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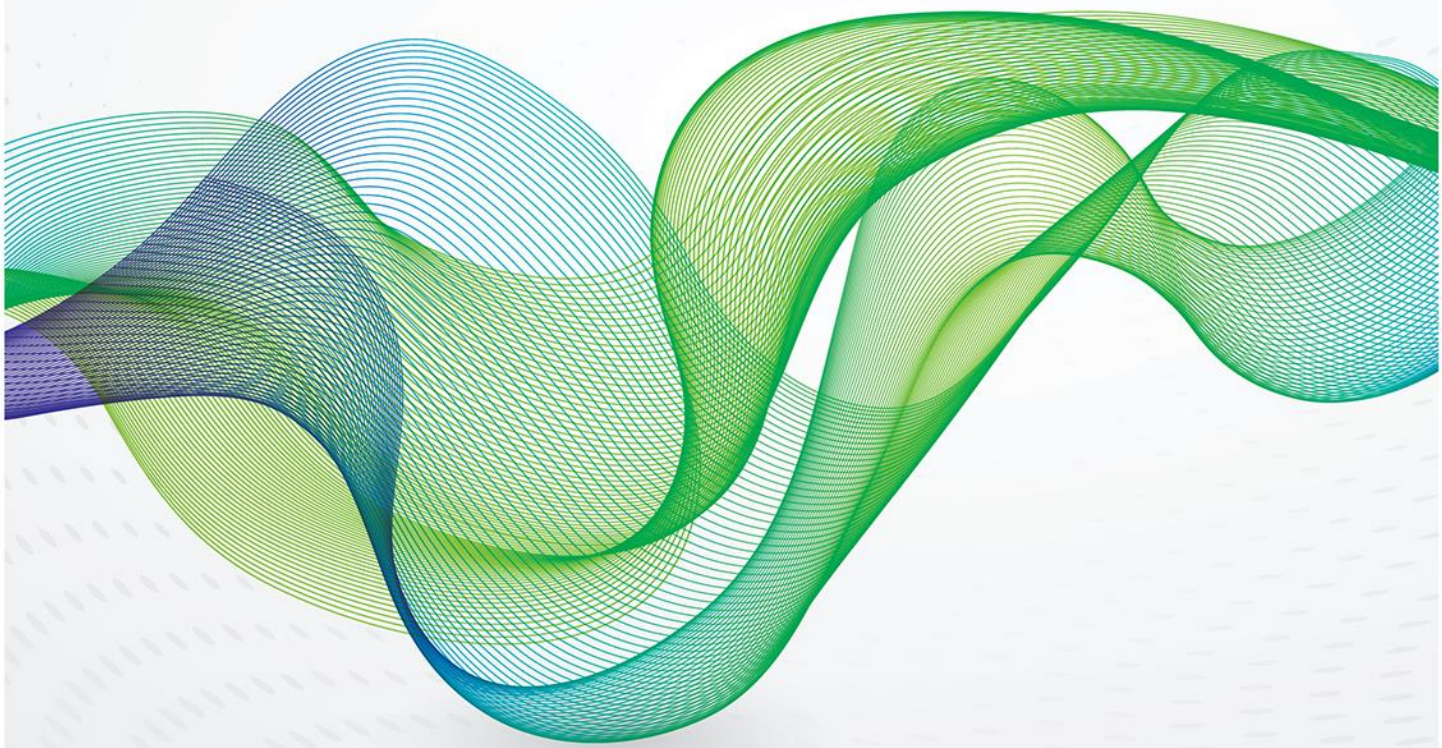
Gasoline Demand in Non-OECD Asia:
Drivers and Constraints



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Abstract[1]

Global oil demand is undergoing a structural shift. This is broadly reflected in changing demand dynamics over the last 15 years. While OECD demand decreased by 3 million barrels per day (mb/d) from 2000-15, demand in non-OECD countries grew by 21 mb/d (IEA, 2015). This shift is characterised by two developments: first, the rapid growth in China's oil consumption from 2000-13, and second, the subsequent 'jump' in India's oil demand growth – which overtook China's in 2015 to emerge as the main engine of non-OECD Asian oil demand growth. As the emerging market economies of non-OECD Asia continue to industrialise, rising per capita incomes are likely to further underpin this structural shift. The shift is particularly visible in gasoline demand – driven primarily by transport – which has defied expectations in terms of the sources of demand growth. Contrary to those expectations, the centre of growth has shifted from West of Suez markets to non-OECD Asia, which had previously been dominated by distillates. Average gasoline demand growth in Asia has nearly doubled from 130 kb/d a year from 2005-10, to 290 kb/d from 2011 onwards. At the same time, climate change mitigation and growing concerns over air quality imply that Asia's economic growth will occur in a carbon-constrained world, and non-OECD Asia may not follow the trajectories of the OECD countries. Given this context, this paper investigates two research questions: first, what are the key drivers of gasoline demand growth in non-OECD Asia, based on historical trends? And second, what are the constraints to gasoline demand growth in this region? The first question is investigated using statistical analyses on a panel dataset of 19 countries in the Asia-Pacific region, of which over half are non-OECD countries. The second question, driven by regional policies, is investigated by looking in depth at the cases of India and China. The paper gives a broad insight into the drivers and constraints on Asian gasoline demand, focusing on the transport sector as a key variable.

[1] The authors are grateful to Bassam Fattouh for comments on an earlier draft of this paper, and to Kate Teasdale and Justin Jacobs for their help with publication.

1. Introduction

Global oil demand is undergoing a structural shift. Over the last 15 years, while OECD demand decreased by 3 million barrels per day (mb/d) from 2000-15, demand in non-OECD countries grew by 21 mb/d (IEA, 2015). This shift is characterised by the rapid growth in China's oil consumption from 2000-13, and the 'jump' in India's oil demand growth – which overtook China in 2015 to emerge as the main engine of non-OECD Asian oil demand growth. As the emerging market economies of non-OECD Asia continue to industrialise, rising per capita incomes will further underpin this structural shift.

The shift is particularly visible in gasoline. Growth in gasoline demand has defied expectations – which were for demand to decline as it was mainly driven by West of Suez markets while East of Suez demand was distillate-heavy. Gasoline growth is now being driven by non-OECD economies in Asia. Asian gasoline demand, which was growing at an average of 130 kb/d a year between 2005 and 2010, nearly doubled to 290 kb/d a year from 2011 onwards.

In consumer theory, the demand for gasoline is a 'derived' demand (Storchmann, 2005; Becker, 1965; Lancaster, 1966; Muth, 1966). It is not gasoline itself which gives benefit to the consumer, but the end-product – namely, mobility (Storchmann, 2005). Hence the key drivers of gasoline demand growth pertain to specific products or sectors. For instance, in India three key sectors have been identified as driving growth in the derived demand for oil (Sen and Sen, 2016):

- Transportation (rising car ownership levels and the growth of the vehicle fleet);
- Infrastructure (road construction); and,
- Manufacturing (the push to expand manufacturing's share within Gross Domestic Product (GDP)).

While the literature[2] suggests an increase in the growth or stock of oil-consuming sectors or products based on historical trends, there are increasing policy constraints on the pace of such trends as the world economy enters a carbon-constrained era of economic growth. Thus, the same trends which applied to the advanced OECD countries may not necessarily hold for non-OECD Asia.

On the one hand, non-OECD Asian economies are expected to enter or continue along high-growth trajectories over the next decade, driven by significant expansions in infrastructure, output and income at the national level; examples include India's nationwide programme to add 30 km of roads/day, and its push to increase manufacturing's share of GDP from 15% to 25% by early next decade through focusing on energy-intensive industry, as well as China's 'One Belt One Road' initiative to create connecting infrastructure across Asia. On the other hand, given the carbon constraint on economic growth arising from the ratification of the Paris Agreement, there is a push towards increasing the efficiency of energy use (such as through stricter fuel efficiency standards in transportation and eliminating fossil fuel subsidies from end-user prices), as well as a greater number of local or regional level initiatives to curb environmental externalities (such as the adoption of Electric Vehicles (EVs), and bans on polluting vehicles). Notably, while the push to increase output and income is primarily occurring at the national level in most non-OECD Asian countries, the constraints to this expansion are currently being driven at the local or regional level. These counteracting trends and the complexity of the policies which underpin them make it unlikely that non-OECD Asian economies will follow the same historical trends in oil consumption as the OECD. There are three potential arguments that can be made:

- One argument is that these economies will enter high-growth trajectories, but that these trajectories could be shorter, and the plateaus in consumption may come sooner than they have in the OECD.

[2] For instance, see Dargay et al (2007), Dargay (2001), and Huo et al (2007).

- A second argument is that technological advancements (such as in storage technologies) will facilitate a faster substitution of oil in its core consuming sectors (for example, gasoline in the transport sector) regardless of the growth in car ownership.
- A third argument is that the fragmented nature of regional-level policy constraints will fail to have a significant impact on nationally-driven movements to industrialise.

Given this context, this paper aims to investigate two research questions: first, what are the key drivers of gasoline demand growth in non-OECD Asia, based on historical trends? And second, what are the key constraints to gasoline demand growth in this region? The first question, driven by historical trends, is investigated by applying statistical analyses to a panel dataset of 19 countries in the Asia-Pacific region, of which over half are non-OECD countries. The second question, driven by local and regional policies, is investigated by looking at the cases of India and China, in which we also examine the plausibility of the three potential arguments. The paper gives a broad insight into the drivers and constraints on Asian gasoline demand, focusing on the transport sector as a key variable.

2. Drivers of Gasoline Demand

2.1 Transport as a Key Driver

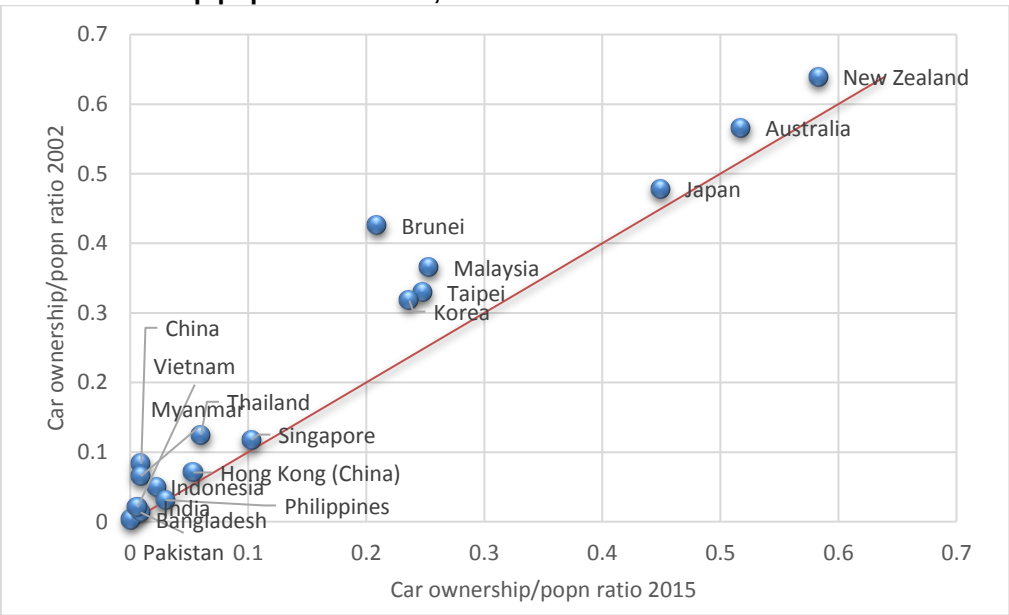
The transport sector accounts for roughly 63% of global oil consumption, and has historically been the fastest growing oil-consuming sector (WEC, 2016). By 2035, it has been projected that 88% of the world's oil demand growth will come from transportation, largely from developing economies (BP, 2016). Medlock and Soligo (2001) show that per capita energy demand in the transport sector steadily increases throughout the process of economic development, eventually accounting for the largest share of total final energy consumption. As oil demand for road transportation is closely linked with the number of cars and other road vehicles in use, projections of future growth in the vehicle stock can provide an insight into future fuel requirements (Dargay and Gately, 1999). In OECD countries, the growth of the vehicle stock, measured in terms of vehicle (or more specifically, car) ownership, has followed a clear path, varying closely with changes in per capita income. As per capita income increased beyond a 'trigger' threshold, car ownership grew exponentially. However, as per capita income in these countries continued to increase to higher levels and reached a second 'trigger' threshold, car ownership levels have begun to level off. This relationship has been formalised in the existing literature: vehicle ownership grows relatively slowly at the lowest levels of per capita income, then about twice as fast at middle income levels (for instance, estimated at $3,000 to $10,000 per capita in Dargay and Gately (2007)), and finally, about as fast as income at higher income levels, before reaching saturation at the highest levels of income (Dargay and Gately, 1999; Dargay et al, 2007; Medlock and Soligo, 2002; Storchmann, 2005; Button et al, 1993).

