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Explaining "peak car" with economic variables

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Abstract

Many western countries have seen a plateau and subsequent decrease of car travel during the 21st century. What has generated particular interest and debate is the statement that the development cannot be explained by changes in traditional explanatory factors such as GDP and fuel prices. Instead, it has been argued, the observed trends are indications of substantial changes in lifestyles, preferences and attitudes to car travel; what we are experiencing is not just a temporary plateau, but a true "peak car". However, this study shows that the traditional variables GDP and fuel price are in fact enough to explain the observed trends in car traffic in all the countries included in our study: the United States, France, the United Kingdom, Sweden and (to a large extent) Australia and Germany. We argue that the importance of the fuel price increases in the early 2000's has been underappreciated in the studies that shaped the later debate. Results also indicate that GDP elasticities tend to decrease with rising GDP, and that fuel price elasticities tend to increase at high price levels and during periods of rapid price increases.

Keywords: Peak car, fuel price elasticity, GDP elasticity, travel demand.

JEL Codes: D61, H54, R41, R43, R48.

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1 INTRODUCTION

In several industrialized countries, car traffic has plateaued or decreased in the last decade or more, after many decades of more or less continuous growth. This phenomenon has attracted a lot of interest and debate, both in the research community and in public debate. In particular, the question is what has caused this apparent trend break. Several authors have argued that standard explanatory variables such as economic growth and fuel price cannot explain it. Some have suggested that declining car use is an effect of urbanization, increased road congestion and restrictions on car driving. But the hypothesis that has generated the most interest and debate is the idea that the trend break is caused by a long-lasting change in lifestyles, attitudes and preferences. This is what usually is referred to as the "peak car" hypothesis: that what we see is a permanent trend break, which cannot be explained by standard explanatory variables such as income, economic activity or fuel prices. Instead, it is argued, it represents a permanent change in lifestyles and preferences, and signals the start of a downward trend in car driving and ownership: some countries have actually experienced "peak car", the point in time where car driving (per capita) reached its peak. (In the subsequent literature section, we discuss more precisely what different authors have meant with the "peak car" concept.)

If this hypothesis holds – that the trend decline is indeed caused by shifts in lifestyles and preferences away from using private cars – it would be good news for transport planning and climate policy. The problems generated by car traffic would to some extent decrease over time, even without policy interventions. There would be less need for strict and politically difficult restrictions on car driving, and the worrying trend of ever increasing emissions would to some extent solve itself. However, the hypothesis also has consequences for the possibility to make transport forecasts. If preferences are changing in the radical and rapid way implied by the peak car hypothesis, transport forecasting would become substantially more uncertain.

The purpose of this paper is to explore to what extent the simplest economic variables – GDP per capita and gasoline price – are able to explain the plateau and decrease in car traffic that has been seen in a number of countries. We limit ourselves to studying six countries: the United States, the United Kingdom, France, Sweden, Australia and Germany. All countries but Germany are chosen for three reasons: they represent interesting examples of industrialized countries with a pronounced trend break in car traffic in the last decade, there is data available, and the countries have not experienced any other major exogenous changes or events that affect traffic[1]. The countries are also different in many respects: car mode shares and average trip distances vary significantly between them, as do transport policy and fuel taxes. Germany is included, although the long term trend in car use is heavily affected by the development after the reunification.

Throughout, we will estimate extremely simple models: just OLS estimations of aggregate vehicle kilometers travelled (VKT) per capita as a function of gasoline price and GDP per capita. Obviously, many other variables also affect the VKT, and more complicated model specifications may be able to explain data better. But our purpose is not to develop as good models as possible – almost on the contrary: our aim is to explore to what extent these two simple variables, and these only, are able to explain the observed traffic trends. If we can refute the default hypothesis that the trends in VKT can be explained by fuel price and GDP, the observed development must indeed be

[1]United Kingdom trends are affected by changes in company car regulations (Le Vine et al., 2013), but this is controlled for in the analysis.

caused by something else. This could be other "hard" (measurable) variables such as urbanization, parking prices or vehicle taxation. But if even such variables are not enough to explain the observed trends, it would be strong support for the more exciting hypothesis that we see effects of changes in "soft" (difficult to measure) variables such as lifestyles, attitudes and preferences.

The paper is outlined as follows. In section 2 we review the peak car literature and show how and why influential articles came to underappreciate the role of rising fuel prices. In section 3 we describe the modelling strategy. Section 4 presents the results, and section 5 concludes.

