Prices Vs Taxes: Evidence from Household Fuel Consumption in India

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Abstract

While fuel taxes has traditionally been an important tool for addressing environmental externalities, in recent years it has also emerged as a significant revenue stream for the Government of India. In light of this we attempt to answer two research questions - First, Do households petroleum consumption in India responds differentially to a change in fuel state-tax and central-tax compared to an equivalent change in the fuel price? Second, how the transition of the petrol pricing mechanism in India from a partially deregulated system (Automatic Pricing Mechanism) to a complete deregulation (Dynamic Pricing Mechanism) impact household's responsiveness to fuel taxes and price in India? Using household-month panel data on petroleum consumption, we find three main results - (1) Household petroleum consumption in India is four times more responsive to a change in the state tax compared to an equivalent change in the tax-exclusive price of petroleum (2) The short-run price elasticity of petroleum demand in India id -0.21 which is nearly half the responsiveness to petroleum state-tax and almost ten times the price elasticity of gasoline demand in the United States. (3) Following the transition to a Dynamic Pricing Mechanism, household's responsiveness to fuel price, central tax and state tax increased by 35%, 87% and 38% respectively.

I. Introduction

In recent years, fuel (petrol and diesel) taxes have emerged as a significant revenue source for the Indian government, aiding economic recovery and serving as a tool for political leaders to garner public support. Despite of complete alignment of fuel prices with the world oil market in 2017, petrol prices in India have been rigid upwards, wherein low global oil prices are offset by high fuel taxes, surging up the fuel prices faced by the consumers (figure 1). From 2014 to 2020, POL (Petroleum, Oil and Lubricant) Products have made up an exorbitant share of more than 50% (40%) of the tax revenue for the central government (state government). At the same time, auto fuel usage has been closely linked to the surging vehicular pollution in India and reduction in vehicular emissions has been recognized as a key goal for achieving net zero carbon emissions by 2070 (COP26) in India.

Despite this critical role of fuel prices and taxes in economic stabilization, political opportunism and environmental emission targets, there has been a dearth of research explaining consumer responses to fuel pricing in India. In this paper, we attempt to fill this gap by answering the following

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research questions: First, do household in India responds differentially to a change in the petrol[1] taxes compared to an equivalent change in the petrol prices in India? Second, how the transition of the petrol pricing mechanism in India from a partial deregulation (Automatic Pricing Mechanism) to a complete deregulation (Dynamic Pricing Mechanism) impact household responsiveness to fuel taxes and price in India.

Our former research question relates to the Tax salience theory in Behavioural Economics. Standard Neoclassical theory predicts that consumers fully optimize fully w.r.t taxes i.e. a one percent change in price reduce demand by the same amount as a one percent change in the price gross of tax. However, the behavioural economics literature have contradicted this theory and shown that consumers responds more to taxes compared to an equivalent change in price (Chetty et al. (2009);Finkelstein (2009)). Particularly for gasoline taxes in the United States, a growing number of research has shown that both the short-run and long-run tax elasticity of gasoline demand in the US is higher than the price elasticity of gasoline demand (Li et al. (2014); Tiezzi and Verde (2016)). Similar evidence of higher responsiveness to taxes relative to prices has also been found for carbon tax in the US (Rivers and Schaufele (2015)).

However, there has been lack of such studies in a developing country context. We contribute to this literature by testing a similar hypothesis for petrol consumption India using micro level household data on monthly petroleum consumption in India.[2] Developing country like India is specifically interesting in this context for two reasons - First, the socio-demographic characteristics of the household using petrol (or owning a vehicle) in India is starkly different from that in the United States - in India, vehicles are owned by a relatively wealthier and older population compared to the US. Second, cheap public transportation are much widely available throughout India compared to developed countries. Therefore, the tax elasticity and price elasticity of petrol demand in India is likely to be higher relative to developed countries like the US.

Till 2010, petrol prices in India were administered and regulated by the Government of India (GOI), insulating consumers from the oil price volatility in the world market. However, in 2014 the GOI partially deregulated petrol price in India - under this regime, domestic fuel prices were changed at a pre-specified regular intervals (bi-weekly or monthly) to align domestic prices with the international prices. June 2017 onwards, petrol prices were fully decontrolled and the country moved towards the system of Dynamic Pricing Mechanism wherein the petrol prices were revised daily in alignment with the world oil prices. While, under the partially decontrolled system consumer might have some speculative motive and incentive to hoard petrol, the scope of speculation was eroded under the Dynamic Pricing Mechanism as petrol prices are revised every morning. The second research question therefore, try to estimate the impact of this change in petrol pricing mechanism on the petrol consumption behavior of households.

Our first research question is similar in spirit to Li et al. (2014), Tiezzi and Verde (2016) and Rivers and Schaufele (2015). However, we provide a more detailed analysis of the question by testing not only how gasoline demand in India responds differentially to taxes and tax-exclusive prices but also to different types of taxes imposed by varying levels of the government in India. Moreover, in contrast to the literature which has answered this research question using state or province level data, we use more granular data at the household level which allows us to capture the within state variations. Further to our knowledge, this is the first paper to investigate the

[1] In India, the popular fuels used for transportation are petrol and diesel. While diesel is mostly used for commercial purposes, the most common fuel used for vehicles in Indian households is petrol Therefore, we exclusively focus on household petrol consumption in this study.

[2] Previous studies on gasoline tax salience in the US have used aggregated level (state or province level) of gasoline consumption data for the analysis. To our knowledge, this is the first paper using micro level household data for the analysis of salience of fuel taxes in a developing country context.

impact of the transition in the fuel pricing mechanism in India on the semi-elasticities of petroleum demand w.r.t taxes and its effect on the price elasticity of petroleum demand in India.

To answer the research questions, we use a household level panel data on consumption of petrol for the time period January 2014 to December 2021 for three major cities in India - Mumbai, Chennai and Kolkata. The choice of cities considered for our analysis is based on the availability of petrol price data[3]. Our monthly data on the household petrol consumption comes from the Consumer Pyramid Household Survey (CPHS) data of the Centre for Monitoring of Indian Economy (CMIE). Daily data on the Retail Selling Price (RSP) of petrol in the above three cities of India and its decomposition into tax-exclusive petrol prices and taxes, has been obtained from the Petroleum Planning Analysis Cell (PPAC) of Government of India. PPAC provides daily data on global crude oil price, the retail sales price, the base price and the taxes for four major cities in India namely Delhi, Chennai, Mumbai and Kolkata. For the purpose of analysis, monthly averages of daily petrol price data was used since, the household petrol consumption data was available at monthly frequency.

