jakarta. The specification provides no significant indication that the immediate fuel price elasticity of vehicle flows differs on roads in or outside of Greater Jakarta. We also find no significant indication that the elasticity differs for heavily-used and less-used roads (column 7). Our estimates might thus not be substantially influenced by road maturity effects.¹³

While Indonesia's fuel subsidy reforms were overnight, they were to some extent anticipated. Anticipatory effects may have occurred: people may have driven more in the lead-up to fuel price increases, while fuel was cheap (Coglianese et al., 2017). To explore, we included the fuel price term for months m and $m+1$ in column 8 of Table 3. The coefficients are statistically insignificant. That the lagged price term is significant and the m and $m+1$ terms are not increases our confidence that we have found a genuine effect.

Column 9 presents an estimate in first differences. We obtain a similar short-run fuel price elasticity. Column 10 presents an estimate that includes the one-month lag of the dependent variable. The immediate fuel price elasticity of vehicle flows remains similar (-0.08 , significant at 1%).

To examine if our results are unduly affected by happenings in any one year, columns 1–8 of Table 4 present estimates that exclude each individual year, one-by-one. The elasticity is reasonably stable. Columns 9 and 10 present time-series estimates for data aggregated across all 19 roads, and across the balanced sample of 13 roads. These use a smaller control set. The fuel price elasticities are again similar.

¹³ We also note that vehicle flows in 2016 exceeded flows in 2015 on all but one of the roads in our study (Jasa Marga, 2017), suggesting that additional capacity may have remained in 2015. Our regressions control for road-specific time trends in recognition of the different trajectories of vehicle flows on each road.

Table 2 Main results.

Dependent variable: Ln Vehicle trips _{r,m}												
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Ln Fuel price _{m-1}	-0.10*** (0.02)	-0.09*** (0.03)	-0.10*** (0.03)	-0.08** (0.04)	-0.09** (0.04)	-0.10** (0.04)	-0.10** (0.04)	-0.10** (0.04)	-0.10** (0.04)	-0.09** (0.04)	-0.09** (0.04)	-0.10** (0.04)
Ln Fuel price _{m-2}		-0.01 (0.04)	0.07 (0.05)	0.05 (0.05)	0.06 (0.05)	0.08 (0.06)	0.07 (0.06)	0.07 (0.06)	0.06 (0.06)	0.06 (0.06)	0.06 (0.06)	0.07 (0.06)
Ln Fuel price _{m-3}			-0.09*** (0.03)	-0.03 (0.04)	-0.04 (0.05)	-0.02 (0.05)	-0.01 (0.05)	-0.01 (0.05)	-0.01 (0.05)	-0.01 (0.05)	-0.01 (0.05)	-0.01 (0.05)
Ln Fuel price _{m-4}				-0.07* (0.04)	-0.02 (0.07)	-0.06 (0.06)	-0.04 (0.06)	-0.05 (0.06)	-0.05 (0.06)	-0.05 (0.07)	-0.06 (0.06)	-0.06 (0.07)
Ln Fuel price _{m-5}					-0.05 (0.04)	0.09* (0.05)	0.07 (0.05)	0.06 (0.04)	0.06 (0.05)	0.06 (0.05)	0.06 (0.04)	0.05 (0.05)
Ln Fuel price _{m-6}						-0.15*** (0.03)	-0.07 (0.05)	-0.06 (0.04)	-0.06 (0.04)	-0.05 (0.04)	-0.06 (0.05)	-0.05 (0.04)
Ln Fuel price _{m-7}							-0.10* (0.05)	-0.12*** (0.04)	-0.13*** (0.04)	-0.12*** (0.04)	-0.11** (0.05)	-0.12*** (0.04)
Ln Fuel price _{m-8}								0.03 (0.03)	0.07* (0.04)	0.06* (0.03)	0.08** (0.03)	0.09*** (0.03)
Ln Fuel price _{m-9}									-0.05 (0.03)	-0.01 (0.02)	-0.03 (0.03)	-0.00 (0.03)
Ln Fuel price _{m-10}										-0.04 (0.03)	0.00 (0.04)	-0.01 (0.05)
Ln Fuel price _{m-11}											-0.05 (0.03)	0.04 (0.03)
Ln Fuel price _{m-12}												-0.12*** (0.03)
Month-of-year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road time trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# Roads	19	19	19	19	19	19	19	19	19	19	19	19
# Observations	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482	1,482
Within-R ²	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Fuel price elasticity	-0.10***	-0.10***	-0.12***	-0.13***	-0.14***	-0.17***	-0.19***	-0.18***	-0.19***	-0.20***	-0.20***	-0.22***

Note: ***, **, and * indicate statistical significance at 1, 5, and 10%. Driscoll and Kraay (1998) standard errors are shown in parentheses, with three lags considered in the autocorrelation process. The within-R² measures the explanatory power of the time-varying explanatory variables. The fuel price is the weighted average of the subsidized gasoline and diesel prices, measured at the end of the month. The additional controls are listed in the Appendix. Coefficients on controls not reported. The total price elasticity is the sum of the coefficients for the distributed lags.

Table 3 Alternative specifications.