The historical relationship between per capita income and vehicle ownership implies that *ceteris paribus*, as the developing non-OECD countries climb to higher levels of per capita income, vehicle ownership could follow a similar trajectory to the OECD, increasing oil demand for transportation. Historical data supports this argument – for instance, Dargay et al (2007) showed that this relationship held for 45 countries in which non-OECD countries comprised more than a third, and for three-fourths of the sample's population, for the time period 1960-2002. In the 15 years since, some have entered lower middle-income levels (based on Purchasing Power Parity or PPP). A more recent dataset on vehicle (car) ownership and per capita income was assembled for this paper, covering the period 2002-2015[3] for 19 Asian countries (the majority of which are non-OECD). This period is especially significant because non-OECD oil demand increased by roughly 21 mb/d from 2000-2015, while

[3] Our analysis covers a shorter time period as public data on vehicle ownership across non-OECD countries is not easily available. Other notable studies have covered much shorter time periods (for instance Storchmann (2005) uses data for 7 years), and therefore a shorter time-series should not detract from our results.

OECD oil demand decreased by 3 mb/d, with this secular decline expected to continue at around 5 mb/d by 2035 (BP, 2016). The two largest non-OECD economies, China and India, are expected to account for 50% of the increase in oil demand to 2035 (BP, 2016).

Figure 1: Car ownership/population ratios, 2002 vs. 2015



Source: Authors

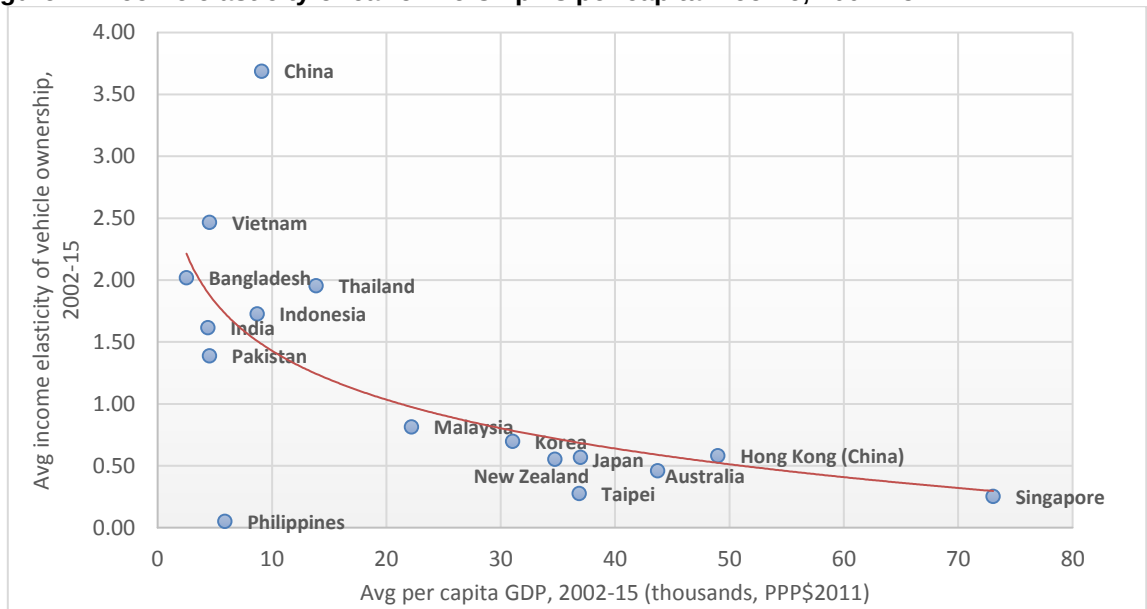
Figure 1 above summarises the changes in car ownership from 2002-15 for the countries in the dataset.[4] [5] Each country's 2002 car/population ratio is plotted on the vertical axis and its 2015 ratio on the horizontal axis. The higher up the country is on the diagonal (1:1 line), the higher its car ownership levels. The greater its distance from the diagonal, the faster was its increase in car ownership relative to per capita income. For instance, Australia's car ownership ratio in 2015 was very high relative to most other countries, at approximately 0.565 (or 565 cars per 1,000 population); however, its average annual growth from 2002-15 was only 0.71% (up from 0.517 in 2002). China's car ownership ratio was relatively low in 2015 (approximately 0.083); however, the average annual growth from 2002-15 was 60% (from 0.009 in 2002). Similarly, India's car ownership ratio was only 0.02 in 2015, but average annual growth from 2002-15 was around 14%. In Vietnam, the corresponding figures were roughly 0.021 (2015) and nearly 18% annual average growth (2002-15). This is a very broad measure of the car ownership to per capita income relationship and does not take into account the specific anomalies and circumstances of each country. For instance, Brunei (a resource-rich country) appears to have experienced a rapid increase in car ownership levels during the period in question despite being a relatively high-income country – this could be due to many other factors such as economic conditions, pricing/subsidies[6] or government policy. Or it could simply be due to issues with the reliability of published data.

Figure 2 provides a more detailed picture of the responsiveness of car ownership to changes in income levels, as it plots the historical ratio of the average annual percentage growth in car ownership to the average annual percentage growth in per capita income, which is widely considered a broad measure/estimate of the income elasticity of car (or vehicle) ownership (Dargay and Gately, 1999).

[4] See Table C in appendices. The graph is based on Dargay et al (2007) and Dargay and Gately (1999).
[5] The figure includes 18 countries, as sufficient data was unavailable on Papua New Guinea.
[6] Resource-rich countries have tended to subsidise fuel prices to citizens, leading to excessive increases in domestic fuel consumption and a potentially lower price-relative-to-income elasticity of car ownership. Due to high private consumption, the vehicle fleet tends to be dominated by private cars (IBP, 2015).

Growth rate ratios are plotted for the majority of countries in our dataset on the vertical axis, and compared with each country's average income (measured by per capita GDP on the horizontal axis) over the period 2002-15. The figure shows that car ownership grew almost twice as fast as income for the lower and middle-income countries (that is, income elasticity was around 2.0). For China, it grew 3.7 times as fast[7], whereas for Vietnam it was nearly 2.5.[8] For India, it was around 1.7 times as fast. The figure also shows that the higher a country's income level, the lower its income elasticity of car ownership – at very high levels of income, car ownership begins to approach zero as saturation is reached.

Figure 2: Income elasticity of car ownership vs per capita income, 2002-15



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These broad estimates (based on historical data from 2002-15) of income elasticity of car ownership can be combined with forecasts on GDP and population to project forward estimates of car ownership levels in both OECD and non-OECD Asian countries, holding constant all other factors that may be likely to influence the growth in the car (or vehicle) fleet (we return to these later). Accordingly, we used International Monetary Fund (IMF) forecasts for GDP to 2021 and UN Population forecasts to the same period to obtain simple projections for car ownership to 2021. Figure 3 graphs the historical data along with these broad projections, with car ownership plotted on the vertical axis and per capita income on the horizontal axis. The multiple series plotted represent both low and high-income countries and the trend can be seen as mimicking an 'S' curve (illustrated by the polynomial trend line).

Each solid line in the graph can be interpreted as representing a country time series (historical and projection) for car ownership levels vis-à-vis per capita GDP, between 2002[9] and 2021. In order to simulate the 'S' curve, we included data on both low and high-income countries (non-OECD and OECD) in the Asia-Pacific region (for instance, New Zealand and Australia are the two series at the top of the graph). It can be seen that countries with relatively higher income elasticity of car ownership

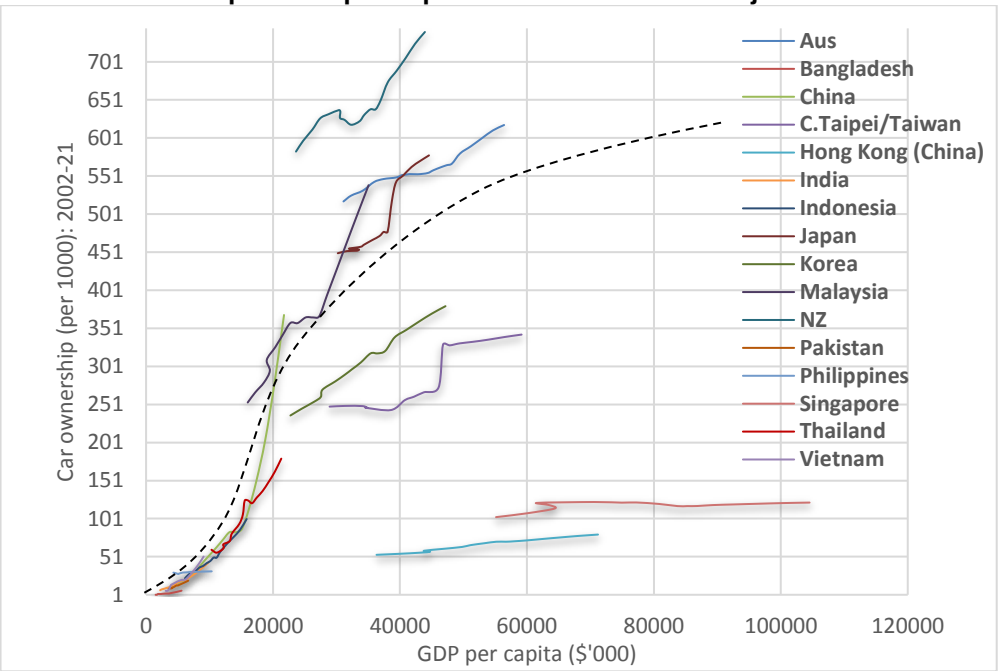
[7] These high values are not limited to Asia. Eskeland and Feyzioglu (1997) for instance showed a similarly high-income elasticity (3.34) for Mexico.

[8] The figure shows the Philippines as an outlier in the dataset with very low-income elasticity; based on available data, its car ownership ratio grew by only 0.23% on average annually from 2002-15. The Nielsen Global Survey of Automotive Demand (2013) estimates that 47% of households did not own cars.

[9] The starting year is 2005 for some countries which lacked historical data.