For the empirical investigation of this question, we employ a Two-Way Fixed Effects (TWFE) model where the outcome variable of interest is the monthly household consumption of petrol in different cities in India. To test the hypothesis of whether household responds differently to taxes compared to an equivalent change in petrol prices, we decompose the petrol price into three components - the tax-exclusive price, the effective central tax rate and the effective state tax rate. The preferred empirical specification also allows us to test whether households in India responds differentially to a change in the central tax compared to an equivalent change in the state tax of petrol.

Further, to investigate how the change in petrol pricing mechanism in India impacted tax and price elasticities of petrol demand, we interact each of the price components with a post dummy indicating month-years after the implementation of the Dynamic Pricing Mechanism in June 2017. The identification of the tax and price elasticities of demand relies on the state-level variations in each of the price component and the assumption of exogeneity of the price components after controlling for necessary variables and fixed effects.

The results shows that households petroleum consumption in India responds almost four times more to a change in the state-taxes of petroleum compared to an equivalent change in the tax-exclusive prices. Furthermore, the responsiveness to state-tax of petroleum is double the responsiveness to an equivalent change in the overall prices. However, we find the household petroleum consumption in India is not responsive to a change in the central taxes. This suggests that central taxes on petroleum could serve as an effective fiscal tool in mitigating economic recessions and bolstering equity. However, it also suggest that in addressing environmental concerns of vehicular pollution and therefore climate change, state-taxes would be more effective compared to central taxes. This result is robust to the exclusion of the periods of fiscal and monetary policy shocks i.e. the Goods and Service Tax (GST) Reform and Demonetization respectively and also remains consistent upon exclusion of the Covid-19 Pandemic period.

Moreover, our analysis also provides evidence on consumer responsiveness to different fuel pricing mechanisms in India, which could be informative in guiding future fuel pricing policies. Results reveals that following a change in the petroleum pricing mechanism from an Automatic Pricing Mechanism (wherein prices were revised bi-weekly or monthly) to a Dynamic Pricing Mechanism (petroleum prices fluctuate daily), the semi-elasticities of petroleum demand w.r.t tax-exclusive price, taxes and also overall price increased considerably. Furthermore, our results also reveal that

[3]We eliminate Delhi from our analysis as Delhi is mostly a Compressed Natural Gas (CNG) due to the state mandatory laws of CNG usage in public transportation. Most private vehicles owned by households in Delhi are CNG based and hence inclusion of Delhi could be a potential threat to identification.

the short-run price elasticity of gasoline demand in India (-0.21) is almost ten times higher than that in a developed country like US. A discussion of the possible factors explaining these results is provided elaborately in SectionV. Results and Discussion.

The rest of the paper proceeds as follows - Section II. Petroleum Pricing: Background provides an overview of how petroleum pricing has evolved in India and the different components of petroleum pricing . Further, in Section III. Data we present the details of the data sources used for the analysis. Section III. Empirical Framework and Section IV. Identification describes the empirical framework and the identification strategy used in the analysis. Finally the results of the main model, discussion of the possible mechanisms and the robustness checks are presented in Section V. Results and Discussion, Section IV. Identification and Section VI. Robustness Checks respectively.

II. Petroleum Pricing: Background

For a long period of time in the past, fuel prices in India were largely regulated by the government. Prior to 2010, India largely followed an Administered Pricing Mechanism (APM)[4] wherein any price shock volatility in the crude oil market were largely absorbed by the government or the oil Marketing Companies (OMCs), insulating Indian consumers from any global crude oil price shocks. This pricing strategy inherently incorporated substantial subsidies provided by the government in the form of markedly reduced petroleum prices for consumers, and issuance of oil bonds to the Oil Marketing Companies (OMCs) to offset their under-recoveries.

Following a sharp rise in the crude oil price volatility in late 2000s and a consequent spike in the OMC under-recoveries, the Administered Pricing Mechanism (APM) adversely impacted the government deficits and the efficiency of the OMCs (Bhattacharya and Batra (2009)). Therefore, in 2010 following the recommendations of the Kirit Parikh Commitee, the Government of India (GOI) deregulated the prices of Petroleum in 2010 and that of Diesel in 2014 subsequently, initiating a pricing mechanism aligning fuel prices to the global oil prices and revising the retail prices in a bi-weekly or monthly interval. Furthermore, in June 2017, the GOI moved towards a Dynamic Pricing Mechanism of petrol and diesel wherein the prices were revised daily aligning petrol and diesel prices to the daily fluctuation in the global oil prices.

Despite the deregulation of petrol prices in India, much of the declines in the global oil prices have been offset by an increase in the petrol taxes Figure (1), resulting in a rise of Retail Selling Price (RSP) of Petrol in India even in periods of low global oil prices. Moreover, taxes have made up a substantial portion of the petrol prices in India. In our period of analysis (2014 – 2021) the average share of taxes (crude oil prices) in the RSP of petrol was 51% (33%). Even the minimum and maximum share of taxes (crude oil price) was 34.45% (24.53%) and 60.84% (48.97) respectively, covering more than 50% of the total RSP of petrol in India.