Dependent variable: Ln Vehicle trips _{r,m}										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Reduced control set	Balanced sample	Alternative price measures			Interactions		With <i>m</i> , <i>m</i> +1 price terms	Differenced	With LDV
Ln Fuel price _{<i>m</i>-1}	-0.10*** (0.02)	-0.09*** (0.02)				-0.08*** (0.02)	-0.10** (0.04)	-0.10*** (0.03)	-0.09** (0.04)	-0.08*** (0.02)
Ln Average gasoline price in nearest urban area _{<i>r,m</i>}			-0.08*** (0.02)							
Ln Subsidized gasoline price _{<i>m</i>-1}				-0.09*** (0.02)						
Ln Subsidized diesel price _{<i>m</i>-1}					-0.16*** (0.04)					
Ln Fuel price _{<i>m</i>-1} * Outside Greater Jakarta dummy _{<i>r</i>}						-0.03 (0.03)				
Ln Fuel price _{<i>m</i>-1} * Popular road dummy _{<i>r</i>}							-0.01 (0.04)			
Ln Fuel price _{<i>m</i>}								-0.02 (0.03)		
Ln Fuel price _{<i>m</i>+1}								0.03 (0.03)		
Month-of-year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road time trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Sub-set	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# Roads	18	13	18	19	19	19	19	19	19	19
# Observations	1,482	1,248	1,085	1,482	1,482	1,482	1,482	1,482	1,463	1,463
Within- <i>R</i> ²	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.47	0.96

Note: ***, **, and * indicate statistical significance at 1, 5, and 10%. Driscoll and Kraay (1998) standard errors are shown in parentheses, with three lags considered in the autocorrelation process. The within-*R*² measures the explanatory power of the time-varying explanatory variables. The additional controls are listed in the Appendix. Coefficients on controls not reported. Column 1: Excludes the GDP, precipitation, temperature, tariff, and election controls. Column 3: The average gasoline price in the nearest urban area covers both subsidized and unsubsidized gasoline, and is not lagged; data for this series are unavailable for 2011 and 2015. Column 6: The Outside Greater Jakarta dummy covers the 10 roads outside the Jabodetabek area. Column 7: The popular road dummy covers the 8 roads with the highest traffic volumes in December 2015 (see Table 1). Column 9: The dependent and non-dummy/non-trend explanatory variables are differenced. Column 10: LDV = lagged dependent variable.

Table 4 Excluding individual years, and using aggregated data.

Dependent variable: Ln Vehicle trips _{r,m}										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Excluding calendar year:								Aggregated	
	2008	2009	2010	2011	2012	2013	2014	2015	19-road	13-road
Ln Fuel price _{m-1}	-0.13*** (0.04)	-0.10*** (0.02)	-0.10*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.10*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.12*** (0.02)
Month-of-year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Road time trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Sub-set	Sub-set
# Roads	19	19	19	19	19	19	19	18	Aggregate	Aggregate
# Observations	1,326	1,324	1,314	1,308	1,290	1,287	1,266	1,259	96	96
Within- R^2 / R^2	0.96	0.96	0.96	0.96	0.96	0.96	0.97	0.96	0.97	0.96

Note: ***, **, and * indicate statistical significance at 1, 5, and 10%. Columns 1–8: Driscoll and Kraay (1998) standard errors are shown in parentheses, with three lags considered in the autocorrelation process. Columns 9–10: Robust standard errors are in parentheses. The within- R^2 measures the explanatory power of the time-varying variables; columns 9–10 show the R^2 . The additional controls are listed in the Appendix. Coefficients on controls not reported. Column 9: Vehicle flows are aggregated across all 19 roads. Column 10: Vehicle flows are aggregated across the balanced sample of 13 roads. Columns 9–10 control for month-of-year dummies, log GDP per capita_{m-1}, the election dummies, and an Idul Fitri dummy. Column 9 also controls for the number of roads included in the aggregation.

Our tables omit the coefficients for the controls. We here provide a brief discussion of these coefficients. Unsurprisingly, vehicle flows tend to increase when an additional lane is added to a road, by a magnitude of around 4%. We find a GDP elasticity of vehicle trips of +0.3 in our aggregate estimate in column 10 of Table 4, although with a significance level outside the standard thresholds. Vehicle flows exhibit seasonality, with June, July, and December having particularly heavy vehicle traffic (holding the other variables constant). Floods in Jakarta and on Prof Dr Sedyatmo Toll Road had negative effects on vehicle flows. We find insignificant effects for the toll tariff, perhaps because tariffs are only updated to keep up with inflation, and also perhaps due to measurement issues.¹⁴ Various other developments, such as the opening of the new Medan Airport in July 2013, appear to have had notable effects on road use in our sample (in Medan's case, on Belmera Toll Road).

We carried out a number of additional robustness checks. We find quite similar short-run fuel price elasticities in specifications with (a) road-specific month-of-year dummies, or (b) year dummies. We also obtain a similar result in balanced-sample specifications with common linear, quadratic, and cubic time trends instead of the road-by-road linear time trends. The elasticity remains similar if we exclude any individual road from our sample. Using unlogged vehicle flows and an unlogged fuel price, we find a negative coefficient for the fuel price variable: a 1,000 IDR per liter increase in the fuel price on average reduces a road's vehicle count in the next month by 62,400. Finally, we obtain similar results using quarterly data. These robustness checks are laid out in our estimation code, available online.

3.2 A no-reform counterfactual

What would the traffic have been like on the 19 roads in our sample if Indonesia's fuel subsidy reforms of 2013 and 2014 had not gone ahead? We use the estimate from column 12 of Table 2 to answer this question, with the results presented in Fig. 5. The simulation suggests that the fuel subsidy reforms of 2013 and 2014 reduced vehicle flows by approximately 10% on the roads in our study in the second half of 2015, relative to the no-reform counterfactual.¹⁵ This equates to more than a halving of the growth in vehicle flows. Use of the roads continued to increase, but less quickly than would have been the case had the gasoline and diesel prices remained at 4,500 IDR per liter (their level at the start of June 2013).