2 THE PEAK CAR LITERATURE

The peak car debate can be traced back to Puentes and Tomer (2008), who discuss United States vehicle kilometer trends in the context of monthly real gasoline price and oil price data. They notice an increasing monthly volatility in gasoline prices since 2006 and focus on the 2008 price peak moment. However, they dismiss a 35% increase in real gasoline prices from 2000 to 2005 as "relatively stable". This makes them conclude: "Thus, only the most recent drop in per capita driving is coupled with gasoline price spikes". Their focus on oil price trends – which have more extreme peaks than gasoline prices – may also have focused their attention on the 2008 peak in the oil price, giving less attention to the increase in gasoline price in the preceding years.

The term *peak car* was coined in a paper by Millard-Ball and Schipper (2011), based on the observation that total growth in car use slowed down around 2004 in eight industrialized western countries. They cite Puentes' and Tomer's argument that the plateau in car travel preceded the rapid increase in oil price, as well as the economic downturn starting in 2008 (remember that also the increase in gasoline price preceded the peak in oil price). Hence they draw the conclusion that the traditional economic variables, GDP and fuel price, "can only provide a partial explanation" (p. 372) of the car use trend. They do not analyze alternative explanations, but note that travel demand theory suggests a saturation point for car travel, analogous to a saturation point for vehicle ownership (Tanner 1978): when every driver has a car there is no need for more cars. They position their paper as a "challenge to travel demand and energy models that project continued rises in VMT and passenger travel".

Metz (2010) also argues that the increase in oil price and the economic downturn "take place too late to explain the phenomenon". He digs deeper into the hypothesis that saturation plays a role in the declining trend in car use. He bases his argumentation on the long-term stability of the average travel time, journey frequency, journey purposes, and proportion of household income devoted to travel. (It should be pointed out, however, that there are massive cross-sectional differences in all of these dimensions across individuals and socio-economic segments.) In a follow-up paper (Metz 2013), he argues that "economic recession or high oil prices are secondary in importance" (p. 268).

Newman and Kenworthy (2011) is another early and influential paper in the peak car literature. They extend the analysis over a longer time period and find that the growth in car use in cities has been slowing down during the entire period 1960-2005 in several western countries. They recognize that effects of rising fuel prices interact with other factors, such as rapid growth in transit use, re-urbanization and culture changes. They do not present any own modeling but adopt the view of the above authors – that the 2008 timing of the oil price increase and economic crisis suggests that these variables are not sufficient to explain car use trends. Finally they argue that the observed trends in car use imply a paradigm shift in the understanding of what constitutes a good city. While this may be true for many reasons, it does not follow from their argument, which is built on an assumption that "the era of cheap oil" has ended.

Metz (2015) finds a stronger trend decline in car use in London than in the rest of the UK, analogous to the results of Newman and Kenworthy (2011). Likely reasons for this difference are increased congestion and travel times in the cities and the substantial package of policy measures introduced in London when a pro-transit government came to power (Broaddus 2014). Bastian and Börjesson (2015b) also find differences in sensitivity to GDP and fuel price between Sweden's two largest cities and the rest of the country. Higher elasticities among urban residents are plausible, since they have better access to public transport and a larger variety of alternative destinations.

Goodwin (2011) summarizes three different views about the observed trends in car use in developed economies in the previous decade: "*car ownership and use in developed economies (a) are still in long-term growth with only temporary interruptions due to economic circumstances; (b) have reached their peak and will show little or no further growth; or (c) have passed a turning point and are now in long-term decline.* " Although he emphasizes that the evidence is not yet conclusive, he argues that the third view is the most likely and that this challenges transport modeling and forecasting: "*It seems to me that evidence for the full version of the peak car hypothesis – we have now passed peak car use and are on a new, firmly established, downward trend – is not yet definite. But the evidence for its full rebuttal – we are still on a long-term trend of increase with only temporary interruptions due to recession – is even less persuasive. The key element of the discussion in the last year has been that there are changing features of car use, which clearly precede the recession, and simply do not fit the traditional forecasts.*"

OECD/ITF (2013) is the first paper that tries to analyze the explanatory power of the economic variables GDP and fuel price, using aggregate time series data from 1980 through 2007 for a number of countries. The crucial difference between their models and the models in the present paper is that the authors assume that elasticities are equal across countries. Since there are substantial differences in fuel price, car ownership and average driving distances between countries, we argue that it is natural to assume that elasticities will also be different. This is indeed confirmed by the large literature studying elasticities of gasoline consumption and VKT.