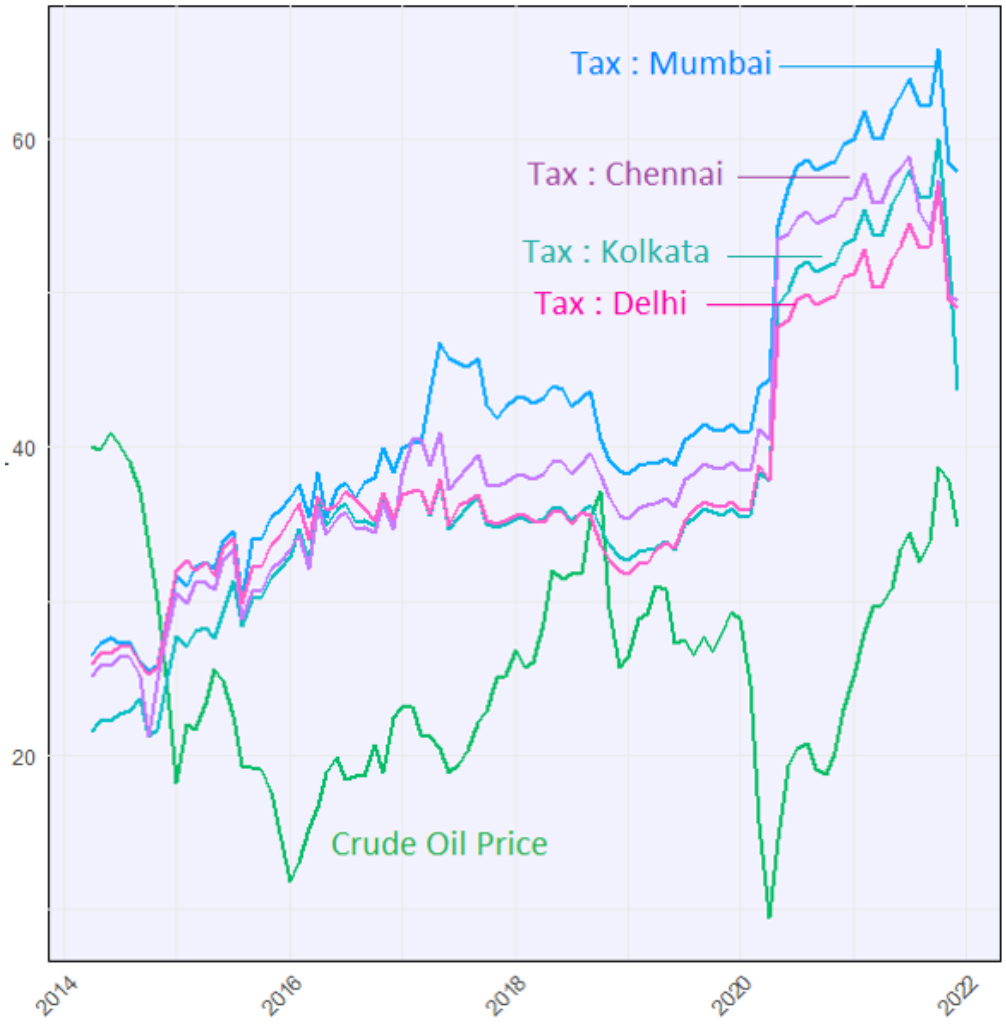
Following Li et al. (2014), we regress the retail selling price (RSP) of petrol for state s and year t on the global crude oil price and the taxes (both central and state tax) to determine whether the increase in taxes are passed on fully to the consumers -

$$RSP_{st} = \alpha CrudeOilPrice_t + \beta taxes_{st} + \delta_s + \delta_t + \epsilon_{st} \tag{1}$$

Where, RSP_{st} is the Retail Selling Price of Petrol in state s and month-year t, $CrudeOilPrice_t$ is the global crude oil price in month-year t, $taxes_{st}$ includes both central and state taxes in state s in month-year t. $delta_s$ is the state-fixed effects controlling for time invariant state fixed factors

[4]Although the Administered Pricing Mechanism was dismantled in India in 2002. However, in 2004 following the sharp volatility in global crude oil prices and to avoid strong political oppositions, the government regained some control over the pricing of petroleum products in India.

Figure 1: Trend of Crude Oil Price and Petrol Taxes In India



like transportation costs[5]. Furthermore, the month-year fixed effect δ_t controls for any seasonality in the prices. The results (Table 3) shows a value of 1.006 on the regression coefficient (β) of the *tax* component, indicating that any change in the taxes are fully passed on to the consumers and are reflected in the final petroleum prices.

III. Data

The empirical analysis exploits the state-level variations in the petroleum taxes and the tax-exclusive prices (or base price) to identify the differential response of household petroleum consumption to a change in the petroleum taxes and tax-exclusive prices in India. To implement this, several data sets are assembled from various sources.

[5]This includes the cost of transporting the petrol from the Oil Marketing Companies (OMCs) to the state dealers.

A. Household Petroleum Consumption

For the data on monthly household consumption of petroleum, we rely on the Consumer Pyramids Households Survey (CPHS) Data collected by Center for Monitoring Indian Economy (CMIE). The CPHS is a nationally representative consumption expenditure survey data of around 236,000 households all over India. In the survey, each household is interviewed for an interval of four months (referred as a wave) and in each wave, data is collected on the household's monthly expenditure on 153 consumer goods for each month of the previous wave, thereby yielding a household level panel data of monthly expenditures on consumer goods in India.

Furthermore, the CPHS collects a rich set of socio-demographic data on the surveyed households including their district and region type of residence, income group, occupation group, age group and gender composition. Other relevant demographic variables like the number of the cars and two-wheelers owned by the household and the time taken to travel ten kilometers (proxy variable for road conditions) are gathered from the complementary data sourced from the Aspirations India initiative, collected by the CMIE, surveying the same set of households as the CPHS.

For the analysis, we focus on the monthly household expenditure on petroleum[6] in three major cities in India namely Mumbai, Chennai and Kolkata[7] for the time period from January 2014 till December 2021. The choice of the cities is purely driven by the availability of petroleum price data for India. Furthermore, the choice of the time period of analysis are driven by two factors - First, the availability of CPHS data which started its survey from 2014 onward and second we exclude the year 2022 from our analysis to avoid the shocks in the crude oil market owing to the geopolitical discords. Table (**??**) provides a summary statistics of the households petrol consumption and some basic sample characteristics. Majority of the households in the sample are gender balanced and consists of mostly grown ups with all literates. Moreover, the sample is dominated by owners of two-wheelers (around 74% of the households owns a two-wheeler and only 16% of the sample owns a car), which is commonly the scenario in urban India. Furthermore, the average household monthly expenditure on petroleum is ₹795 and that on the public transportation is ₹370 for the period of analysis from 2014 till 2021.

B. Petroleum Price: Data

We obtain the petroleum price data for the time period 2014 to 2021 from the Petroleum Planning Analysis Cell (PPAC), provided by the Government of India (GOI). The PPAC reports daily petroleum Retail Selling Price data[8] for four major cities in India namely Delhi, Kolkata, Chennai and Mumbai, which is averaged to the monthly level for our analysis. Furthermore, it provides the detailed price build up data[9] for the four major cities for the month of April of each year and the

[6] Although CPHS do not directly provide data on household's expenditure on petrol, it does provides expenditure data on petrol and diesel and diesel specifically. Hence, we derive the household expenditure on petroleum in India by subtracting the household's expenditure on diesel from the household's combined expenditure on petrol and diesel.

[7] The CPHS variable of monthly expenditure on petroleum includes both expenditure on petroleum and Compressed Natural Gas (CNG). In Delhi owing to the state mandatory laws of CNG usage in public transportation, there has been a steady rise in the proportion of CNG vehicles owned by households. Hence, we eliminate Delhi from our analysis of household petroleum consumption to reduce the measurement error in the monthly petroleum expenditure variable.