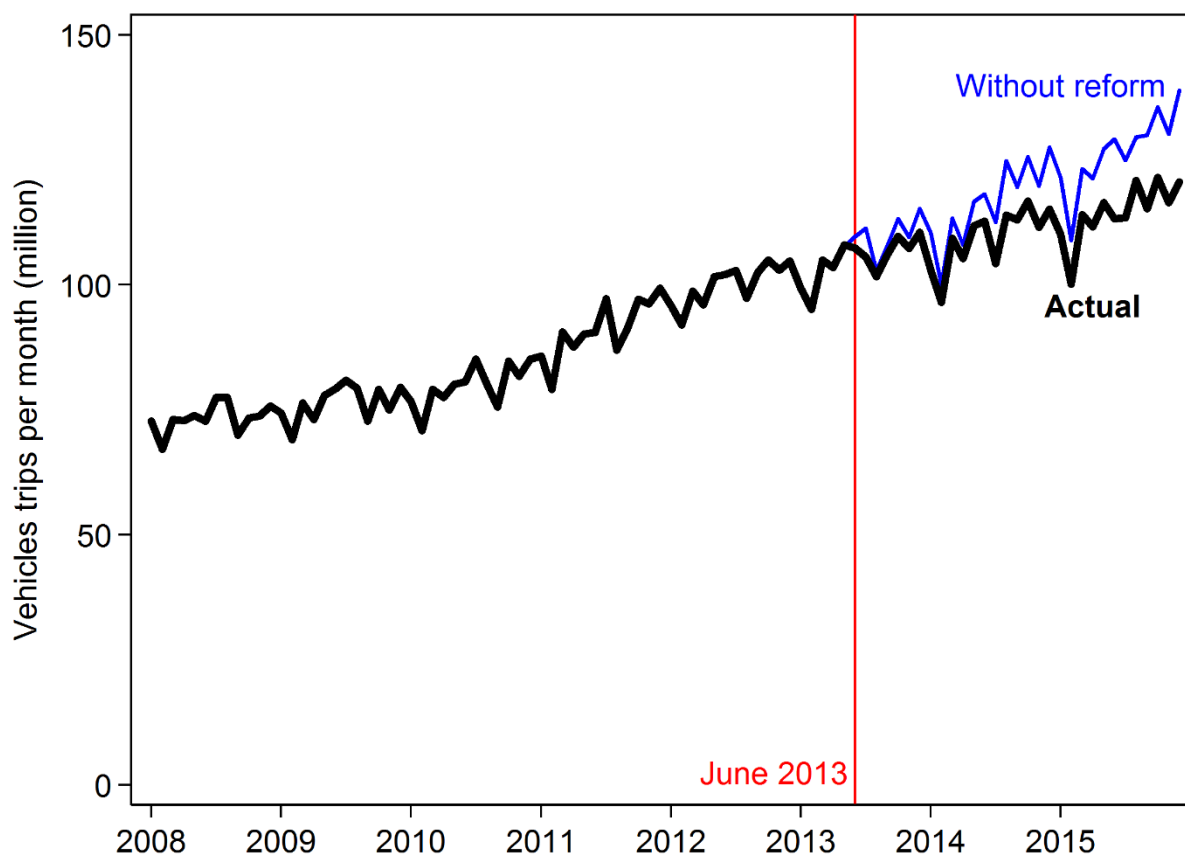
Indonesia's subsidized fuel prices were lowered in early 2016 due to the falling world oil price, likely partially reversing the effect visible in Fig. 5. Nevertheless, the prices remain well above

¹⁴ Tariffs are typically increased biennially in accordance with Law No. 38 of 2004 and Government Regulation No. 15 of 2005. It is challenging to identify the toll tariff elasticity of vehicle flows given that (a) some tariff changes coincided with road extensions and changes in ticket collection systems, and (b) tariffs vary by entry/exit point and vehicle type. We have controlled for changes in ticket collection systems and for road extensions (see Appendix).

¹⁵ This is the difference between our regression model prediction and the model prediction in the scenario in which the subsidized gasoline and diesel prices were left unchanged from June 2013 onwards. We report the average effect for the second half of 2015. The effect is subject to a confidence interval.

the pre-reform levels.¹⁶ Under Indonesia's new system of fuel price setting, prices may be adjusted upward again in due course.

Fig. 5 Actual and estimated without-reform traffic flows, 19-road aggregate.



Note: The without-reform scenario uses the estimates from column 12 of Table 2 and assumes that the 2013 and 2014 fuel subsidy reforms were not implemented, so that the subsidized gasoline and diesel prices remained at 4,500 IDR per liter. Scenario estimates have been summed across the 19 roads. The scenario is subject to a confidence interval. The increase in vehicle numbers is a result of supply-side as well as demand-side factors. Examples of supply-side factors are road additions, extensions, ticketing changes, and increases in lane counts. These have been controlled for in our modelling. The actual series is from Jasa Marga (2016).