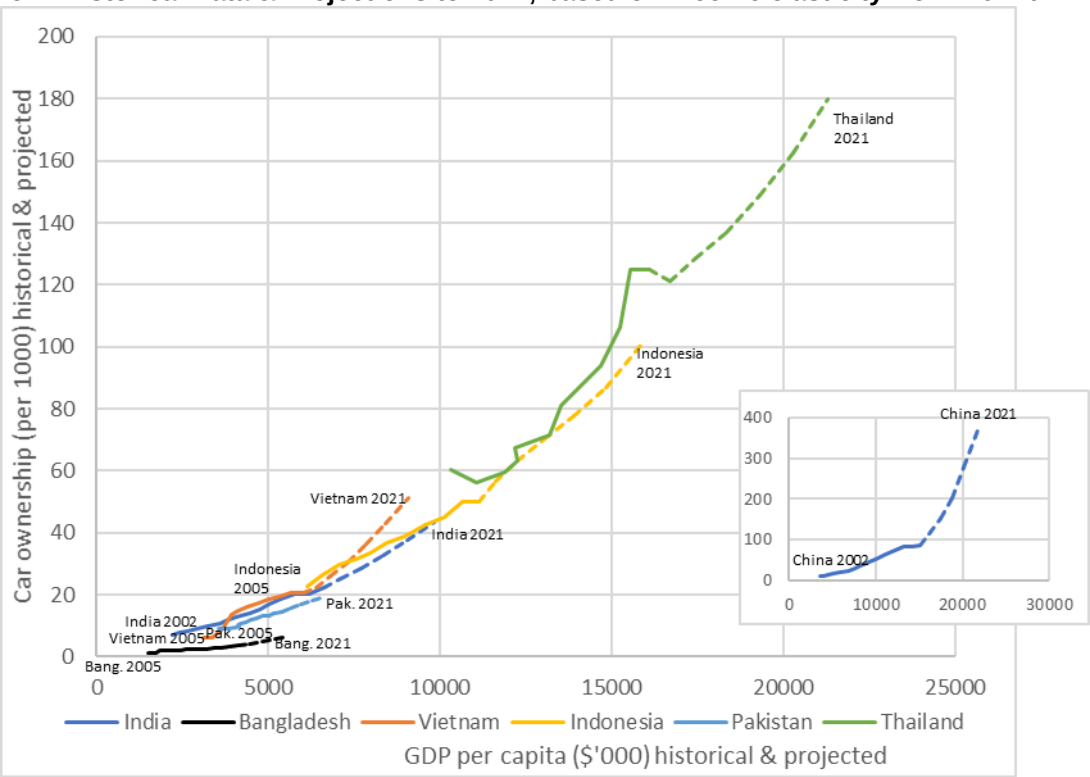
are clustered in the bottom left of the graph. Figure 4 below expands further upon these countries to give a clearer picture; it plots historical data and projections on car ownership levels (2002-2021) focusing on countries with an estimated income elasticity of car ownership between 1.0 and 2.0.

Figure 3: Car Ownership & GDP per capita: Historical Data & Projections to 2021



Source: Authors

Figure 4: Historical Data & Projections to 2021; based on income elasticity from 1.0-2.0*



Source: Authors; *Inset graph shows China

Some broad observations can be made here. Although Vietnam's car ownership level in 2005 was lower than India's, its projected car ownership levels rise much faster with its per capita GDP, as it has an estimated historical income elasticity of roughly 2.5 compared with India's at 1.7. Thus, Vietnam's projected car ownership level goes from roughly 6 per 1000 (in 2005) to 50 per 1000 people, compared with India's which rises from 9 to around 44 per 1000 people by 2021. Thailand has the highest starting car ownership level among the group of countries, rising from roughly 60 to 180 per 1000 by 2021, at an estimated income elasticity of roughly 2.0. It is followed by Indonesia, which with an estimated income elasticity of 1.7 rises from 23 cars per 1000 people in 2005 to over 100 by 2021. Although Bangladesh similarly has an estimated income elasticity of nearly 2.0, its very low levels of car ownership (around 1 per 1000) and projected per capita income see car ownership levels rising to just over 6 per 1000 by 2021, according to this broad calculation. Car ownership levels in Pakistan rise from around 9 to 19 per 1000 by 2021 based on an estimated income elasticity of 1.4. The non-OECD Asian country with the highest income elasticity is China, and although it has not been plotted within Figure 4 to allow for a clearer scale, it is included as an inset (within the figure above), showing car ownership rising from very low levels (around 10 per 1000) in the early 2000s to well over 300 per 1000 by 2021, based on an estimated (historical) income elasticity of 3.7. [10] Table 1 below depicts the broad estimates shown in Figure 4 for 2002 and 2021.

Table 1: Car Ownership projections for Asia (and Pacific) based on historical income elasticity

	Estimated Historical Income elasticity	GDP per capita 2002 ($)	Cars per 1,000 people (2002)	GDP per capita 2021 ($)	Cars per 1,000 people (2021)
Australia	0.46	36,364	518	56,408	618
Bangladesh	2.02	1,730	1	5,587	6
China	3.69	4,285	9	21,733	368
Taipei	0.27	21,066	248	59,166	343
Hong Kong (China)	0.58	34,366	54	71,202	80
India	1.61	2,651	7	9,837	43
Indonesia	1.73	6,119	23	15,848	100
Japan	0.57	32,248	450	44,574	578
Korea	0.70	23,008	236	47,176	380
Malaysia	0.81	16,417	254	35,058	539
New Zealand	0.55	29,637	583	43,931	740
Pakistan	1.39	3,533	9	6,648	19
Philippines	0.05	4,322	30	10,341	32
Singapore	0.25	51,435	103	104,537	122
Thailand	1.95	9,905	60	21,303	180
Vietnam	2.47	2,920	6	9,065	51

Source: Authors

The estimates in Figure 4 (and Table 1) are broadly indicative of individual country projections on car ownership and per capita income. They are considerably higher than, for instance, Dargay et al (2007), who project vehicle ownership to 2030.[11] We can however obtain further information on the

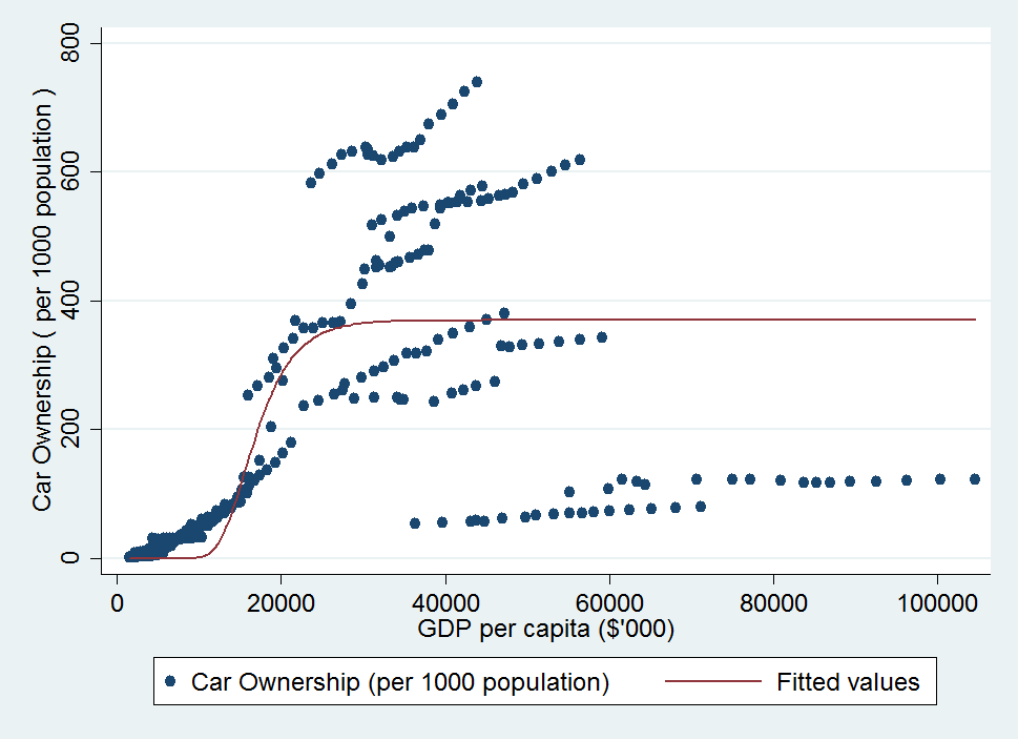
[10] This is significantly higher than Dargay et al (2007) who base their projections on an income elasticity of 2.2 for China, but close to Wang et al (2011) who estimate an income elasticity of 3.96 for their projections to 2022. Some of Dargay et al (2007)'s projections for 2002-2030 have underestimated actual growth (see footnote 11).

[11] For instance, Dargay et al (2007) estimate India's car ownership per 1,000 people at 17 in 2030. However, actual car ownership levels for in India even as early as 2015 were higher than the 2030 projection (20 per 1,000 people) implying that our projection is not implausible (albeit based on a simple statistical extrapolation).

dataset (historical and projected) as a whole by fitting an arbitrary nonlinear regression function by least squares. This is based on the 'S' curve or Gompertz distribution (an asymmetric sigmoid shape) which allows for asymmetry in the curve.[12] The results are shown in Figure 5 below.

The fitted line (overlaid on a scatter plot of the data) suggests a lower 'plateau', or level of saturation, of car ownership in Asia than seen in other OECD countries – at around 400 cars per 1000 people. Previous estimates for countries in Western Europe put the plateau in excess of 500 per 1000 people and close to 800 in the USA. This observation, an estimate rather than a prediction, has interesting implications: non-OECD Asian countries represent around 60% of global population, two-thirds of the world's poor population and yet only 34% of global energy demand. Storchmann (2005) argues that the income elasticity of demand for vehicles in developing countries is higher than in developed countries because of the extremely high marginal rate of consumption of automobiles in the former lower-income countries. As opposed to developed countries, in lower-income countries cars are seen as a luxury good and their stock is far away from saturation – cars constitute a first purchase or necessity (i.e. citizens of developing countries purchase their first vehicles as their incomes increase, often moving up the ladder of mobility from two wheelers to four wheelers). This suggests substantial potential for growth in car ownership – yet results from the arbitrary nonlinear regression indicate that this potential could be constrained relative to OECD trajectories, with knock-on effects on oil consumption in transport. We return to factors that could potentially constrain gasoline consumption in transport later in the paper (in the case studies).

Figure 5: Car Ownership Levels (Historical and Projected) Fitted Values from a Gompertz Function



Source: Authors

[12] We Stata's *nl* command with *gom3* option. The model estimated is $Y = \beta_1 * \exp(-\exp(-\beta_2 * (X - \beta_3)))$.