[8] PPAC reported bi-weekly or monthly data till June 2017 and switched to daily price reporting since the adoption of the Dynamic Pricing Mechanism on June 16, 2017.

[9] Petroleum price in India mainly comprises of four broad components - the base price which is the ex-refinery price (it is the price paid to the refineries by the dealers including the state specific transportation charges) which varies across the states due to the differential transportation charges across states, the excise duty (specific tax) levied by the central government which is the same across the states, the dealers commission (which has a fixed component and an ad valorem component computed on the base price plus the central tax, with the exception of Delhi where

monthly price build up data of Delhi only. Therefore to derive the monthly price build up data for the three cities i.e. Kolkata, Chennai and Mumbai we treat Delhi as the reference state and assume that the difference in the base price between Delhi and the other three cities which mostly reflects the transportation cost is same over the year (the other components like central tax is same across all the four cities and dealers commission charged in a city is same over the year). Given the monthly data on the RSP, once we have computed the monthly base price data, we can easily derive the state taxes by subtracting the base price, dealers commission and the central taxes from the RSP. The trend of the different price components from 2014 to 2021 in the four cities (Delhi, Mumbai, Chennai, Kolkata) is presented in Figure 2.

Figure 2: Trend of Petrol Price Components Four Major Cities In India (2014-2021)

This depicts that in all four cities, the periods of a sharp decline in the base price (which reflects the crude oil prices) were accompanied by a less than proportionate fall in the Retail Selling Price

the ad valorem component is computed on the state tax inclusive price) and finally the state taxes computed on the aggregate of the base prices, the excise duty and dealers commission. An outlook of the price build up of petroleum in Delhi in shown in Table 3.

owing to an increase in the central or sales taxes. Moreover, the share of taxes in the final petrol prices have been mostly high (more than 50%) since 2015 in all four cities as depicted by Figure 3.

Figure 3: Share of Taxes and Crude Oil Prices in Petrol Price for Four Major Cities In India (2014-2021)

III. Empirical Framework

Our main empirical specification uses a standard two way fixed effects (TWFE) linear regression model to compare the effects of taxes and tax-exclusive prices on household petroleum consumption in India and test whether these effects altered in response to a change in the fuel pricing mechanism (Transition to a Dynamic Pricing Mechanism). To capture this, we essentially decompose the final prices into three components - the tax exclusive price (or the base price), the effective central tax and the effective state taxes (similar to the empirical setup in Chetty et al. (2009)) and use the state-level variations in each of these components to identify the effects of tax-exclusive price, central taxes and state taxes on household petrol consumption. The empirical model is as follows -

$$\ln(Y_{hcmy}) = \beta_0 + \beta_1 \ln(P_{cmy}) + \beta_2 \ln\left(1 + \frac{T^C_{hcmy}}{P_{cmy}}\right) + \beta_3 \ln\left(1 + \frac{T^S_{cmy}}{P_{cmy} + T^C_{hcmy}}\right) + \beta_4[ln(P_{cmy}) \times Post] + \beta_5\left[\ln\left(1 + \frac{T^C_{cmy}}{P_{cmy}}\right) \times Post\right] + \beta_6\left[\ln\left(1 + \frac{T^S_{cmy}}{P_{cmy}T^C_{hcmy}}\right) \times Post\right] + \beta_7 X_{hct} + \delta_c + \delta_m + \delta_y + \delta_{InterviewSlot} + \delta_h + \epsilon_{hcmy} \quad (2)$$

Where, Y_{hcmy} represents the petroleum consumption of household h in city c in month m and year y; P_{cmy} represents the tax-exclusive price (or base price) of petroleum; T^S_{cmy} & T^C_{hcmy} denotes the state and central taxes on petroleum respectively; X_{hcmy} includes a vector of household characteristics like age group, occupation group, gender composition, income group, family size, No. of cars and two-wheeler owned by the household, household expenditure on public transportation in month m and year y and the time taken by the household to travel ten kilometers which is a proxy variable for road infrastructures; δ_c, δ_m, δ_y, δ_h and $\delta_{InterviewSlot}$ are the city, month, year, household and interview time fixed effects respectively.

The petroleum price decomposition in our empirical specification allows us to identify the differential impacts of taxes and tax-exclusive prices on household's petroleum consumption through the state level variations in the tax-exclusive price (or base price), effective central taxes and effective state taxes on petroleum in India. Given the price decomposition, under the assumption of complete tax burden being borne by the consumers, it can be shown that if $\beta_1 = \beta_2 = \beta_3$, then $|\frac{\delta Y}{\delta P}| = |\frac{\delta Y}{\delta T^C}| = |\frac{\delta Y}{\delta T^S}|$ i.e. the semi-elasticity of petroleum demand in India w.r.t tax-exclusive prices is equal to the semi-elasticities of petroleum demand w.r.t the taxes (central as well as the state tax) in India (Proof shown in Appendix A.1). On the other hand, it an also be shown that if $\beta_1 < \beta_2$, β_3, then households are more responsive to a change in petrol taxes than an equivalent change in tax-exclusive price of petrol i.e. $|\frac{\delta Y}{\delta P}| < |\frac{\delta Y}{\delta T^C}|$, $|\frac{\delta Y}{\delta T^S}|$. Therefore, our empirical model tests essentially tests whether $\beta_1 < \beta_2$, β_3.

Furthermore, to analyze whether these price semi-elasticities changed with the transition to a Dynamic Pricing Mechanism of fuel in India, we interact each of the price components with a post dummy(taking a value 1 for all month-years after June 2017 and 0 otherwise). This empirical specification allows us to test whether the semi-elasticities of petroleum demand in India w.r.t tax-exclusive prices and taxes changed (i.e. β_4 , β_5 , $\beta_6 \neq 0$) with the transition in the fuel pricing mechanism in India.

IV. Identification

To identify the semi tax-exclusive price elasticity and the semi tax elasticity of fuel demand in India, we exploit the state-month level variations in the the tax exclusive price and the effective central and state tax rates across India.[10] The primary identification assumption is that after including necessary controls and the time, state, household and interview slot fixed effects, there are no other variables influencing the household fuel consumption, which could also effect the price components of fuel. The justification of this assumption in our empirical model relies on the following:

- First, the tax-exclusive price of petrol mainly comprises of the crude oil price determined in the world market. Given that India is a price taker in the world crude oil market, hence any household level shocks in petrol demand are unlikely to impact the tax exclusive price of petrol, thereby

[10]While the crude oil price is consistent across all states in India, the tax-exclusive price of fuel varies due to differential transportation and state-specific costs (mainly includes state surcharge and siding charges).

insulating the model parameter (β_1) from the simultaneity bias. Moreover, the other components of tax-exclusive price (state specific surcharges and freight costs) constitutes less than 5% of the tax-exclusive price and are determined by the state-budget unlikely to be effected by household petroleum demand.