What would be the effect of a new fuel excise of 1,000 IDR per liter?¹⁷ As of December 2015, this would have involved an increase in our weighted fuel price measure of around 14%. Applying a 12-month elasticity of -0.2 , this would imply around 3% fewer vehicles on these

¹⁶ As of July 2017 the price of subsidized gasoline was 6,450 IDR per liter. In nominal terms, this is 43% higher than the pre-reform price.

¹⁷ A motor vehicle fuel tax (of typically 5%) is currently in place, with revenue going to sub-national administrations. Indonesia also has a 10% sales tax. In net terms fuel has been subsidized, however.

roads, *ceteris paribus*. This does not reflect long-run responses. Fuel excise is thus an instrument with the potential to provide some degree of relief in terms of the traffic pressure on Indonesia's roads.

4. Relating the results to estimates for other countries

A summary of estimates of prior studies of the fuel price elasticity of road trips (or of VKT) is presented in Table 5. The table suggests that our estimates of the fuel price elasticity of toll road trips in Indonesia are broadly consistent with estimates from the US and other countries.

For the US, Small and Van Dender (2007) reported a gasoline price elasticity of VKT of -0.05 in the short run and -0.22 in the long run. Burger and Kaffine (2009) estimated the short-run gasoline price elasticity of vehicle kilometers travelled (VKT) on Los Angeles freeways at around -0.15 during peak congestion hours. Bento et al. (2013) estimated a weekly gasoline price elasticity of highway traffic flows of -0.05 for roads without carpool lanes in Los Angeles. Gillingham (2014) and Gillingham et al. (2015) used vehicle-level data for California and Pennsylvania, reporting gasoline price elasticities of VKT of -0.2 and -0.1 over multi-year and same-year time horizons, respectively. Huang and Burris (2015) found an average same-month gasoline price elasticity of -0.06 for trips on toll roads, concluding that toll-road travel might be less sensitive to changes in fuel prices than is travel on non-toll roads.

Studies outside the US also tend to provide very inelastic estimates. Crôtte et al. (2009) found a same-year fuel price elasticity of VKT of -0.12 in Mexico City, a city with traffic jams of a similar notoriety to Jakarta's. Khoo et al. (2012) reported a short-run fuel price elasticity of vehicle trips of -0.16 in Malaysia. Delsaut (2014) reported a short-run fuel price elasticity of VKT of -0.14 in France, with a long-run response of -0.28 . A review of studies from developed countries by Goodwin et al. (2004) found a mean fuel price elasticity of VKT of -0.1 in the short run and -0.3 in the long run. International studies reveal that the long-run price elasticity of gasoline demand is in the range -0.2 to -0.6 (e.g. Dahl, 2012; Havranek et al., 2012; Burke and Nishitateno, 2013; Burke, 2014; Arzaghi and Squalli, 2015).

Table 5 Summary of selected prior estimates of the fuel price elasticity of vehicle use.

Study	Country	Fuel price elasticity of road use		Note
		Short run (if estimated)	Long run (if estimated)	
<i>US</i>				
Small and Van Dender (2007)	US	-0.05	-0.22	Elasticity is for VKT
Burger and Kaffine (2009)	US	-0.15		Elasticity is for VKT during peak congestion hours in Los Angeles
Bento et al. (2013)	US	-0.05		Roads without carpool lanes in Los Angeles. Elasticity is for number of trips
Gillingham (2014)	US	-0.22		Vehicle-level data for California. Effect allows > 1 years of response, but is not long-run. Elasticity is for VKT
Gillingham et al. (2015)	US	-0.10		Vehicle-level data for Pennsylvania. Elasticity is for VKT
Huang and Burris (2015)	US	-0.06		Mean for a sample of toll roads. Elasticity is for number of trips
<i>Other countries</i>				
Matas and Raymond (2003)	Spain	-0.34	-0.53	Elasticity is for number of vehicle trips on toll roads
Crôte et al. (2009)	Mexico	-0.12		Elasticity is for VKT
Khoo et al. (2012)	Malaysia	-0.16		Uses road sensor data for 2008
Delsaut (2014)	France	-0.14	-0.28	Elasticity is for VKT
Kwon and Lee (2014)	South Korea	-0.11		Elasticity is for number of vehicle trips
Odeck and Johansen (2016)	Norway	-0.11	-0.24	Elasticity is for VKT

Note: Studies are chronologically ordered. Listed papers are a sample of prior studies. “Short run” and “long run” do not have the same definitions in all studies.

5. Conclusion

This paper examined the effects of Indonesia's historic fuel subsidy reforms of 2013 and 2014 on one of the country's leading contemporary challenges: traffic jams. Using data for a monthly panel of 19 toll roads we estimate the immediate fuel price elasticity of vehicle flows at -0.1 . The one-year elasticity is larger (-0.2), reflecting additional response opportunities over a longer time-span. The long-run elasticity is likely larger still. We estimate that Indonesia's 2013–2014 fuel subsidy reforms eased traffic flows on the roads in our study by around 10% by the second half of 2015, relative to the counterfactual without reform. This is likely to have permitted a material improvement in travel speeds. Because higher fuel prices only disincentivize less-valuable road trips, fuel subsidy reforms provide a relatively efficient macro-level approach for improving the efficiency of road use.

Indonesia's fuel subsidies are yet to disappear entirely. The government has been reluctant to increase fuel prices under its new system of price adjustments, so subsidies are continuing in the form of occasional payments to cover Pertamina's losses on sales of Premium gasoline. Diesel continues to receive a fixed per-liter subsidy, and fuel distribution costs remain subsidized. Our estimates imply that a complete phase-out of Indonesia's fuel subsidies would be able to contribute to further easing the traffic. Such a reform is also likely to deliver a host of other fiscal and economic benefits. If well communicated and linked to identifiable benefits, fuel subsidy reform can be popular (Burke and Resosudarmo, 2012).