2.2 Other Determinants of Gasoline Demand

Previous empirical studies on oil demand using cross-sectional or time series data have focused on estimating the relationship between per capita income and vehicle ownership, using the latter as a key indicator for derived demand. This is based on the assumption that given the historical dominance of per capita income in determining vehicle ownership, this simplification should not detract from the validity of the projections obtained (Dargay and Gately, 1999). Within the stock of vehicles, passenger cars are the largest consumers of oil products and have the highest growth rate (Storchmann, 2005). Further, passenger cars increase more rapidly than goods vehicles (trucks), as the production of services grows faster with income than the production of goods (Ingram and Liu, 1997).[13] The fact that cars are traded goods allows for the use of market exchange rates, also making comparisons of cross-country data easier. The economic rationale behind the use of 'S' curves for estimating vehicle ownership is provided by product life-cycle and diffusion theories, where the take-up rate for new products is initially slow, then increases as the product becomes more established, and finally diminishes as the market comes closer to saturation (de Jong et al, 2004).[14]

Despite the predominant share of passenger vehicles in gasoline consumption, there are arguably other determinants of gasoline demand that should be taken into account. Several of these are consistently identified in the existing literature, which utilises pooled cross-sectional or panel datasets to measure the effects of economic and demographic variables on the levels and rates of vehicle ownership and/or gasoline demand. Button et al (1993) while focusing on vehicle ownership as the main dependent variable consider per capita income, fuel price, urbanisation, and the degree of industrialisation of a country as the main explanatory variables. Similarly, Ingram and Liu (1997) consider per capita income, motor vehicle prices, population density, the provision of roads, and the provision of 'motor vehicle transport services'[15] as key explanatory variables determining motorisation. Dargay and Gately (1999) list several variables that could potentially be considered as influencing vehicle ownership and thus the derived demand for gasoline: costs (fixed and variable); demography (the adult/population ratio); population density; urbanisation; and, road density. Storchmann (2005) takes a slightly different approach: in addition to per capita income, fuel prices, the fixed cost of new cars and population density as explanatory variables determining gasoline demand, it considers income inequality (or the distribution of income) as important explanatory variables.[16] Medlock and Soligo (2002) base their estimates on the assumption that individuals purchase vehicles subject to their budget constraint and some function that describes the rate at which the vehicle is devalued; individuals therefore invest in the vehicle stock in each period in order to facilitate a flow of services. Thus, the demand for vehicle stocks is a function of the consumer's wealth and the user cost of motor vehicles (for which fuel prices are used as an indicator).[17] Ingram and Liu (1999) probe the determinants of motorisation and road provision by regressing per capita income, population density, and fuel prices on the ratio of vehicles to roads. Wang et al (2011) on the other hand question the premise that vehicle ownership will level off at higher levels of per capita income and use data for China to project forward rates of vehicle ownership that are far higher than other studies.[18] Similarly,

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[13] Moavenzadeh and Gletner (1984) for instance point out that in general, passenger traffic grows at two to three times that of freight traffic in developing countries (Button et al, 1993).

[14] Interestingly, Ingram and Liu (1999) observed that the estimated 'saturation' levels tend to increase over time.

[15] Measured by a combination of vehicles and roads (vehicle/road ratio).

[16] De Jong et al (2004) argue that for developing countries, the income of the top 20% of the population may be a better explanatory variable than overall income.

[17] Medlock and Soligo (2002) draw from 'lifetime utility theory': individuals maximise the present value of their lifetime utility which is derived from flows of consumption goods and services provided by a stock of physical assets – in this case, motor vehicles.

[18] Primarily based on higher GDP growth forecasts than most other studies, as well as fewer constraints regarding 'vehicle saturation' levels (i.e. they assume that China will be able to absorb huge numbers of vehicles, barring aggressive policy intervention to restrain car ownership).

Huo and Wang (2012) look at total car stock as a function of income distribution, fuel prices and population in China.

Existing empirical studies provide useful insights not just on the determinants of the demand for gasoline, but also on the relationships between variables, which are distinctively different for developed versus developing countries.

- The relationship between car ownership and fuel prices is different for developed versus developing countries. Demand for cars tends to be price elastic in the former, whereas developing countries have a higher income elasticity of demand relative to price elasticity.
- Urbanisation has different relationships with car ownership when observed across country income groups. In developed countries, car ownership tends to drop with higher rates of urbanisation, particularly as public transportation improves. In developing countries, urbanisation tends to occur alongside growth in car ownership.
- Income distribution also tends to demonstrate different relationships with gasoline demand. Storchmann (2005) specifically argues that in developing countries an unequal income distribution is needed to enable people to buy automobiles and thus drive car ownership growth, whereas in developed countries an unequal income distribution would exclude some people from acquiring automobiles. Thus, depending on a country's income level, inequality has a diverging impact on the ability to buy durable goods, which affects gasoline demand.

Empirical work of the type in the literature cited above is primarily based on the determinants of past growth, based on the reasonable assumption that this can help researchers understand how policy interventions may influence future growth. However, it is important to note that these empirical models do not capture another important aspect of the determinants of the derived demand for gasoline – namely, consumer behaviour or attitudinal variables. The data requirements for behavioural studies are onerous, as they rely on consistent attitudinal surveys carried out within countries, and are therefore beyond the scope of this paper.[19] Nevertheless, it can be argued that price and income elasticities of demand estimated in a partial equilibrium approach capture some behavioural elements related to consumer spending decisions.

3. Empirical Estimation

This section explores the impact of other determinants on the derived demand for gasoline using a simple empirical estimation. Previous empirical work (discussed above) identified a consistent set of variables used as determinants of the derived demand for gasoline (see Table 2). We collated data on these variables for 19 countries in the Asia-Pacific region, of which more than half are non-OECD countries (see Appendix C for details), covering the years 2002-15. The data therefore represent a panel containing both cross-sectional and time series information, where each cross section represents a country.[20]

[19] De Jong et al (2004) provide a comprehensive survey of models that can be applied to account for the behavioural aspect of gasoline demand.

[20] Panel data analyses present certain advantages. Studies that have used only time series data tend to solely emphasize short-run elasticities whereas those which use only cross-section data place emphasis on long-run elasticities. A panel dataset provides a broader picture, allowing for a more general interpretation of results. Panel data techniques are also better placed to deal with unobserved heterogeneity in the micro-units (Kennedy, 2008).

Table 2: Description of Untransformed Variables

Variable Name	Variable Label	Units
Dependent Variable		
Gasoline Consumption	gdd	kb/d
Explanatory & Control Variables		
Per Capita Income	gdppc	US$'000
Vehicle Ownership	vo	Cars per 1,000 people
Share of Manufacturing in GDP	gdpman	% of total GDP
Fuel Price	price	Brent crude US$/barrel
Other Variables		
Urban population	urpop	Thousands
Total Population	pop	Thousands
Road Length	rdl	Kilometres (Kms)
Road Density	rden	Kms per 1,000 km^2

*variables scaled by population are indicated in later tables by the suffix *-pc,* and logged variables by prefix *-l.*

Variables in the dataset are scaled by population (where feasible) in order to normalise them prior to carrying out any analysis. The correlations between variables[21] appear to confirm the existence of many of the relationships demonstrated by the literature described in the section above. For instance, per capita income and per capita vehicle ownership have large significant positive correlations with gasoline demand per capita (0.63 and 0.91, respectively), whereas price has a low correlation (0.04). Similarly, road density is positively correlated with per capita income but negatively with gasoline demand – implying that higher-income countries have higher road density but with a dampening impact on gasoline demand. The data is however subject to certain limitations. For instance, for the purposes of estimation, motor vehicles are treated as a continuous variable and the vehicle fleet as homogenous, whereas in reality vehicles are purchased in integer units and the vehicle fleet has heterogenous characteristics (e.g. on quality and efficiency).

Previous studies have used different specifications to model the determinants of gasoline demand, including log-log (Storchmann, 2005), quasi-logistic or 'log-odds' (Button et al, 1993), log-quadratic (Medlock and Soligo, 2001), and sigmoid (based on Gompertz function) models (Dargay et al, 2007; Dargay, 2001; Dargay and Gately, 1999) – although the latter are primarily used with car ownership as the dependent variable, rather than gasoline demand. We opt for a simple log-log specification for the purposes of our analysis, given potentially nonlinear relationships between the variables.[22] This specification also yields coefficients that can be interpreted as elasticities – or the impact of a percentage change in an explanatory variable on percentage changes in the dependent variable. The limitation of our specification is that it provides constant elasticity estimates, whereas models based on sigmoid functions, for instance, allow for varying elasticities. The literature provides mixed evidence on the restrictions of our specification in relation to estimating the determinants of gasoline demand: Ingram and Liu (1999), for instance, state that constant elasticities are robust but have limited predictive power, while Ingram and Liu (1997) claim that varying elasticity estimates do not have greater predictive power than constant elasticity estimates.

We specify our model using gasoline consumption as the dependent variable, upon which we regress three explanatory variables – per capita income, vehicle ownership and share of manufacturing in

[21] Table D in the appendices.
[22] See Appendix F for a note on econometric method and Appendix G for fractional polynomial prediction plots.

GDP. The fuel price (Brent, in US$/bbl)[23] is included as a control for the price elasticity of demand, which as we have discussed manifests differently in developed versus developing countries. Variables are log-transformed in order to allow for interpretation of elasticities. A key issue in our specification is that of *endogeneity* – per capita income and vehicle ownership are both included as regressors, yet as discussed in Section 2.1, per capita income (which is considered exogenous in the literature)[24] is a determinant of vehicle ownership. This necessitates that we instrument for vehicle ownership, using an appropriate instrumental variable which should be correlated with the endogenous variable, but uncorrelated with the error term in our specification. We use *road length* (per capita, logged) to instrument for vehicle ownership as it fulfils these conditions.[25] Finally, economic reasoning implies that past decisions have an impact on current behaviours – the dependent variable may therefore be influenced not just by the regressors, but also by past values of itself. We therefore include the lagged value of the dependent variable (logged gasoline consumption – *lgdd*) as a regressor. This also captures the effect of potentially omitted variables.

We run four model estimations:

- *Model 1 and Model 2 (Asia Pacific):* estimations are run on the whole Asia-Pacific dataset, without and with a lagged dependent variable among the regressors.
- *Model 3 and Model 4 (Non-OECD Asia):* estimations are run on data for non-OECD Asia only, without and with a lagged dependent variable among the regressors.

The results from the four estimations are summarised in Table 3 below.[26] We reiterate here that the purpose of the analysis is not to be predictive, but to provide insights into the general responsiveness of gasoline demand to the key drivers in non-OECD Asia.

We first consider results for all Asia-Pacific countries (OECD and non-OECD) in the dataset: Models 1 and 2. We find that per capita income has a strong positive effect on gasoline consumption, while at the same time, price effects appear relatively more influential than income effects (although the results are significant at 10% indicating that they may not be statistically robust) – reflective of the influence of OECD countries in the dataset. We also find that an increase in manufacturing GDP leads to an increase in gasoline consumption (of around 10%). The coefficient for the impact of vehicle ownership on gasoline consumption is positive but extremely high, indicating the possibility of omitted variable bias. Model 2 therefore shows results from an estimation containing a lagged dependent variable as a regressor (which potentially captures omitted effects) but we do not find significant results.

[23] This is considered an acceptable indicator as most Asian countries have removed subsidies on gasoline, bringing prices in line with international levels.
[24] See Storchmann (2005).
[25] Appendix D shows that per capita road length (rdlpc) is highly correlated with per capita vehicle ownership (vopc) and has very low correlations with other explanatory variables. Further, road length is used to instrument for vehicle ownership in several other studies (Storchmann, 2005; Ingram and Liu (1997).
[26] We use Stata routine 'ivregress' to run our empirical model, which supports estimation via generalised method of moments (GMM) for models where one or more of the regressors are endogenously determined (see Appendix F). The routine performs three tests for multicollinearity before estimation, and provides standard errors that are robust to heteroscedasticity. We also perform two postestimation tests: one for overidentifying restrictions which checks the validity of the instruments, and another for endogeneity which tests whether endogenous regressors in the model are in fact exogenous. The tests confirm the validity of our results (see Appendix E). We also report R-squared statistics, although it should be noted that R-squared statistics have a limited interpretation in instrumental variable regressions.