Second, central (and state) taxes are determined by economic conditions and political factors. Therefore, after controlling for year fixed effects, state fixed effects and household total expenditure[11], taxes should be uncorrelated with other factors influencing household petroleum consumption.

Third, supply shocks in the world oil market are likely to impact petroleum prices as well as household consumption through inflation. Controlling for household monthly total expenditure is likely to absorb the effect of supply shocks in the world market.

Other factors which could threaten the identification is a change in the price of other substitute fuels like Diesel. A sharp fall in the price of diesel and thereby public transportation could induce households to substitute private vehicle usage with public transits, thereby impacting household petroleum consumption[12]. In our empirical specification, we control for this substitution effect by including monthly household expenditures on public transportation in our model.

Furthermore, road conditions or the number of vehicles owned by the households could also impact households monthly consumption of petrol. To absorb these effects we control for the number of vehicles owned by households in each month-year and the time taken by a household to travel ten kilometers (which is a proxy variable for road conditions) respectively. Any other household specific time-invariant factors are captured by the household fixed effect. Furthermore, seasonality in household petrol consumption are absorbed by the month fixed effect variable.

Previous studies using Consumer Pyramids Households Survey (CPHS) found evidence of recall bias in the household's reported consumption expenditures (Wadhwa (2019)) where the economic conditions at the time of interview influenced the reported expenditure values. To control for this effect, in our main specification (2) we include a interview time fixed effects such that any time variant economic factors impacting household responses are absorbed.

V. Results and Discussion

Table (4) shows the Ordinary Least Square estimates of the Two-Way Fixed Effects (TWFE) Log-Log regression specification (2) & (3). Specification (2) allows us to identify the semi-elasticities of petroleum demand w.r.t tax-exclusive price, central tax and state tax in India, after controlling for household level characteristics (age group, income group, gender composition, occupation group, household size), household expenditures on public transits which is a substitute for petroleum, road conditions and a set of fixed effects. Interaction with the *Post* dummy allows us to identify how the semi-elasticities of petroleum demand in India changed following a transition in the pricing mechanism from a partially deregulated system to a full deregulation.

Furthermore, to identify whether household petroleum consumption in India responds differentially to a change in the taxes compared to an equivalent change in the Retail Selling Price (RSP), we estimate a similar specification as Model (2) replacing the price decomposition with the RSP of

[11] Any state level economic factors such as unemployment level or state GDP impacting household petroleum consumption, is also likely to effect the household's total expenditure. Therefore, controlling for monthly household total expenditure, should absorb any state level economic factors impacting petroleum consumption.

[12] Public transportation in Chennai, Kolkata and Mumbai are mostly diesel based. hence a sharp in the price of diesel and therefore public transit costs could induce household substitution of private car/two-wheeler with public transportation.

petroleum [13]. The heteroskedasticity robust standard errors are clustered at the household level.

The results presented in table (4) shows that the absolute value of the coefficient on the state tax of petroleum is 0.43 which is almost four times larger than the absolute value of the coefficient on the tax-exclusive price of petroleum which is 0.16. Moreover, results of Model (3) shows that the price elasticity of petroleum demand in India is -0.21 which is nearly half of the coefficient on state-taxes in Model (2)[14]. This suggests that household petroleum consumption in India almost four time more responsive to state-taxes compared to an equivalent change in the tax-exclusive price and almost twice more responsive to state-tax relative to an equivalent change in overall price (or Retail Selling price) of petroleum. However, we do not find any statistically significant result on the effect of central tax of petroleum on household petroleum consumption in India.

A possible explanation for the higher responsiveness to petroleum taxes could be the high salience of petroleum taxes. At the gasoline stations in India, the tax-inclusive prices of petroleum are posted at the counter such that the consumers do not separately observe the taxes and tax-exclusive prices. Such a price-posting set up might lead one to conclude that households should not respond differently to change in taxes compared to overall prices. However, in the Indian political landscape, petroleum or fuel taxation is a popular instrument for garnering public support and criticizing opposing factions. Therefore, changes in petroleum (or fuel) taxes in India are highly subject to public debates and receives considerable media attention, making it more salient or visible to the consumers. Since this paper focuses on the urban population (three major cities namely Mumbai, Chennai and Kolkata) where petroleum is consumed by relatively wealthier and educated households, the salience theory of fuel taxation becomes even more plausible.

Moreover, we find that the differential response to taxes is purely driven by state tax changes: there is no effect of changes in effective central taxes on household petroleum consumption in India. A possible mechanism driving this could be differential perception of the benefits that a particular type of tax accrues. If households believe that a ₹1 raise in central tax contributes more effectively to public welfare (would be employed in improving economic conditions) compared to similar ₹1 raise in state taxes, then this could account for their heightened responsiveness to state tax changes compared to central tax change. Another possible explanation could be higher salience of state taxes compared to central tax - If petroleum state tax changes are subject to more local debates and discussions compared to central taxes, this could make state tax changes more visible to the households.

Also, the higher responsiveness to petroleum state taxes compared to tax exclusive price, central tax and overall petrol price could be driven by the households belief on the persistence of state tax changes (Li et al. (2014); Scott (2012)). If households believe that state tax changes will be more persistent (In other words, state tax changes will be permanent) compared to central tax or tax-exclusive price changes, then this could alter their short-run vehicle choices (inducing households to choose fuel efficient vehicles or other fuel types like Diesel or Compressed Natural Gas (CNG)) and results in greater short-run responsiveness to state-taxes.

Our second major result shows that the coefficient of all the *Post* dummy interaction terms are negative: -0.56 on the tax-exclusive price interacted with *Post*, -0.87 on the effective central-tax rate interacted with *Post* and -0.38 on the effective state-tax rate interacted with *Post* dummy. This shows that following the transition from a partially deregulated Automatic Pricing Mechanism to a

[13]

$$\ln(Y_{hcmy}) = \gamma_0 + \gamma_1 \ln(RSP_{cmy}) + \gamma_2[\ln(RSP_{cmy}) \times Post] + \gamma_3 X_{hcmy} + \delta_c + \delta_m + \delta_y + \delta_{InterviewSlot} + \delta_h + \epsilon_{hcmy} \quad (3)$$

[14]The price elasticity of petroleum demand estimates we derived are consistent with the literature (Shaw (2020); Kanjilal and Ghosh (2018))

fully deregulated Dynamic Pricing Mechanism of Petroleum in India, the household responsiveness to both the tax-exclusive price and taxes increased. Model (3) shows that even price elasticity of petroleum demand in India increased following the transition in the pricing mechanism.