Looking forward, our results support the argument that an adequate fuel excise could contribute to reducing over-use of Indonesia's valuable road resources (Parry et al., 2014). Fuel excise could complement more directly-targeted approaches, such as congestion pricing, a trial of which has been proposed for Jakarta. Fuel excise is a cheap revenue option: it is easier to collect excise from a small number of fuel retail companies than it is to collect personal income tax from the population of income earners. Fuel excise could also help Indonesia meet its tax revenue growth targets; central government tax collections are currently stuck at only 11% of GDP (Bank Indonesia, 2016). Fuel excise collections are consistent with the suggestion of Ramsey (1927) to tax goods that are price inelastic, would be a progressive form of revenue raising (World Bank, 2012), and would help to reduce emissions from the sector (Stern, 2007).

References

- Abdussalam, A., 2014. 'Pertamina lifts subsidized fuel oil sale restriction', *Antara News*, <http://www.antaranews.com/en/news/95448/pertamina-lifts-subsidized-fuel-oil-sale-restriction>.
- Arzaghi, M. and Squalli, J., 2015. 'How price inelastic is demand for gasoline in fuel-subsidizing economies?', *Energy Economics* 50, 117–124.
- Badan Pusat Statistik, 2016a. *Number of Motor Vehicles by Types, Indonesia 1949–2014*, <https://www.bps.go.id/linkTableDinamis/view/id/1133>.
- Badan Pusat Statistik, 2016b. *Number of Passenger of Railways Transportation, 2006–2016 (thousand persons)*, <https://www.bps.go.id/linkTableDinamis/view/id/815>.
- Bank Indonesia, 2016. *Indonesian Financial Statistics*, <http://www.bi.go.id/en/statistik>.
- Bento, A.M., Hughes, J.E. and Kaffine, D., 2013. 'Carpooling and driver responses to fuel price changes: Evidence from traffic flows in Los Angeles', *Journal of Urban Economics* 77, 41–56.
- Breusch, T. and Pagan, A., 1980. 'The Lagrange multiplier test and its application to model specification in econometrics', *Review of Economic Studies* 47, 239–253.
- Burger, N.E. and Kaffine, D.T., 2009. 'Gas prices, traffic, and freeway speeds in Los Angeles', *Review of Economics and Statistics* 91(3), 652–657.
- Burke, P.J., 2014. 'Green pricing in the Asia Pacific: An idea whose time has come?', *Asia & the Pacific Policy Studies* 1(3), 561–575.
- Burke, P.J. and Nishitatenno, S., 2013. 'Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries', *Energy Economics* 36, 363–370.
- Burke, P.J. and Resosudarmo, B., 2012. 'Survey of recent developments', *Bulletin of Indonesian Economic Studies* 48(3), 299–324.
- Castrol, 2015. *Stop-Start Index*, http://www.castrol.com/en_au/australia/products/cars/engine-oils/castrol-magnatec-brand/stop-start-index.html.
- CEIC, 2016. *CEIC Data*, www.ceicdata.com.
- Coglianesi, J., Davis, L.W., Kilian, L. and Stock, J.H., 2017. 'Anticipation, tax avoidance, and the price elasticity of gasoline demand', *Journal of Applied Econometrics* 32(1): 1–15.

- Coordinating Ministry of Economic Affairs and Japan International Cooperation Agency, 2012. *JABODETABEK Urban Transportation Policy Integration Project in the Republic of Indonesia*. March.
- Crôte, A., Noland, R.B. and Graham, D.J., 2009. 'Estimation of road traffic demand elasticities for Mexico City, Mexico', *Transportation Research Record* 1, 99–105.
- Creutzig, F., 2014. 'How fuel prices determine public transport infrastructure, modal shares and urban form', *Urban Climate* 10, 63–76.
- Dahl, C.A., 2012. 'Measuring global gasoline and diesel price and income elasticities', *Energy Policy* 41, 2–13.
- Delsaut, M., 2014. 'The effect of fuel price on demand for road and rail travel: An application to the French case', *Transportation Research Procedia* 1, 177–187.
- Demographia, 2016. *Demographia World Urban Areas*, 12th Annual Edition, April.
- Dickey, D. A. and Fuller, W.A., 1979. 'Distribution of the estimators for autoregressive time series with a unit root', *Journal of the American Statistical Association* 74(366), 427–431.
- Driscoll, J.C. and Kraay, A.C., 1998. 'Consistent covariance matrix estimation with spatially dependent panel data', *Review of Economics and Statistics* 80(4), 549–560.
- Gillingham, K., 2014. 'Identifying the elasticity of driving: Evidence from a gasoline price shock in California', *Regional Science and Urban Economics* 47, 13–24.
- Gillingham, K., Jenn, A. and Azevedoc, I.M.L., 2015. 'Heterogeneity in the response to gasoline prices: Evidence from Pennsylvania and implications for the rebound effect', *Energy Economics* 52, S41–S52.
- GIZ, 2014. *International Fuel Prices 2012/2013*. 8th Edition. Bonn and Berlin, Germany.
- Goodwin, P., Dargay, J. and Hanly, M., 2004. 'Elasticities of road traffic and fuel consumption with respect to price and income: A review', *Transport Reviews* 24(3), 275–292.
- Hanna, R., Kreindler, G. and Olken, B.A., 2017. 'Citywide effects of high-occupancy vehicle restrictions: Evidence from “three-in-one” in Jakarta', *Science* 357(6346), 89–93.