Table 3: Results from Estimations

	Asia-Pacific		Non-OECD Asia	
	Model (1) *Static* lgddpc	**Model (2)** *Dynamic* lgddpc	**Model (3)** *Static* lgddpc	**Model (4)** *Dynamic* lgddpc
lvopc	0.963***	3.621	0.824***	0.246*
	(0.0403)	(13.97)	(0.0774)	(0.103)
L. lgddpc	-	-2.739	-	0.728***
		(14.45)		(0.108)
lgdppc	0.129^{+}	0.471	0.583***	0.156*
	(0.0780)	(2.033)	(0.0988)	(0.0608)
lprice	-0.289^{+}	-1.110	-0.537**	-0.184^{+}
	(0.149)	(4.431)	(0.196)	(0.108)
lgdpman	0.105*	0.364	-0.252	-0.142
	(0.0488)	(1.472)	(0.283)	(0.100)
_cons	1.900*	7.424	-0.195	0.473
	(0.924)	(27.18)	(1.663)	(0.586)
N	160	158	89	87
R^2	0.898	.	0.854	0.981

Standard errors in parentheses; $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Models 3 and 4 contain results pertaining only to non-OECD Asia, which are of greater interest. We find that in the static model, vehicle ownership, GDP and per capita income all lead to a positive impact on gasoline consumption. The dynamic specification shows that a 1% increase in vehicle ownership could potentially lead to a 25% increase in gasoline consumption. This result, however, needs to be strongly qualified by the fact that the statistical analysis does not account for country-specific policy interventions which could change the outcome. The income effect is also marginally stronger than the price effect in Model 3, and the dynamic estimation in Model 4 which corrects for omitted variable bias yields a plausible coefficient of 16%.[27] Interestingly, we do not find statistically significant results for share of manufacturing in GDP, which leads us to the important conclusion that income and vehicle ownership are the key drivers of gasoline consumption in non-OECD Asia. The coefficient on the lagged dependent variable is large and significant, implying a potential limitation of the model, in that there may be other country-specific drivers of gasoline consumption which have yet to be identified.

This empirical estimation is, however, subject to the constraints of statistical analyses as discussed above, and is meant to provide broad insights into the drivers of gasoline demand. However, in the next section we move to discuss the constraints to gasoline demand growth in transport, focusing on country-specific experience.

[27] Relatively poor statistical significance (p<0.10) for the coefficient on price in Model 4 suggests limited interpretability for the price effect.

4. Constraints to Gasoline Demand Growth in Transport: The Cases of India and China

The section above highlighted the central role of transport as a key driver of oil demand growth in non-OECD Asia. As also seen in Section 2.1, China and India have high income elasticities of vehicle ownership; they are also collectively expected to account for over half of the total increase in oil demand (estimated at 15 mb/d) to 2035 (BP, 2017). However, both countries have recently adopted policy measures to push their economies towards energy consumption trajectories that could potentially be met more sustainably, both in terms of economy and the environment – and there are two main sets of policy measures that are likely to pose the greatest constraints to gasoline demand in transport going forward. Namely, fuel efficiency standards, and the electrification of the vehicle fleet – both leading to a potential drop in oil consumption. In the sections below, we examine these in greater detail for India and China.

4.1 India – the Race to Leapfrog to Electric Vehicles

India's need for oil has surged as its economy has grown, with transportation accounting for 40% of total demand. India is now the world's sixth largest car market, with over 3 million units sold in 2016. From 2010-15, car sales have been increasing by around 2 million units annually, with the vast majority of new car sales going to fleet expansion. Unlike developed markets where the majority of new cars are replacing ageing vehicles that are being scrapped, the average Indian car is roughly 5 years old, and the size of the vehicle fleet continues to increase rapidly alongside rising vehicle sales. Furthermore, most of the sales growth is accounted for by two-wheelers, reflecting the entry of new consumers into the passenger vehicle transportation market. In the coming years, as the economy continues to expand and incomes rise, the number of cars is set to increase exponentially. Yet, in an ambitious new plan, the Indian government aims to save the country an estimated $60 billion in energy bills by 2030 and decrease carbon emissions by 37% by switching the country's transportation system towards EVs. To achieve this goal, government Think Tank NITI Aayog has recommended offering fiscal incentives to EV manufacturers — while simultaneously discouraging privately-owned petrol and diesel-fueled vehicles. The ambitious target is underpinned by the fact that India currently has a low per capita ownership of vehicles, and has the potential to make a leap directly to a new mobility paradigm which involves shared, electric and connected cars. This could leverage India's inherent advantages in technology and favourable demographics, while offsetting pressures that would have otherwise developed from higher import bills as the country's oil resources are small.[28]

Current EV Market

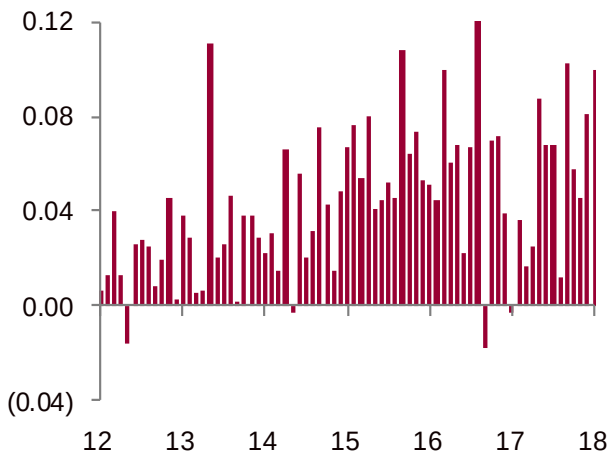
The current base for EVs is low, at 4,800 vehicles in 2016 representing 0.2% of the total fleet, having grown y/y by 450 cars (ICCT, 2016). The government is targeting 6 million electric and hybrid vehicles on the roads by 2020 under the National Electric Mobility Mission Plan 2020 and Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) programme. The 2030 target implies a stock of over 50 million electric vehicles (HT, 2017), and although India's government seems committed to the target it will face many challenges in implementation. EVs are unlikely to severely dent India's gasoline demand growth over the next five years, given that the starting base is small. If the 6 million EV fleet target for 2020 is achieved, it could displace roughly 90,000 b/d of gasoline demand in the country; a lower EV fleet of around 2 million – which may be closer to being achievable – could displace 20,000-30,000 b/d of gasoline demand in the country.

Currently, there is only one EV maker in India (Mahindra & Mahindra). The group plans to expand its production capacity for electric vehicles to 5,000 units a month by mid-2019, from 500 units a month

[28] India imports around 80% of its oil consumption of roughly 4.49s Mb/d.

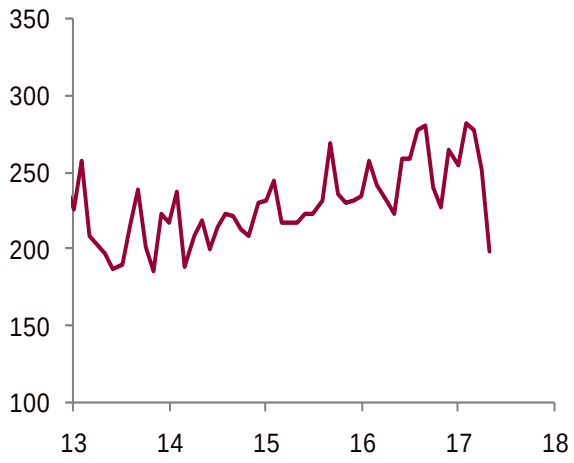
(PTI, 2017). In response to this policy proposal, however, other Indian automakers are gearing up. The Tata Group is working on a comprehensive hybrid and EV strategy that includes developing lithium batteries as well as charging stations. Tata Motors is holding discussions with various state governments to conduct road trials of its EVs. The company is already in the process of introducing the first batch of five diesel-hybrid buses to the city of Mumbai as part of an order for 25 such vehicles (Auto Today, 2017). It is also planning to hold trials of its electric buses in cities including New Delhi, Bangalore and Mysore as it aims to win more such orders from state transport undertakings (Nikkei Asian Review, 2017). While local companies are gearing up, collaboration with foreign companies will also be needed to meet the target, as current supply chains are inadequate. But the government's 'Make in India'[29] policy and its preference for locally-made components could slow EV development. However, in the long run, this policy could benefit the country through an indigenous manufacturing hub which unifies technology (IJAREEIE, 2017).

Figure 6: Indian gasoline demand, y/y, mb/d



Source: PPAC (2017); APQ (2017)

Figure 7: Indian car sales, ex-two wheelers, thousand



Source: Source: PPAC (2017); APQ (2017)

[29] Make in India campaign http://www.makeinindia.com/policies

Implications for the power sector

While automakers prepare to meet the challenge of new vehicle demand, the power sector also needs to gear up, by building capacity as well as improving plant load factors and distribution networks. India has 330 GW of installed generating capacity consisting of 57 GW of renewables and 198 GW of thermal (Sen, 2017). Assuming an electric vehicle has a 100 KWh battery size, the annual additional power demand for 6 million EVs is expected to be 93 TWh, which would require 10 GW of power plant capacity in 2020. According to our estimates 2 million EVs would take roughly 3 GW of power plant capacity, which represents 1% of installed capacity (EY, 2016; APQ, 2017).

While the country is likely to have sufficient power capacity to meet incremental demand from EVs, it will need to overcome a number of structural challenges that are keeping power capacity at low utilisation rates. Despite abundant coal resources, development has been stymied by bureaucratic hurdles around various ministries and permits for land acquisition (Cornot-Gandolphe, 2016). Feedstock sourcing, especially for natural gas, will be a limiting factor given the rising need for imports alongside import infrastructure constraints. Gas also cannot compete with coal in the power sector at current electricity prices, unless there is an explicit disincentive to using coal (such as a carbon tax).[30] The reliance on hydro resources has also left the country dependent on reservoir levels during peak demand periods, often resulting in power cuts. Distribution infrastructure is inefficient with large transmission losses, and power theft is perennial, deterring private investments while leaving state utilities with poor finances that restrict their capacity to upgrade (Sen et al. 2016). Current power capacity is largely underutilized despite urban areas facing erratic power cuts and the country aiming to electrify more rural areas (Prasad, 2017). This implies that upcoming power capacity projects have already been earmarked for solving current challenges. Additional stress on the power grid from EVs will require a revamp of the sector to improve efficiencies at current power plants as well as the distribution network.

Policy makers could, however, come around to seeing the utility in EVs not only for transportation but also for its benefits to the power sector. For the power sector, EVs offer an opportunity to encourage distributed generation, reducing dependence on electricity distribution companies (Discoms) and setting up commercially sustainable micro grids, especially in remote areas. Batteries used in EVs usually have a vehicle lifetime of 8-10 years, but they have significant potential after that for alternative uses, especially as cheap storage for renewable energy capacity. It also helps improve utilisation of existing domestic coal capacity by providing demand assurance to sustain a certain baseload. Plant load factors have declined from 77% in 2010 to less than 60% currently (Prasad, 2017). With most of the charging expected to be done during off-peak hours, utilities can better manage their base load rather than rely on expensive sources for generating peak load. India's largest power generation utility (NTPC) is looking to set up charging stations, with plans to halve the cost of setting up these charging stations to $1,500 each, as a way to expand its market (PV Magazine, 2017).

There is thus scope for baseload management at current capacity to improve plant load factors to over 70% and more, to absorb the strain of millions of EVs on the power grid. In order for the EV push to also conform with India's COP21 commitments, electricity will need to be generated from renewables, of which the government plans to generate 175 GW by 2022 (100 GW will be from solar power).