A relevant explanation for this result could be a shift in the households perception of the persistence of price change following the introduction of the Dynamic Pricing Mechanism. Prior to the implementation of the Dynamic Pricing Mechanism, petroleum prices in India were modified at a bi-weekly or sometimes even at a monthly interval, resulting in consumers observing consistent (or same) prices for extended periods. However, with the Dynamic Pricing Mechanism, the petroleum prices were fully aligned to the global oil prices leading to daily fluctuations (new prices are posted daily at 6 A.M. in the morning). As a results household could now observe different petroleum prices during their bi-weekly or monthly visit to the gasoline station. This increase in the frequency of price change under the Dynamic Pricing Mechanism could have driven household to update their belief on the persistence of petroleum price changes in the future, making them more responsive to petroleum taxes and prices. Finally, our results show that the short-run price elasticity of petroleum demand in India is -0.21 which is almost ten times higher than the price elasticity of gasoline demand in the United States. This might be driven by two factors - First, the wide availability of affordable public transits within and across states in India which makes it feasible for households to easily substitute private vehicles with public transportation in the event of a hike in petroleum price. Second, the socio-demographic characteristics of the households owing a vehicle in India is widely different from that in a Developed County like the US. In India, cars are owned by relatively wealthier and educated households who have grater flexibility in making vehicle choices which in turn impact gasoline demand.

VI. Robustness Checks

During the time-period of our analysis from 2014 to 2021, the Government of India (GOI) implemented various fiscal and monetary policy changes that could have influenced the household petroleum consumption expenditure - First, on July 1, 2017, GOI made a major tax reform in the indirect tax system in India: It introduced the Goods and Services (GST) tax, replacing all indirect taxes at the center and the state level with a uniform tax rate for all commodities throughout the country. Although petroleum (or fuel) taxes were not covered under this reform, however, it might have impacted household petroleum consumption through its effect on household employment status or through a change in the price of the complementary goods like vehicles.

Second, in 2016 the government made a bold monetary policy reform in India. On November 8, 2016 at 8:15 PM, the GOI announced the demonetization banning all 500 and 1000 Rupee notes in circulation in the economy, which made up around 86% of the total currency of the economy. This created an utter chaos with people forming long queues outside banks and ATMs to get their old currencies exchanged. This could have potentailly impacted household petroleum consumption through different channels - Initially gas stations and other utilities were allowed to accept old currency which could have heightened petroleum consumption. However, the government withdrew this provision at the gas stations on December 2, 2016. Moreover, Demonetization had cascading effect on household's income, employment, borrowing behavior and also on consumption expenditures on both durable and non-durable goods (Wadhwa (2019); Kumar (2017); Karmakar and Narayanan (2020)).

Apart from the policy shocks, Covid-19 Pandemic also plagues our period of analysis. During the pandemic period, work-from-home and zonal lock downs impacted households outdoor travels. Therefore, to check the sensitivity of our results to the policy shocks and pandemic period, we

estimate a similar specification as model (2) for a sample excluding the span of six-month following the policy shocks and the pandemic period that is February 2020 onwards.

Table (5) shows the results of the robustness check where Model 1, Model 2, Model 3 and Model 4 presents the estimates of the OLS regressions excluding the Covid Pandemic period, the GST reform period, the time period of Demonetization and all the time periods of policy shocks and Covid Pandemic shock respectively. In all four specification, the results that households petroleum consumption behavior responds more to 1% change in state-taxes compared to an equivalent change in tax-exclusive price and central-taxes remains consistent and this results is therefore not sensitive to the policy reforms or the Pandemic shock.

Moreover, the result of an increase in the semi-elasticities of petroleum demand w.r.t taxes and tax-exclusive prices following the transition to a Dynamic Pricing Mechanism is insensitive to the exclusion of the GST or the Demonetization reform period. However, upon excluding the Pandemic period from our sample we find that the households responsiveness of petroleum consumption to a change in the state taxes decreased following the transition to a Dynamic Pricing Mechanism.

During the Pandemic period household's vehicle usage and consumption of petroleum reduced due to factors (transition to work-from-home culture and periodic lock downs) other than the tax (and price) rise. Excluding the Pandemic period, therefore, removes the impact of the Covid-19 shock on the household fuel consumption and shows that with the transition to a Dynamic Pricing Mechanism household's responsiveness to state taxes in fact decreased. This could be possible if the Automatic Pricing Mechanism (when prices were posted bi-weekly or monthly) generated speculative behavior, wherein household anticipated future changes in state taxes and accordingly hoarded petroleum under the expectation of future rise in state taxes. The result of an increase in the semi-elasticties of petroleum demand w.r.t central tax and tax-exclusive price following a transition to the Dynamic Pricing Mechanism holds in all four robustness check specification and therefore is not sensitive to the policy shocks and to the inclusion of the Covid Pandemic period.

VII. Conclusion

In the recent years fuel tax in India has been a significant fiscal tool for the government in recovering from recessions. Between 2014 and 2021, an evident surge in both state and central fuel taxes occurred, during the Covid-19 pandemic, addressing the fiscal challenges posed by the crisis. At the same time, with the growing environmental concerns over reducing CO_2 emissions in India, curbing excessive fuel consumption in becoming pivotal. Given the critical role that fuel taxes and prices play is achieving economic stabilization and long term environmental goals of CO_2 emissions reduction, it is crucial to investigate consumer responsiveness to fuel taxes and prices and explore how different fuel pricing policies impacts fuel consumption in India. Such study is imperative to guide future fuel pricing policy decisions of the country.

In light of this, we answers two research questions - First, whether households petroleum consumption in India responds differently to a change in petroleum prices compared to an equivalent change in petroleum state tax and petroleum central tax. This research question helps understand the efficacy of fuel taxes in India in achieving fiscal and environmental goals. Further, it informs whether consumers are more responsive to state or central taxes of fuel and therefore helps understand the efficacy of the taxes imposed by different levels of governments in achieving the dual goals. Second, we explore how households fuel consumption in India responds to different fuel pricing mechanisms. To answer this question we exploit the transition in the fuel pricing mechanism in India from a partially deregulated Automatic Pricing System to a fully deregulated Dynamic Pricing System.