Havranek, T., Irsova, Z. and Janda, J., 2012. 'Demand for gasoline is more price-inelastic than commonly thought', *Energy Economics* 34, 201–207.

Howes, S. and Davies, R., 2014. 'Survey of recent developments', *Bulletin of Indonesian Economic Studies* 50(2), 157–183.

Huang, C. and Burris, M.W., 2015. 'The short-run impact of gas prices fluctuations on toll road use', *Case Studies on Transport Policy* 3, 137–150.

International Energy Agency, 2015. *Fossil Fuel Subsidy Database*, <http://www.worldenergyoutlook.org/resources/energysubsidies/fossilfuelsubsidydatabase>.

Jasa Marga, 2016. *Traffic Volume*, <http://www.jasamarga.com>.

Jasa Marga, 2017. *Jasa Marga Update IQ 2017*, Jakarta.

Khoo, H.L., Ong, G.P. and Khoo, W.C., 2012. 'Short-term impact analysis of fuel price policy change on travel demand in Malaysian cities', *Transportation Planning and Technology* 35(7), 715–736.

Kwon, Y. and Lee, J., 2014. 'Asymmetric responses of highway travel demand to changes in fuel price: An explanation via fuel price uncertainty', *Transportation Research Part A: Policy and Practice* 63, 56–66.

Matas, A. and Raymond, J.L., 2003. 'Demand elasticity on tolled motorways', *Journal of Transportation and Statistics* 6(2/3), 91–108.

Ministry of Energy and Mineral Resources, 2015. *2015 Handbook of Energy & Economic Statistics of Indonesia*. Republic of Indonesia, Jakarta.

Ministry of Finance, 2017. *Data Pengelolaan Keuangan Negara*, <http://www.kemenkeu.go.id/katalogdata>.

Mustami, A.A., 2017. 'RAPBN-P 2017: Subsidi energi naik Rp 25,8 triliun', *Kontan*, <http://nasional.kontan.co.id/news/rapbn-p-2017-subsidi-energi-naik-rp-258-triliun>.

National Aeronautics and Space Administration, 2016. *Giovanni v 4.20.5*, <http://giovanni.sci.gsfc.nasa.gov/giovanni>.

Odeck, J. and Johansen, K., 2016. 'Elasticities of fuel and traffic demand and the direct rebound effects: An econometric estimation in the case of Norway', *Transportation Research Part A: Policy and Practice* 83, 1–13.

Parry, I., Heine, D., Lis, E. and Li, S., 2014. *Getting Energy Prices Right: From Principle to Practice*, International Monetary Fund, Washington DC.

Ramsey, F.P., 1927. 'A contribution to the theory of taxation', *Economic Journal* 37(145), 47–61.

Ross, M.L., Hazlett, C. and Mahdavi, P., 2017. 'Global progress and backsliding on gasoline taxes and subsidies', *Nature Energy* 2, 16201.

Small, K.A. and Van Dender, K., 2007. 'Fuel efficiency and motor vehicle travel: The declining rebound effect', *Energy Journal* 28(1), 25–51.

Stern, T., 2007. 'Fuel taxes: An important instrument for climate policy', *Energy Policy* 35(6), 3194–3202.

Sugiyama, Y., Fukui, M., Kikuchi, M., Hasebe, K., Nakayama, A., Nishinari, K., Tadaki, S. and Yukawa, S., 2008. 'Traffic jams without bottlenecks – experimental evidence for the physical mechanism of the formation of a jam', *New Journal of Physics* 10, 7 pages.

Waze, 2015. *Global Driver Satisfaction Index*, <http://wazeblogs-en.blogspot.ie/2015/09/global-driver-satisfaction-index.html>.

World Bank, 2012. *Indonesia Economic Quarterly: Redirecting Spending*, April, Jakarta.

World Bank, 2017. *World Development Indicators*, <http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators>.

Appendix. Variable definitions.

Ln Vehicle trips

Log number of trips by motor vehicles on a road during a month. 18 of the roads are restricted to only motor vehicles with four or more wheels. Motorcycles are allowed on Bali Mandara Toll Road. The data represent the number of toll tickets issued. For some roads, more than one ticket is issued for a single trip on the road. We include control variables to capture the effects of changes to toll booths and ticketing arrangements during the study period. Source: Jasa Marga (2016). For this and other variables, “log” means the natural log.

Ln Fuel price

Log of the weighted average of the official subsidized prices of Premium (RON88) gasoline and diesel, in IDR per liter as measured at the end of the month. Source: CEIC (2016). Weights: 0.87 for gasoline, 0.13 for diesel. This is based on the share of Group I vehicles (cars, small trucks, buses; 87% of vehicle flows) versus Group II–IV vehicles (trucks with two or more axles) as of January 2008. The Group I share was similar at the end of our study period (88% in December 2015). Data on vehicle shares are from Jasa Marga (direct correspondence). “Premium” is the name given to the subsidized gasoline type.

Ln Average gasoline price in nearest urban area

Log average urban price paid for gasoline in the nearest urban area, in IDR per liter. Uses the average price paid by consumers during the month, as compiled by Badan Pusat Statistik. We do not lag this variable. The variable is not available for 2011 or 2015. Source: CEIC (2016).