While the power sector can accommodate the expansion of EVs by improving utilisation rates, the biggest infrastructure challenge comes from expanding the charging infrastructure. While plug-in sockets at household and commercial centres can be used, ultimately the infrastructure required to charge EVs and lorries within a few minutes would have to be built from scratch. The challenge with

[30] See Sen (2017) for details.

expanding the retail fuel network has been the dearth of reliable power supply in small towns and remote highways. If such fuel stations were also to meet the demand of charging EVs, during power cuts and low voltage periods the owners would have to set up generators. To incentivise the build out of charging stations, the government is considering using a private retail method, using the same model for distributed charging as was the case for privately-owned phone booths, implying that anyone could set up a charging station and earn a small income from it.

Policy measures to enable EV penetration

The up-front price of the vehicle is likely to be a limiting factor, as they currently cost more than those based on internal combustion engines (Shakti, 2017). That said, several measures are being considered that could reduce the initial cost of buying an EV. For the individual user, the initial cost of buying EVs can be brought down by as much as 50% if EVs are sold without batteries which will then be swapped out rather than embedded (NITI Aayog, 2017). One option being considered is to allow drivers to buy the car and lease the battery, which they can switch when they need to recharge (Froese, 2017).

In order to build scale rapidly, India's government is considering rolling out an EV-based public transport system with auto-rickshaws and buses sold with batteries that can be swapped after a certain distance (QI, 2017). Auto-rickshaws, for instance, travel between 80 km and 130 km daily, so batteries could, in theory, be swapped at around the 40 km-mark (QI, 2017). A swappable battery system is also an alternative being considered for city buses. With close to 95% of buses in the country traveling 30 km per trip routes, batteries can be swapped at the terminal point where the bus turns around for the return journey (QI, 2017). While this solves the challenge of having charging stations that need to charge the batteries rapidly, as well as the cost of buying an electric vehicle for the user, it would still require considerable investment to set up a battery swapping station, as well as a convergence in technology across the industry, which is a challenge that will have to be overcome with the right incentives for the sector, but it is possible to achieve. Adopting a shared ownership model over an individual ownership model could bring down the cost of both ownership and travel. India's ride hailing companies are also partnering with manufacturers to grow its fleet (e.g. Ola with Mahindra) by offering discounts on the cars, vehicle financing and maintenance plans to drivers (ET Auto, 2017).

Currently, India has roughly 31 million passenger cars and 150 million two and three-wheeler vehicles. The country consumes an average of 0.5 mb/d of gasoline and 1.56 mb/d of diesel. The current target of 6 million EVs by 2020, if realised, could potentially displace roughly 90,000 b/d of fuel demand in the country (APQ, 2017). Given the charging infrastructure limitations, and the challenges of ramping up domestic manufacturing, a lower achievement of say 2 million EVs is more likely, and would displace around 30,000 b/d of fuel demand (APQ, 2017). In the near term, EVs are unlikely to be big disruptors to an otherwise steady gasoline demand story, with growth set to rise by 8-10% year-on-year on average through 2020. It is the post-2020 timeframe where EV adoption is likely to pick up pace, once charging infrastructure grows. The impact on fuel demand could be large if commercial vehicles such as trucks are also electrified. The Indian government has already set in motion efforts to electrify the diesel-dependent railways, which will lead to further displacement of fuel.

4.2 China – Implications of New Energy Vehicles and Fuel Efficiency

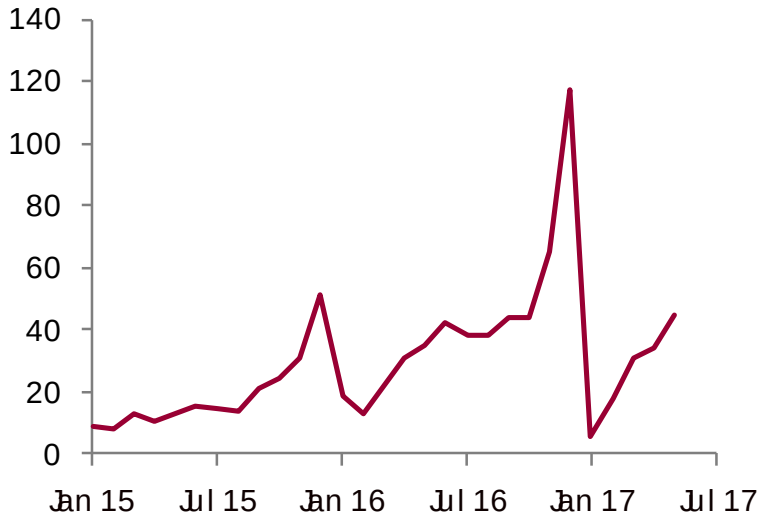
Unlike India, China's ambitious efforts to tackle tailpipe emissions are already starting to slow gasoline demand growth, but the government's measures go beyond EVs to include policies to raise fuel efficiencies in internal combustion engine vehicles, promoting use of hybrid vehicles, as well as natural gas vehicles (NGVs). Even the advent of bike sharing apps is chipping away at gasoline demand growth. Already in 2017, China's gasoline demand growth is expected to slow to 0.11 mb/d (3.5%), almost half of the 2016 growth rate (SCMP, 2017), as incremental car sales slow from over

13% in 2016 (China Daily, 2017b) to 5%[31] at best in 2017, and alternative energy vehicles begin to chip away at demand growth. Going forward, EVs alone could displace 45,000 to 55,000 b/d of demand growth, with measures to increase fuel efficiencies knocking off even higher volumes. In other words, had Chinese gasoline demand growth maintained the average growth rates seen between 2011 and 2015 (0.23 mb/d, or 11%), the country would have consumed an additional 0.25-0.30 mb/d of gasoline every year through 2020. At current rates, however, with car sales slowing, efficiency gains rising and new energy vehicle sales rising, demand growth could average 0.15-0.20 mb/d through 2020 (APQ, 2017).

New Energy Vehicle (NEV) Plan and Impact on Gasoline Demand

The country's NEV plan—which includes plug-ins, EVs and gas-fired vehicles—was rolled out in 2012 with goals through to 2020 (China State Council, 2012), and after some teething pains is now increasingly starting to gain traction. China's electric car fleet is dwarfed by conventional cars; last year's sales of the latter were more than 25 times the country's entire electric car fleet. Electric cars make up 0.5% of China's fleet and the effects on fuel demand patterns are still marginal. Yet China's NEV push meets three distinct goals. First, to reduce some of the country's hefty oil import bill and enhance energy security (Zheng, 2017). Second, it should support the country's environmental goals, though as in India, it will require substantial progress on plans for renewables to take up a growing share of power generation given the predominance of coal in the energy mix. Third, NEVs are also part of the 'Made in China 2025' programme, China's industrial upgrading plan (SCC, 2015). This goal resonates with China's carmakers, the majority of which see this as an opportunity to leapfrog their western competitors.

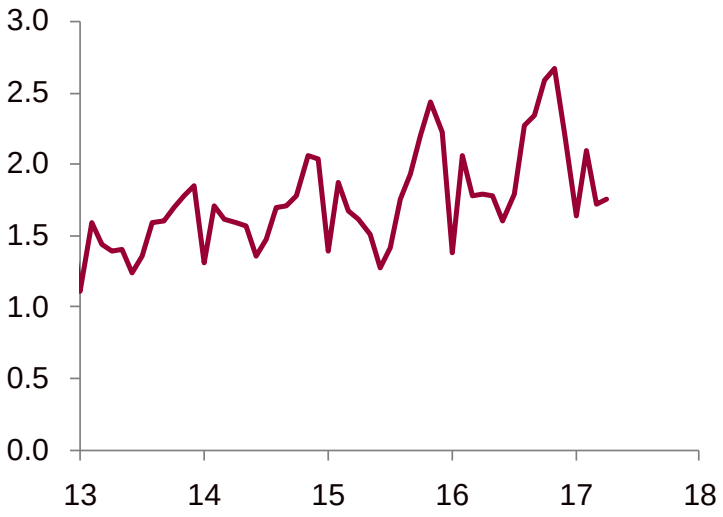
Figure 8: China NEV sales, thousand units



Source: CAAM, Energy Aspects analysis, APQ (2017)

[31] According to the China Association of Automobile Manufactures (CAAM), cited in China Daily (2017b).

Figure 9: China car sales, million units



Source: CAAM, Energy Aspects analysis, APQ (2017)

By 2020, Beijing plans to have 5 million NEVs on the road. This target includes 4.3 million passenger vehicles, around 0.3 million taxis, 0.2 million buses and 0.2 million special vehicles. The 'Made in China 2025' programme also highlights infrastructure development: it aims to install 4.3 million private charging outlets (essentially one charger par car) and 0.5 million public chargers for cars, 4,000 charging stations for buses, 2,500 for taxis, 2,500 for special vehicles and about 2,400 city public charging stations. At the end of 2016, China had 1 million EVs and 150,000 charging stations, or one for every seven cars. The government is aiming to add another 100,000 charging stations by the end of 2017 (IEA, 2016).

Issuing a plan is not enough, though. To encourage EV sales, China's Ministry of Finance has been providing subsidies ranging from RMB 30,000 to 60,000 ($4,400-8,800) for electric passenger vehicles and subsidies of RMB 500-600,000 ($74,000-88,000) for commercial vehicles (MoF, 2015), most of which are also matched by provincial governments. Local subsidies vary significantly as they tend to favour local carmakers. The city of Beijing, for example, is home to Beijing Automotive Industry Corp (BAIC), which makes pure electric cars, so Beijing city offers high subsidies for pure electrics but no subsidies at all for plug-in hybrids. By contrast, Shanghai provides generous subsidies for plug-in hybrids, largely because the Shanghai government owns SAIC, which makes that type of vehicle. Localities therefore have a substantial say in NEV penetration rates and tailor their subsidies to fit only locally made cars, or direct city governments to purchase locally made electric cars for their fleets.

The central government has also waived sales tax and license taxes for EVs. Indeed, several of China's major metropolitan areas control the growth of their vehicle population in order to limit traffic congestion by employing a license lottery or auction system, from which EVs are generally excluded. In Beijing, EVs are also excluded from driving restrictions on heavily polluted days, making them increasingly appealing to local drivers. And in order to support domestic industry, the government scrapped a purchase tax on locally produced NEVs. On the supply side, the government has introduced multiple R&D programmes to promote battery technology development, and has been encouraging charging infrastructure development (MoF, 2016; IEA, 2016). These measures have helped accelerate adoption rates: from total production of just over 8,000 five years ago, new electric

vehicle production in China grew to nearly half a million by 2015 with sales reaching 450,000. In 2016, that number surged again by 53% y/y to 507,000 units sold.[32]

At the same time, the government's generous subsidies led over 200 Chinese companies to enter the NEV space, some of which have been happy to take subsidies without producing commercially viable vehicles. In September 2016, the Chinese government fined five manufacturers that collected over $120 million in subsidies but either failed to produce the vehicles, or sold vehicles with lower battery ranges than the models they received the subsidies for. The government subsequently launched a nation-wide investigation (Cui et al, 2017) and reviewed its subsidy scheme, leading it to slash subsidies by 20% in January 2017 and plan to phase them out completely by 2020 (Cui et al, 2017).