Using household month level data, we find that household petroleum consumption in India responds almost four times more responsive to fuel state-tax compared to an equivalent increase in the fuel tax-exclusive price. Moreover, we find that household in India do not responds differently to a change in the central taxes. The results also shows that the price elasticity of petroleum demand in India is -0.21 which is half the responsiveness to fuel state-taxes. This results is robust across various sample specifications and therefore provides strong evidence on the efficacy of the central taxes in bolstering fiscal health of the economy and that of the state-taxes in addressing vehicular pollution concerns.

Our second main results indicates that consumers in India are more responsive to fuel taxes under a Dynamic Pricing Mechanism wherein fuel prices are allowed to fluctuate daily compared to an Automatic Pricing Mechanism where prices were posted at a bi-weekly or monthly interval. This result is informative in guiding future fuel pricing policy decisions in India. The potential mechanism behind these results could be higher salience (or visibility) of fuel taxes to households in India, different perception of households in India on the utilization of central and state taxes in improving public welfare or greater persistence of change in state-taxes influencing consumer long-run fuel choice decisions and thereby short-run fuel consumption. Further empirical investigation is required to identify the most plausible mechanisms driving these results.

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A. Appendix

A.1. $\beta_1 = \beta_2 = \beta_3 \implies |\frac{\delta lnY}{\delta P}| = |\frac{\delta lnY}{\delta T^C}| = |\frac{\delta lnY}{\delta T^S}|$

Proof: Petroleum Price in India mainly comprises of three components - the tax-exclusive price (or the base price) denoted as P, the central tax denoted as T^C and the state-tax denoted as T^S -

$$Price = P(1 + \frac{T^C}{P})(1 + \frac{T^S}{P+T^C})$$

We hypothesize that households in India responds differently to a change in the tax-exclusive price P compared to an equivalent change in the taxes i.e. T^C or T^S. To test this we consider the following regression model -

$$\ln(Y_{hcmy}) = \beta_0 + \beta_1 \ln(P_{cmy}) + \beta_2 \ln\left(1 + \frac{T^C_{cmy}}{P_{cmy}}\right) + \beta_3 \ln\left(1 + \frac{T^S_{cmy}}{P_{cmy} + T^C_{cmy}}\right) + \beta_7 X_{hcmy} + \delta_c + \delta_m + \delta_h + \delta_m + \delta_y + \delta_{InterviewSlot} + \epsilon_{hct} \quad (4)$$

Differentiating equation (3) w.r.t P, T^C and T^S, we get the semi-elasticity of petrol demand w.r.t tax-exclusive price, the central tax and the state tax respectively -

$$\frac{\delta \ln Y}{\delta P} = \epsilon_P = \frac{\beta_1}{P} - \frac{\beta_2 T^C}{P(P+T^C)} - \frac{\beta_3 T^S}{(T^C+P)(T^C+T^S+P)} \quad (5)$$

$$\frac{\delta \ln Y}{\delta T^C} = \epsilon_{T^C} = \frac{\beta_2}{(P+T^C)} - \frac{\beta_3 T^S}{(T^C+P)(T^C+T^S+P)} \quad (6)$$

$$\frac{\delta \ln Y}{\delta T^S} = \epsilon_{T^S} = \frac{\beta_3}{(T^C+T^S+P)} \quad (7)$$

Setting $\beta_1 = \beta_2 = \beta_3$, equation (4), (5) and (6) can be written as -

$$\frac{\delta \ln Y}{\delta P} = \epsilon_P = \beta_3[\frac{1}{P} - \frac{T^C}{P(P+T^C)} - \frac{T^S}{(T^C+P)(T^C+T^S+P)}]$$

$$or, \epsilon_P = \beta_3[\frac{P(P+T^C)}{P(P+T^C)(P+T^C+T^S)}]$$

$$or, \epsilon_P = \frac{\beta_3}{(P+T^C+T^S)} \quad (8)$$

$$\frac{\delta \ln Y}{\delta T^C} = \epsilon_{T^C} = \beta_3[\frac{1}{(P+T^C)} - \frac{T^S}{(P+T^C+T^S)}]$$

$$or, \epsilon_{T^C} = \beta_3[\frac{P(P+T^C)}{P(P+T^C)(P+T^C+T^S)}]$$

$$or, \epsilon_{T^C} = \frac{\beta_3}{(P+T^C+T^S)} \quad (9)$$

$$\frac{\delta \ln Y}{\delta T^S} = \epsilon_{T^S} = \frac{\beta_3}{(P+T^C+T^S)} \quad (10)$$

From equations (7), (8) & (9) we get -

$$\beta_1 = \beta_2 = \beta_3 \implies |\frac{\delta Y}{\delta P}| = |\frac{\delta Y}{\delta T^C}| = |\frac{\delta Y}{\delta T^S}|$$

Tables & Figures

Variable	N	N = 82,985[1]
age_group	82,985	
Balanced households with no Seniors		15,975 (19%)
Balanced households with Seniors		888 (1.1%)
Children - dominant		199 (0.2%)
Grown-up - dominant		35,048 (42%)
Other households of the Young		1,743 (2.1%)
Others households of Grown-ups		15,882 (19%)
Seniors - dominant		8,656 (10%)
Youngsters - dominant		4,594 (5.5%)
Gender Composition	82,985	
Balanced		31,079 (37%)
Female Dominated		6,316 (7.6%)
Female Majority		13,793 (17%)
Male Dominated		7,504 (9.0%)
Male Majority		18,627 (22%)
Only Females		3,928 (4.7%)
Only Males		1,738 (2.1%)
Household Income	82,985	
<=36000		40 (<0.1%)
>3600000		12 (<0.1%)
100000 - 120000		3,049 (3.7%)
1000000 - 1200000		1,021 (1.2%)
120000 - 150000		5,250 (6.3%)
1200000 - 1500000		593 (0.7%)
150000 - 200000		11,367 (14%)
1500000 - 1800000		161 (0.2%)
1800000 - 2000000		63 (<0.1%)
200000 - 250000		11,568 (14%)
2000000 - 2400000		55 (<0.1%)
2400000 - 3600000		25 (<0.1%)
250000 - 300000		9,568 (12%)
300000 - 400000		12,886 (16%)
36000 - 48000		43 (<0.1%)
400000 - 500000		10,034 (12%)
48000 - 60000		139 (0.2%)
500000 - 600000		6,253 (7.5%)
60000 - 72000		251 (0.3%)
600000 - 700000		3,835 (4.6%)
700000 - 800000		2,436 (2.9%)
72000 - 84000		580 (0.7%)
800000 - 900000		1,416 (1.7%)
84000 - 100000		1,371 (1.7%)