Ln GDP_{m-1}

Log gross domestic product of Indonesia during the previous month. GDP is only available quarterly. We construct a monthly proxy by weighting quarterly GDP by that month’s industrial production index relative to other months in that quarter:

$$GDP_m = GDP_q * \frac{\text{Industrial production index}_m}{\sum_{1^{\text{st}} \text{ month of quarter}}^{3^{\text{rd}} \text{ month of quarter}} (\text{Industrial production index}_m)}$$

The industrial production index is a measure of manufacturing output, the source of 21% of Indonesia’s GDP in 2015 (Bank Indonesia, 2016). The index has a base of 100 in 2010; we rebased early years. GDP is measured in IDR, 2000 prices; we rebased the data for 2015.

Number of days in the month

Equal to the number of days in each month.

Idul Fitri dummies

1 for the month of the first day of Idul Fitri; 0 otherwise. These months are: October 2008, September 2009, September 2010, August 2011, August 2012, August 2013, July 2014, and July 2015. In two years (2011 and 2014), the first day of Idul Fitri fell during the final four days of the month. We use a separate “next-month dummy” for these cases. Source: timeanddate.com. Both the same-month and next-month Idul Fitri dummies were interacted with the road fixed effects to allow the effect of Idul Fitri to vary by road.

Lanes

The number of lanes across a road's width, counting both directions. For roads with different lane counts at different locations we use the simple average of the minimum and maximum. The lane counts are for the roads themselves, not exits. The lane data are for branch, not section. This affects only two joining-road pairs: the lanes of Cipularang Toll Road and Padalarang-Cileunyi Toll Road are measured using Purbaleunyi branch, and the lanes of Jakarta Inner Ring Road and Prof Dr Sedyatmo Toll Road are measured using data for Cawang-Tomang-Cengkareng branch. Includes motorcycle lanes for Bali-Mandara Toll Road. Lanes are measured at the end of the month. Source: Jasa Marga (direct correspondence).

Ln Toll tariff

Natural log of the toll tariff for vehicles in Group I (cars, small trucks, buses), measured in IDR and at the start of the month. The long-distance tariff is used, with exceptions that include: for Semarang-Solo Toll Road, the tariff for Section 1 is used; for Surabaya-Gempol Toll Road, the Dupak-Waru toll tariff is used. Tariff adjustment decisions typically affect all vehicles, and the proportional tariff adjustment can vary by Group. A temporary toll tariff reduction during 7–23 July 2015 has been controlled for by a dummy (see next variable). Source: Jasa Marga Annual Reports and direct correspondence, BPJT (<http://bpjt.pu.go.id/info-tarif-tol>), others.

Eid 2015 toll tariff reduction dummy

President Widodo announced temporary Eid al-Fitr toll tariff reductions of 25–35% over 7–23 July 2015. This dummy equals 1 in July 2015; 0 otherwise.

Jabodetabek train improvement time trend

Jabodetabek Commuterline adopted electronic ticketing in July 2013. (Jabodetabek = Greater Jakarta.) At around this time there were other improvements to the train service, including to parking, stations, safety, cleanliness, and comfort, with introduction of air-conditioning to all carriages; additional carriages and trains; the conversion of all trips to commuter class and the discontinuation of economy class; and reduced, distance-based fares. These changes induced an increase in passenger numbers from July 2013 (Badan Pusat Statistik, 2016b). Two other likely contributing factors are: 1) the fuel subsidy reforms may have induced substitution from private vehicles, and 2) underreporting was likely a more serious issue prior to the introduction of electronic ticketing, as some passengers could ride without a ticket. To capture the effect of the improvements to Jabodetabek Commuterline we include a time trend that increases linearly from July 2013 onwards for roads in Greater Jakarta. This variable equals 0 for other roads, and for all roads prior to July 2013. Other improvements to train services are partly captured by the road time trends. The increase in passenger numbers on Jabodetabek Commuterline was partly offset by a slight reduction in passengers using the TransJakarta bus network.

Precipitation

Area-averaged precipitation during the month, in millimeters. Data are for the closest location from: Bandung, Bogor, Cirebon, Denpasar, Jakarta, Jakarta-Cikampek Toll Road, Medan, Purwakarta, Semarang, and Surabaya. Source: National Aeronautics and Space Administration (NASA, 2016), series TRMM_3B43.

Temperature

Area- and time-averaged daytime surface temperature during the month, in degrees Celsius. Data are for the closest location from: Bandung, Bogor, Cirebon, Denpasar, Jakarta, Jakarta-Cikampek Toll Road, Medan, Purwakarta, Semarang, and Surabaya. Source: NASA (2016), series AIRX3STM v006.

Presidential election dummy

Equals one in July 2009 and July 2014; 0 otherwise.

Legislative election dummy

Equals one in April 2009 and April 2014; 0 otherwise.

Prof Dr Sedyatmo Toll Road flood dummy

Prof Dr Sedyatmo Toll Road was cut by flood for several days in February 2008. This dummy equals 1 for Prof Dr Sedyatmo Toll Road in February 2008; 0 otherwise.

Jakarta January 2013 flood dummy

Jakarta was hit by a flood in January 2013. This dummy equals 1 for Jakarta roads in January 2013; 0 otherwise.

Prof. Dr. Sedyatmo Toll Road ticketing change dummy

In September 2009 there was a change to the ticketing and toll collection system on Prof. Dr. Sedyatmo Toll Road. This dummy equals 1 for Prof. Dr. Sedyatmo Toll Road from September 2009 onwards; 0 otherwise.