After the government cut subsidies, NEV sales plummeted in January 2017, compared to a 132% y/y increase in January 2016, but recovered in subsequent months. In May 2017, NEV sales totalled 45,000, up 28.4% y/y, while 51,000 NEVs were produced, a 38% y/y increase.[33] These growth rates have slowed compared to 2016 and could continue to decelerate as subsidies are phased out, but the government is currently drafting new regulations which will also include a requirement that EVs account for 8% of total car sales, perhaps as soon as 2018, and 12% by 2020 (Bloomberg, 2017). Automakers that fall short of their production quotas can import EVs, or purchase credits from other EV makers. While the aim is to encourage EV production with both carrots and sticks, following the large subsidy scandals, Beijing is also looking to cut the number of players down to just 10. Those that survive the cull will benefit from subsidies designed to nurture a competitive domestic industry and create a vibrant consumer market for new energy vehicles. In addition, sales of low-speed electric vehicles (LSEV: an indigenous Chinese innovation that looks a lot like an electric golf cart, used traditionally in rural China) have also grown considerably from under 100,000 in 2010 to 600,000 in 2015, skyrocketing to almost 1 million vehicles in 2016, because of their small size, cheap price and the fact that they can be driven without a license. Although initially popular in rural China, LSEVs have become common in China's third and fourth tier cities and are increasingly making inroads into the country's larger cities as an energy efficient alternative to traditional gasoline fired cars, public transportation and two-wheelers. That said, the lack of regulations on LSEV production and sales as well as rising safety concerns associated both with driving them and with the disposal of the lead-acid batteries will likely prompt the government to tighten oversight over LSEVs (IEA, 2016). This could lead to a slowdown in sales growth, but auto industry sources in China still expect sales to reach 2 million by 2020. Even though NEVs will not transform fuel demand patterns, they could shave off an estimated 40,000 to 50,000 b/d of gasoline demand by 2020 (APQ, 2017).

At the same time, NEVs—large or small—are only part of the reason for the softness in gasoline demand growth seen in 2017-to-date: the rise of electric buses and two-wheelers are further slowing gains in gasoline demand growth. China currently has an estimated stock of over 200 million electric two-wheelers, following a rapid uptick when conventional two-wheelers were banned in several cities in order to reduce local pollution. Electric bike sales began modestly in the 1990s and started to take off in 2004, when 40,000 were sold. In late 2016, that number had reached 20 million. China is also leading the global deployment of electric bus fleets, with more than 170,000 buses already circulating today.

That said, a number of challenges remain: Chinese battery technology is relatively weak and the driving range for Chinese models, despite significant improvements, remains lower than Western carmakers, while charging times are still longer. Second, battery costs remain high and the fragmented nature of the Chinese automotive industry discourages economies of scale in R&D. The hefty subsidies currently in place reduce the urgency for carmakers to cut battery costs, but as the government begins to phase out subsidies, failure to trim expenses could impede EV penetration into the Chinese car fleet. Third, even though Beijing is focusing increasingly on infrastructure

[32] According to CAAM.
[33] Ibid.

development, regulatory approvals for land acquisition or facility installation in residential compounds could slow the infrastructure rollout and increase the costs associated with it.

Nonetheless, even though the government may fail to reach its 5-million-unit target in 2020, NEVs will become a larger component of the Chinese car fleet and will slow demand growth for gasoline. CNPC estimates that in 2015, NEVs shaved off roughly 80,000 b/d of gasoline demand and according to government estimates, by 2020 NEVs will displace 0.3-0.4 mb/d of gasoline demand (CSD, 2017).

Impact of higher fuel efficiencies, NGVs and bike-sharing

The biggest factor for gasoline demand, however, is fuel efficiency targets. Beijing has set out ambitious targets for reducing average fuel consumption from 6.9 litre/100km in 2015 to 5.0 litre/100km in 2020. In 2016, domestic passenger vehicle manufacturers claimed to have reached an average of 6.95 litre/100km and after including credits from NEV production, the average fuel consumption decreased to 6.6 litre/100km, suggesting that the government is on track to meet its goal (ICET, 2016). If these fuel efficiencies continue to be rolled out, they will be key in reducing gasoline demand growth—potentially displacing 50,000 to 80,000 b/d (with even further upside depending on the efficiencies implemented as well as the overall miles driven in the country) (APQ, 2017).[34]

Beijing has equally ambitious targets for natural-gas vehicles (NGVs). The government is looking to increase the number of NGVs in China from 5.2 million in 2015 to 10.5 million units by 2020. NGVs have already benefitted from government support, including production subsidies as well as R&D funding for technology development. Highway tolls are also waived for NGVs. But there are a number of constraints to promoting NGVs more rapidly. First, as demand growth is recovering, natural gas supplies are failing to keep up and are prioritised for industrial and residential use. Second, major gas producing regions such as Shandong, Xinjiang, and Sichuan, boast high levels of NGVs—the three provinces combined account for more than half of China's NGVs—as they can supply gas for transportation at close to well-head price, but in other potential consumer hubs, especially along China's coastal provinces where air pollution is at its most severe, prices for natural gas in transportation are higher (Hao et al, 2016). Moreover, the priority for natural gas in these provinces is phasing out coal-fired boilers so gas in transport will have a less prominent role. As more coal use is phased out through late 2017 and early 2018, incremental supplies in these provinces could start going into the transportation sector.

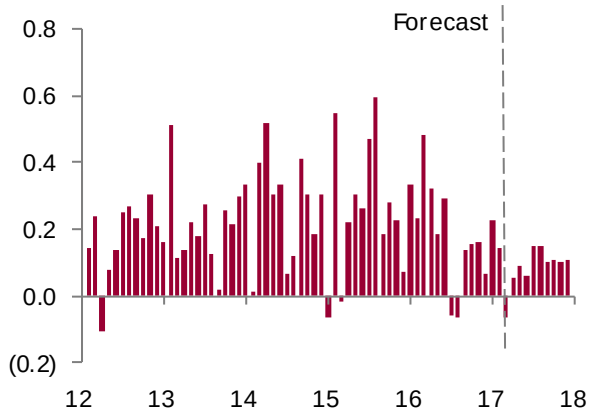
Finally, bike sharing apps are also denting gasoline demand growth. This latest craze picked up in mid-2016 and has since brought more than 2 million bikes to city streets, operated by around 30 companies. These rival companies offer bikes—at steep discounts as they compete for market share—around China's largest cities that can be unlocked using mobile apps. But unlike similar initiatives around the world, bikes can be picked up and left anywhere by scanning a QR code on the frame, making them convenient for users, even though the piles of bikes left around the city has frustrated the authorities (Horwitz, 2017). An estimated 20 million people used these bike-share schemes in 2016 and that figure is expected to reach over 200 million by 2020, according to a report by research firm Research and Markets. There are some 30 operators deploying bike-sharing services since mid-2016. In light of the rapid expansion, large municipalities such as Beijing and Shanghai are tightening regulations over bike sharing, especially on parking standards (Jaganathan and Tan, 2017; Yifan, 2017).

All these measures combined start to affect China's gasoline demand patterns even though in a fleet of over 200 million conventional vehicles, the impact of 5 million units is extremely limited. The country's gasoline demand at 3.1 mb/d may still rise to around 3.6 mb/d in 2020 (APQ, 2017). Had the country continued on its 2011-2015 path, of 11% average growth rates, it would be adding around 0.25-0.30 mb/d of demand each year. But with NEVs denting demand at the margins and fuel

[34] Energy Aspects estimates.

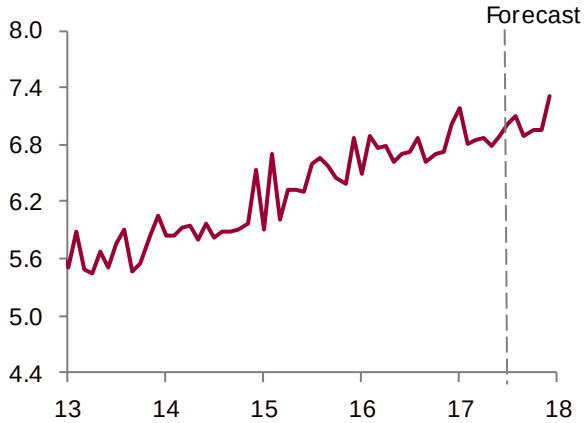
efficiency gains reducing consumption, gasoline demand growth in China may hover around 0.10-0.15 mb/d going forward, or a more modest 3-4% (APQ, 2017).[35]

Figure 10: China gasoline demand, y/y change, mb/d



Source: NBS, China Customs, Xinhua, Energy Aspects

Figure 11: Asian gasoline demand, mb/d



Source: JODI, NBS, METI, KNOC, PPAC, BREE, Energy Aspects

5. Conclusion: between slower gasoline growth and new paradigms

Asia is the world's second largest gasoline consumer after North America, accounting for 6.7 mb/d of demand in 2016 and with rising incomes and motorisation levels, Asia will remain the most significant driver of gasoline demand growth. Indeed, between 2000 and 2015 non-OECD oil demand increased by roughly 21 mb/d while OECD oil demand decreased by 3 mb/d and many expect this secular decline to continue. The two largest non-OECD economies, China and India, are expected to account for 50% of the increase in oil demand to 2035, so the growth models and motorisation paths that China and India adopt will be hugely significant for gasoline demand growth.

[35] Energy Aspects estimates

This paper investigated the following research questions: first, what are the key drivers of gasoline demand growth in non-OECD Asia, based on historical trends? And second, what are the constraints to gasoline demand growth in this region? The first question, driven by historical trends, was investigated using statistical analyses on a panel dataset of 19 countries in the Asia-Pacific region, of which over half are non-OECD countries. The dynamic specification of our model suggested that on average a 1% increase in vehicle ownership could potentially lead to a 25% increase in gasoline consumption – but this result needs to be strongly qualified by the fact that the statistical analysis does not account for country-specific policy interventions which could change the outcome. Results from the statistical analysis also confirmed that income and vehicle ownership are the key drivers of gasoline consumption in non-OECD Asia. When looking solely at the income elasticity of car ownership alongside GDP and population, our results suggested that car ownership in Asia could plateau at lower levels than in OECD countries, at around 400 cars per 1000 people, roughly half of the US model (800 cars per 1000 people). Our case studies showed that China and India are both charting different courses. Both have seen rising oil imports take a toll on their foreign exchange reserves, and the need to tackle poor air quality is leading them to substitute traditional vehicles and improve efficiencies. While India's efforts may only begin to displace around 15,000 to 20,000 b/d of gasoline demand around 2020, China's policies to encourage NEV penetration, combined with more stringent fuel economy standards, are already slowing demand growth, displacing around 0.1-0.15 mb/d of gasoline demand every year.

If we return to the three potential arguments set out in Section 1, it is evident that policy constraints on gasoline demand growth, while in many cases initiated at the regional or city level, are being consolidated at the national level. While these economies are entering or are already in high growth trajectories with car ownership levels rising, oil demand growth in transport is likely to slow relative to a baseline as policies to substitute away from oil in transport are implemented on a widespread basis and backed by strong political commitment. Oil demand growth could slow further if battery technologies improve rapidly and costs come down, and if these countries transition to different mobility models with ride sharing gaining prominence – causing rapid and disruptive change in transport. Displacement of gasoline consumption will then be even higher—especially in India after 2020.

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Appendices

A. Data Sources

Data was obtained from the International Road Federation Statistics, World Bank World Development Indicators, ASEAN Statistical Database, UNESCAP Database, UN Population Statistics, Energy Aspects, International Organization of Motor Vehicle Manufacturers, and country-specific statistical divisions where necessary.