Continued on next page

Variable	N	N = 82,985[1]
900000 - 1000000		969 (1.2%)
Education Group	82,985	
All Graduates household		13,821 (17%)
All Matriculates household		11,869 (14%)
Graduates dominated household		1,429 (1.7%)
Graduates majority household		14,860 (18%)
Graduates minority household		8,731 (11%)
Households of all illiterates		572 (0.7%)
Households of all literates		14,973 (18%)
Households of some literates		2,025 (2.4%)
Matriculates dominated household		685 (0.8%)
Matriculates majority household		10,791 (13%)
Matriculates minority household		3,185 (3.8%)
Not applicable		44 (<0.1%)
Car Ownership	82,985	13,141 (16%)
Two-Wheeler Ownership	82,985	61,424 (74%)
Expenditure on Petroleum	82,985	795 (0, 1,267)
Expenditure on Public Transportation	82,985	370 (200, 600)

[1]n (%); Median (IQR)

[1]n (%); Median (IQR)

Table 2: Effect of Changes in Taxes and Crude oil Prices on Retail Selling Price of Petrol in India

	RSP_{st}
Base Price	1.010***
	(0.002)
Tax	1.006***
	(0.0005)
Num.Obs.	372
R2	1.000
R2 Adj.	1.000
R2 Within	1.000
R2 Within Adj.	1.000
AIC	−2185.8
BIC	−1801.7
RMSE	0.01
Std.Errors	by: state
FE: state	X
FE: month-year	X

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

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Table 3: Price Build-up of Petroleum in Delhi on September 16, 2016

Sr No	Component	Unit (Rs. /Ltr.)	Share in Final Price
1	Base Price/Ex-Refinery Price (including freight)	26.31	40.97%
2	Central Tax	21.96	34.20%
3	State Tax	13.65	21.25%
4	Dealer's Commission	2.29	3.5%
5 = 1 +2 + 3 + 4	Retail Selling Price	64.21	100%

Source: Petroleum Planning and Analysis Cell (PPAC)

Table 4: Effect of Petroleum Tax-Exclusive Price, Central Tax and State tax on Household Petroleum Consumption in India

	Model 1	Model 2
log(Retail Selling Price)		-0.21^{***}
		(0.04)
log(Retail Selling Price) × Post		-0.35^{***}
		(0.06)
log(tax-exclusive price)	-0.16^{**}	
	(0.06)	
log(1 + effective central tax rate)	-0.12	
	(0.10)	
log(1 + effective state tax rate)	-0.43^{***}	
	(0.05)	
log(tax-exclusive price) × Post	-0.56^{***}	
	(0.07)	
log(1 + effective central tax rate)× Post	-0.87^{***}	
	(0.12)	
log(1 + effective state tax rate)× Post	-0.38^{***}	
	(0.08)	
post	2.57^{***}	1.54^{***}
	(0.32)	(0.24)
Num. obs.	82985	82985
Num. groups: hh_id	1518	1518
Num. groups: district	3	3
Num. groups: Interview-Slot	86	86
Num. groups: Month	12	12
Num. groups: year	8	8
Controls	Yes	Yes
R^2 (full model)	0.67	0.66
R^2 (proj model)	0.39	0.38
Adj. R^2 (full model)	0.67	0.66
Adj. R^2 (proj model)	0.39	0.38

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Note: The outcome variable in both Model 1 and Model 2 is the household monthly petroleum consumption. The specification tested in Model 1 is regression model 2 and the specification tested in Model 2 is the regression equation 3. Both Model 1 and Model 2 includes the following control variables: age composition, gender composition, occupation group, income group, travel group, household size, monthly household expenditure on public transportation, monthly household total expenditure and the time taken by a household to travel ten kilometers. Both Model 1 and Model 2 controls for month, year, state, household and interview time fixed effects and the standard errors are clustered at the household level.

Table 5: Robustness Check: Excluding Covid-19 Pandemic Period, GST Reform Period and Demonetization Period

	Model 1	Model 2	Model 3	Model 4
log_tax_exclusive_price	-0.17^{**}	-0.18^{**}	0.08	-0.08
	(0.06)	(0.06)	(0.07)	(0.07)
log(1 + central_tax_rate)	-0.15	-0.17	-0.04	-0.17
	(0.10)	(0.10)	(0.10)	(0.10)
log(1 + state_tax_rate)	-0.47^{***}	-0.32^{***}	-0.19^{***}	-0.36^{***}
	(0.05)	(0.05)	(0.05)	(0.06)
post × log_tax_exclusive_price	-0.57^{***}	-0.54^{***}	-0.73^{***}	-0.59^{***}
	(0.09)	(0.07)	(0.08)	(0.09)
post × log(1 + central_tax_rate)	-0.88^{***}	-0.82^{***}	-0.84^{***}	-0.89^{***}
	(0.17)	(0.12)	(0.12)	(0.18)
post × log(1 + state_tax_rate)	0.22^{*}	-0.80^{***}	-0.45^{***}	1.36^{***}
	(0.09)	(0.11)	(0.08)	(0.23)
post	2.41^{***}	-8.22	3.14^{***}	1.01
	(0.39)	(93.69)	(0.33)	(212.32)
Num. obs.	67204	77944	77259	56437
Num. groups: hh_id	1516	1518	1518	1516
Num. groups: district	3	3	3	3
Num. groups: months	12	12	12	12
Num. groups: month_slot	64	83	83	58
Num. groups: year	7	8	8	7
R^2 (full model)	0.67	0.68	0.68	0.68
R^2 (proj model)	0.34	0.40	0.40	0.35
Adj. R^2 (full model)	0.66	0.67	0.67	0.67
Adj. R^2 (proj model)	0.34	0.40	0.40	0.35

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Note: The outcome variable in Model 1, Model 2, Model 3 and Model 4 is the household monthly petroleum consumption. The robustness check in Model 1 excludes the Covid-19 Pandemic period, Model 2 excludes the six months time span after the Goods and Service Tax (GST) reform in India, Model 3 excludes the six-month time span after Demonetization in India and Model 4 excludes the Covid Pandemic period along with the time period of the GST reform and Demonetization in India. All the models include the following control variables: age composition, gender composition, occupation group, income group, travel group, household size, monthly household expenditure on public transportation, monthly household total expenditure and the time taken by a household to travel ten kilometers. Further, all the models control for the month, year, state, household and interview time fixed effects and the standard errors are clustered at the household level.