Kuhnimhof et al. (2013) use travel surveys since the 1970s/80s to explore the drivers of the peak car phenomenon in France, Germany, the UK and the USA. Their earlier result, showing a declining propensity to acquire a driving license among young adults (Kuhnimhof et al. 2012) is confirmed and extended. They show that the decline in car use has not occurred only among young adults, although they have reduced their driving more than other groups in three of the four analyzed countries. Moreover, they find that an increase in car availability and use among the elderly has had an upward effect on aggregate car use in all countries. They also find some differences across the countries: in France and the US, the slowdown of the growth in car use after the 1990s was mainly due to a general decline in travel demand, whereas in Germany and the UK, the mode shift was more important. A key contribution of this paper is that the trend decline in driving (in some groups) started in the beginning and mid 1990s rather than a decade later where the rest of the peak car debate has had its focus. Bastian and Börjesson (2015a) find the same for Sweden.

Goodwin and Van Dender (2013) summarize the peak car debate in a special issue in Transport Reviews and conclude that "*New econometric work suggests that an* *aggregate model focusing on GDP effects and fuel prices is too crude to capture the diversity and various dynamics underlying aggregate car travel demand and how it changes*". This conclusion, that the traditional forecast model parameters GDP and fuel prices are not sufficient to explain the underlying car travel trend is similar to the main conclusions in Goodwin (2012), Newman and Kenworthy (2011) and Metz (2010; 2013), and seems to be a recurrent conclusion in the peak car literature.

Most of the papers published after this special issue have taken it more or less for granted that traditional economic variables cannot explain the traffic decline or plateau in the 2000's, and hence there must be other mechanisms and causes. A recent paper by Metz (2015) summarizes the peak car debate, defining the term "peak car" as referring to the observation that the average annual distance travelled by car ceased to grow in most of the developed economies some years before the recession in 2008, and therefore needs other explanations that the standard economic factors included in standard transport models.

To summarize, the factors hypothesized in the peak car debate up to now are: a trend decline in younger people holding driving licenses (Delbosc and Currie 2013; Kuhnimhof et al. 2012); UK company car taxation changes (Le Vine, Jones, and Polak 2013); travel demand saturation (Metz 2010; Newman and Kenworthy 2011); a shift away from car use in urban areas (Goodwin 2012); technological factors constraining faster travel (Metz 2013); ICT (van Wee 2015); and a switch to air travel (Millard-Ball and Schipper 2011). However, there are also indications that car use is increasing in some groups, in particular among seniors (Kuhnimhof, Zumkeller, and Chlond 2013).

Our literature review focuses mainly on the debate about trends in aggregate car use and its relation to aggregate economic variables. There is of course also a broad, related literature on trends and changes in travel behavior in general and in particular socioeconomic groups, and how it is affected by a wide range of variables. Since the focus of the present paper is the particular question of the relation between aggregate car use and economic variables, we have limited our literature review to this question, but it should be acknowledged that several of the papers above study a wider range of issues than this particular one.

3 METHODOLOGY

For each country, we estimate a simple constant-elasticity model on yearly observations of aggregate data:

$$\ln(VKTcap_t) = \beta_0 + \beta_1 \ln(fuelprice_t) + \beta_2 \ln(GDPcap_t) + \varepsilon_t$$

$VKTcap_t$ is vehicle kilometers per capita in year t, $fuelprice_t$ is the average gasoline price (in real terms and including all taxes) in year t, and $GDPcap_t$ is GDP per capita[2] in year t in real terms. ε_t is a normally distributed random error. The gasoline price trend approximates the fuel price trend because the diesel price runs in close parallel with the gasoline price[3]. The model specification hence tacitly assumes that drivers adapt

[2] GDP, rather than average personal income, was chosen for several reasons. First, it is easily available for all counties. Second, it is a cumulative measure capturing not only average personal wage earnings but rather the activity of the economy (including all sectors in the economy) and is therefore a more appropriate than average income or similar.

[3] Diesel is more energy efficient than gasoline, so if the share of diesel cars increases, which it did in most European countries 2009-2012 (International Council on Clean Transportation 2014), this might have an effect on driving costs. However, European Vehicle Market Statistics (International Council

instantly to changes in fuel price or GDP. Smoothing gasoline prices over 2 to 3 years was also explored; it gave in generally similar results. Data sources are listed in the appendix.

The model is first estimated for the period 1980-2013 for each country (or to 2014 or 2015 for countries where data is available). The choice to start the estimation time series in 1980 is because there is data available in all the countries for this period, that the extreme gasoline price volatility of the oil crises in the 1970's have passed, and that this excludes the main part of the sweeping social changes in the 1960s and 1970's, which not only included car ownership surging from being uncommon to being almost ubiquitous, but also many other radical changes such as the substantial increase in female labor participation.

The predicted values of these models are then compared to the observed VKT per capita in the respective country. Particular attention is given to the period after 2003, given the focus of this study. We also check whether the model fit is different in the first part of the period (1980-2003) compared to the second part (2003-2013/2014).