B. Descriptive Statistics

Variable Name	Var. Label	Mean	SD	Min	Max
Gasoline Consumption (b/d)	gdd	246.7008	418.0532	.9153005	2669.905
Gasoline Cons. Per Capita (Bbls)	gddpc	1.543749	1.775675	.0160921	6.270487
Fuel Price (US$/bbl)	price	78.55291	27.90167	32.96797	117.2294
Per Capita Income (US$)	gdppc	22714.19	22122.47	656.5597	80192
Vehicle Ownership (cars/'000)	vo	182.7467	205.2189	.99466	638.6898
Total Vehicles	vtot	1.08e+07	1.85e+07	77000	1.16e+08
Vehicle Ownership Per Capita	vopc	.1827467	.2052189	.0009947	.6386898
Road Density (Kms/1,000km^2)	rden	1250.278	2415.168	43	14080
Share of Manufacturing in GDP (%)	gdpman	19.30533	7.90537	1.283804	32.718
Population	pop	1.92e+08	3.75e+08	346000	1.40e+09
Urban Population	urpop	8.18e+07	1.55e+08	250000	7.79e+08
Road Length (kms)	rdl	594829.1	1237639	1943	5231922
Road Length Per Capita (kms)	rdlpc	.0048348	.0088344	.0001343	.0411939
N					*266*

C. List of Countries

OECD	**Non-OECD**
Australia	Bangladesh
Brunei	China
Chinese Taipei/Taiwan	India
Hong Kong China	Indonesia
Japan	Malaysia
South Korea	Myanmar
Singapore	Pakistan
New Zealand	Papua New Guinea
	Philippines
	Thailand
	Vietnam

D. Correlation Matrix

	gdd	gddpc	price	gdppc	vo	vtot	vopc	rden	lrden	gdpman	pop	urpop	rdl	rdlpc
gdd	1													
gddpc	-0.0223	1												
price	0.0512	0.0425	1											
gdppc	-0.155	0.627***	0.168*	1										
vo	0.0513	0.906***	0.0622	0.486***	1									
vtot	0.922***	0.0531	0.128	-0.0668	0.190*	1								
vopc	0.0513	0.906***	0.0622	0.486***	1	0.190*	1							
rden	-0.135	0.0463	0.102	0.324***	-0.00120	-0.118	-0.00120	1						
lrden	-0.116	-0.111	0.0780	0.387***	-0.109	-0.0334	-0.109	0.744***	1					
gdpman	0.433***	-0.252**	-0.0137	-0.246**	-0.174*	0.326***	-0.174*	0.175*	0.0854	1				
pop	0.664***	-0.355***	-0.0633	-0.408***	-0.356***	0.501***	-0.356***	-0.134	-0.0235	0.317***	1			
urpop	0.817***	-0.302***	-0.0265	-0.357***	-0.288***	0.649***	-0.288***	-0.146	-0.0597	0.401***	0.966***	1		
rdl	0.617***	-0.214**	0.00412	-0.312***	-0.212**	0.527***	-0.212**	-0.123	-0.0106	0.189*	0.947***	0.893***	1	
rdlpc	0.00917	0.810***	-0.0353	0.274***	0.769***	0.0141	0.769***	-0.192*	-0.378***	-0.353***	-0.153	-0.142	0.0128	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

E. Postestimation Tests

Test of Endogeneity		
H_0: Variables are Exogenous		
Models 1 & 2: GMM 'C' statistic	chi2(1) = 42.6183 (p-value = 0.0000)	[H_0 rejected]
Models 3 & 4: GMM 'C' statistic	chi2(1) = 7.92765 (p-value = 0.0049)	[H_0 rejected]

No overidentifying restrictions.

F. Econometric Method

The starting point for analysis in panel data techniques is to look at Least Squares Dummy Variable (LSDV) estimators. However, LSDV performs well only when *T* is adequately large; with 30 years suggested as a minimum threshold (Judson and Owen, 1999). Kiviet (1995) devised a bias-corrected LSDV estimator (LSDVC), later refined by Bun and Kiviet (2003), which is generally seen to have the lowest RMSE[36] for panels of all sizes; its applicability was, however, limited to balanced panels. A version of the bias-corrected LSDV estimator (LSDVC) for unbalanced panels was developed by Bruno (2005), which operates under two assumptions; first, it has a strictly exogenous selection rule, and second, it classifies the error term $\mathcal{E}_{it}$ as an 'unobserved white noise disturbance' (Bruno, 2005). The LSDVC estimator's exogenous selection rule conflicts with our model specification which includes endogenous regressors, as described in Section 3. A number of consistent Instrumental Variable (IV)[37] and Generalised Method of Moments (GMM)[38] estimators have been proposed in the literature as alternatives to the LSDV and LSDVC estimators, and we run our estimations using an instrumented variable regression (STATA routine *ivregress)*.[39] This fits a regression of *depvar* on *varlist₁* and *varlist₂*, using *varlistᵢᵥ* (along with *varlist₁*) as instruments for *varlist₂*.[40] It supports estimation using generalised method of moments (GMM) estimators.

The model estimated under this routine is as follows:

$y_i = Y_i\beta_1 + x_{1i}\beta_2 + u_i$ (Structural equation)

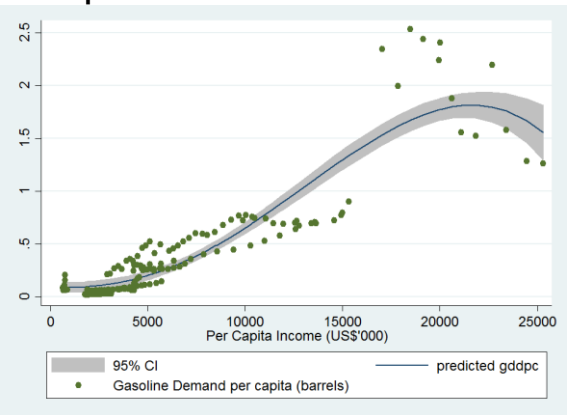
$Y_i = x_{1i}\Pi_1 + x_{2i}\Pi_2 + v_i$ (First-stage equation)

Here, y_i is the dependent variable for the *i*th observation, Y_i represents the endogenous regressors, x_{1i} and x_{2i} represent the instruments and u_i and v_i are zero-mean error terms, and the correlations between u_i and the elements of v_i are presumably non-zero. In our estimation method, apart from any additional exogenous variables that are specified, other exogenous variables that appear in the regression equation are automatically included as instruments. The results are robust to heteroscedasticity.

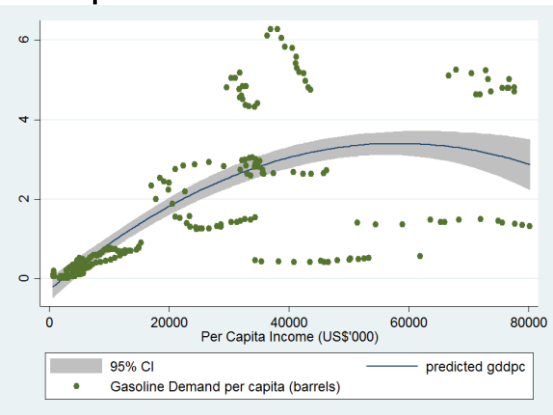
[36] Root Mean Square Error.
[37] Baum (2006).
[38] Hall (2005).
[39] The syntax for *ivregress* assumes that you want to fit one equation from a system of equations or an equation for which you do not want to specify the functional form for the remaining equations of the system. An advantage of *ivregress* is that you can fit one equation of a multiple-equation system without specifying the functional form of the remaining equations.
[40] *varlist₁* and *varlistᵢᵥ* are the exogenous variables, and *varlist₂* the endogenous variables.

G: Fractional Polynomial Prediction Plots[41] on Gasoline Consumption per Capita

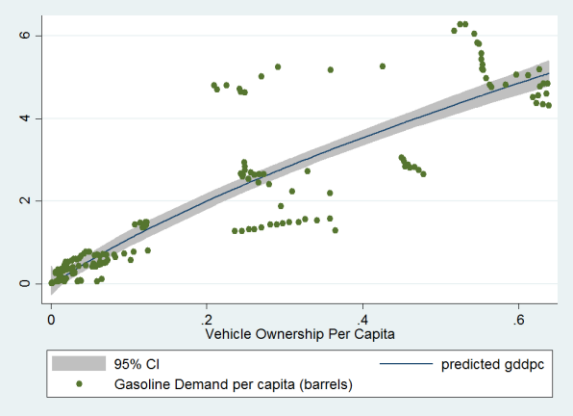
Per Capita Income: Asia-Pacific



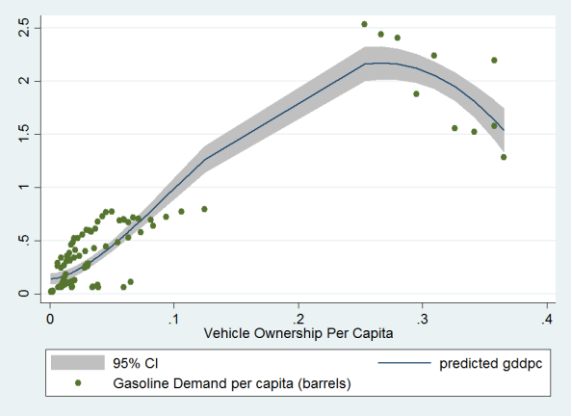
Per Capita Income: Non-OECD Asia



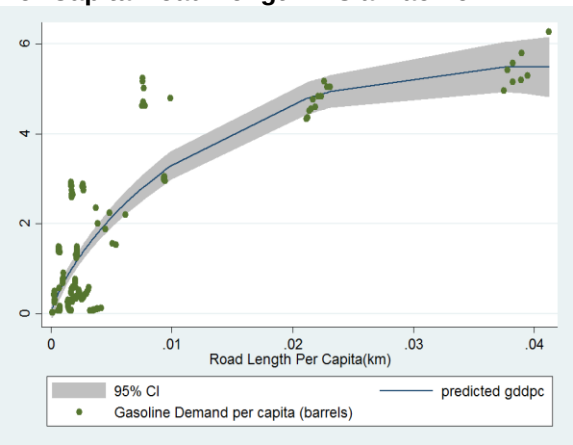
Per Capita Vehicle Ownership: Asia-Pacific



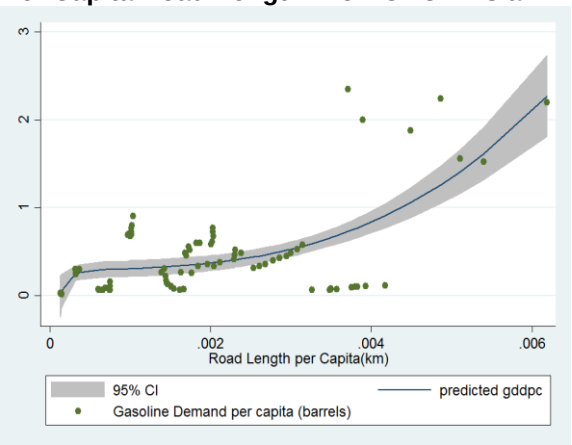
Per Capita Vehicle Ownership: Non-OECD Asia



Per Capita Road Length: Asia-Pacific



Per Capita Road Length: Non-OECD Asia



[41] Calculates the prediction for *yvar* (gasoline consumption) based on the estimation of a fractional polynomial of *xvar* and plots the resulting curve along the confidence interval of the mean; these plots are a tool for graphically estimating relationships between variables.