Bogor Outer Ring Road first month dummy

Bogor Outer Ring Road opened on 23 November 2009. This dummy equals 1 for Bogor Outer Ring Road in November 2009; 0 otherwise. The rationale is that this was a part-month.

Jagorawi Toll Road ticketing change dummy

In January 2011 Taman Mini Main Toll Gate was relocated to Cimanggis Main Toll Gate. This resulted in an increase in issued tickets. This dummy equals 1 for Jagorawi Toll Road from January 2011 onwards; 0 otherwise.

Jakarta-Cikampek Toll Road ticketing change dummy

In March 2011 Pondok Gede Timur toll booth was relocated to Cikarang, and the ticketing system was changed. This resulted in an increase in issued tickets. This dummy equals 1 for Jakarta-Cikampek Toll Road from March 2011 onwards; 0 otherwise.

Cipularang Toll Road ticketing change dummy

The opening of Cikarang Main Toll Gate in March 2011 saw a reduction in the number of vehicles ticketed for Cipularang Toll Road. This dummy equals 1 for Cipularang Toll Road from March 2011 onwards; 0 otherwise.

Padalarang-Cileunyi Toll Road ticketing change dummy

The opening of Cikarang Main Toll Gate affected the number of vehicles ticketed for Padalarang-Cileunyi Toll Road. This dummy equals 1 for Cipularang Toll Road from March 2011 onwards; 0 otherwise.

Semarang-Solo Toll Road first month dummy

Semarang-Solo Toll Road opened on 12 November 2011. This dummy equals 1 for Semarang-Solo Toll Road in November 2011; 0 otherwise. The rationale is that this was a part-month.

Semarang-Solo Toll Road opening

The opening of Semarang-Solo Toll Road may have affected traffic on the connecting Semarang Toll Road. This dummy equals 1 for Semarang Toll Road from November 2011 onwards; 0 otherwise.

Opening of Cijago Toll Road

Cinere-Jagorawi Toll Road opened on 27 January 2012. This dummy equals 1 for Jagorawi Toll Road from February 2012 onwards; 0 otherwise.

Opening of Porong arterial road dummy

The opening of Porong arterial road likely led to more vehicles accessing Surabaya-Gempol Toll Road. This dummy equals 1 for Surabaya-Gempol Toll Road from April 2012 onwards; 0 otherwise.

Semarang diversion dummy

The repair of Setiabudi and Pudak Payung arterial roads from June to August 2013 caused vehicles to use Semarang Toll Road instead. This dummy equals 1 for Semarang Toll Road from June to August 2013, 0 otherwise.

New Medan Airport dummy

On 25 July 2013, a new airport opened in Medan, which had the likely effect of boosting traffic on Belmera Toll Road. This dummy equals 1 for Belmera Toll Road from July 2013 onwards; 0 otherwise.

Semarang-Solo Toll Road extension dummy

Section 2 of Semarang-Solo Toll Road opened on 4 April 2014. This dummy equals 1 for the Semarang-Solo Toll Road from April 2014 onwards; 0 otherwise.

Bogor Outer Ring Road extension dummy

Section 2A of Bogor Outer Ring Road opened on 4 June 2014. This dummy equals 1 for Bogor Outer Ring Road from June 2014 onwards; 0 otherwise.

JORR W2 North Toll Road extension dummies

On 22 July 2014 an additional two kilometers of JORR W2 North Toll Road opened (Ciledug-Ulujami section), connecting the full JORR. This may have had implications for roads linking to the JORR. We use six dummies. The first equals 1 for JORRW2 North Toll Road from August 2014 onwards; 0 otherwise. The second equals 1 for JORR from August 2014 onwards; 0 otherwise. The third equals 1 for Jakarta-Tangerang Toll Road from August 2014 onwards; 0 otherwise. The fourth equals 1 for Ulujami-Pondok Aren Toll Road Section from August 2014 onwards; 0 otherwise. The fifth equals 1 for Jakarta Inner Ring Road from August 2014 onwards; 0 otherwise. The sixth equals 1 for Jagorawi Toll Road from August 2014 onwards; 0 otherwise.

August 2014 fuel restrictions

Restrictions on fuel sales were introduced in Jakarta and on toll roads in August 2014, but removed by the end of the month (Abdussalam, 2014). This dummy equals 1 for August 2014; 0 otherwise.

Gempol-Pandaan Toll Road first month dummy

Gempol-Pandaan Toll Road opened on 12 June 2015. This dummy equals 1 for Gempol-Pandaan Toll Road in June 2015; 0 otherwise. The rationale is that this was a part-month.

Gempol-Pandaan Toll Road opening dummy

The opening of Gempol-Pandaan Toll Road likely led to more vehicles using Surabaya-Gempol Toll Road. This dummy equals 1 for Surabaya-Gempol Toll Road from June 2015 onwards; 0 otherwise.

Cikampek-Palimanan Toll Road opening

In June 2015 Cikampek-Palimanan Toll Road opened, connecting Jakarta-Cikampek Toll Road and Palikanci Toll Road. Two dummies are included. The first equals 1 for Jakarta-Cikampek Toll Road from July 2015 onwards; 0 otherwise. The second equals 1 for Palikanci Toll Road from July 2015 onwards; 0 otherwise.

See Jasa Marga's Annual Reports for details on the 19 roads.

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