However, just looking at model fit for the period 1980-2013 is not enough. Hence, we estimate the model on different 20-year or 30-year periods, to explore how elasticities have changed over time in the different countries. We are particularly interested in looking for signs of changes in the elasticities in the period after 2003. In addition, these estimations also enable us to explore the stability of our results, and to what degree the inclusion of large sudden variable changes affects the model results.

Our models and econometrics may appear overly simplistic, so let us repeat the logic of our arguments. Our purpose is not to estimate the best or most reliable elasticities possible, but simply to explore whether the changes in the gasoline price and the GDP per capita are sufficient to explore the development in VKT per capita in the 2000's. To do this, we estimate (admittedly simplistic and short-run) elasticities, check whether they are stable over time, and check whether they are in line with the existing literature (especially studies preceding the 2000's), and finally check whether these elasticities give predictions consistent with observations during the 2000's. What we are saying is hence not "the elasticities *are* such and such" – that would necessitate more advanced econometrics; our main point is "given these elasticities, which (as we will see) are in line with earlier and more advanced studies, and seem to be reasonably stable over time – can we predict the development of VKT per capita during the 2000's, using only the observed GDP per capita and gasoline price?".

on Clean Transportation 2014) show that new diesel cars are larger (page 51) and 50% more expensive (page 71) than the average new gasoline car, and fuel efficiency per km has only improved by 10% since 2001 (page 75). Bastian and Börjesson (2015) regress fuel price per liter adjusted for fuel efficiency in the car fleet on total car distance travelled. However, this model has worse model fit than the model using gasoline price. This may be because the fuel efficiency is overstated in measurements, or because many drivers have no clear perception of the fuel efficiency. Another tentative explanation is that newer and more fuel-efficient cars tend to be bought by companies and households that are less price-sensitive than the average driver. Since more efficient cars are also more expensive, drivers may purchase a more expensive but efficient vehicle if this pays off in the longer run, taking into account the distance that she will drive. If this is the case, it is not clear that the driving cost has really reduced with more efficient cars.

4 RESULTS

In this section we first present results by country, and then summarize the main conclusions in the final subsection. Estimation results for the main models are summarized in Table 1. Table 2 summarizes the root mean square relative error (relative RMSE), which measures the general predictive power of the models, and the average relative error, which takes into account the sign of the relative error and hence is sensitive to whether the model under- or overpredicts during a specific time period. A model which underpredicts just as often as it overpredicts will have an average of relative error of zero. The error measures in time period (T_0, T_1) are defined as

$$Relative\ RMSE = \frac{1}{T_1 - T_0}\sqrt{\sum_{t=T_0}^{T_1}\left(\frac{m(t)}{x(t)} - 1\right)^2}$$

$$Average\ relative\ error = \frac{1}{T_1 - T_0}\sum_{t=T_0}^{T_1}\left(\frac{m(t)}{x(t)} - 1\right)$$

4.1 United States

2003 marked the beginning of an unprecedented increase and volatility in gasoline prices in the United States. Real gasoline prices doubled during the six years until 2008. Then prices crashed by nearly one third during the economic crisis in 2009 but quickly rebounded to a new all-time-high in 2011. US gasoline pump prices closely reflect the high price volatility in the markets for crude oil and refining, as opposed to European countries, where much higher taxes constitute over half the pump prices (EIA 2014).

Estimating the model on US data for the period 1980-2015 results in a gasoline price elasticity of -0.14 and a GDP per capita elasticity of 0.71 (see Table 1). The model-predicted and the observed VKT per capita are shown in Figure 1, along with the independent variables. The model closely predicts the observed VKT per capita, even for the 2000s decade – in particular the plateau and subsequent decline in VKT per capita after 2003 (see Table 2).

Estimating the elasticities on different 20-year subsets reveals some interesting patterns (see Figure 2). GDP per capita elasticities appear to be decreasing over time, as GDP and car ownership increases. Moreover, during the 1970s, when the gasoline price was low, the gasoline price had no statistically significant effect on the VKT, possibly partly due to the nearly perfect correlation of the GDP and the VKT trends in the 1970s. The gasoline price elasticity increases, however, during the second oil crisis 1980-1981, during which the real gasoline price increased by 60%. It appears that the key to predicting the post-2003 VKT per capita is to use an estimation period with sufficiently high and variable gasoline prices, such as the early 1980s and/or the early 2000s.

Once the early 2000's are included in the models, our simple estimation results give elasticities which are broadly consistent (although actually a bit low) with the vast literature which has estimated US elasticities with more advanced methods – see for example the survey by Dahl and Sterner (1991), who find (short-run) fuel price elasticities in the range -0.2 – -0.3 and income elasticities around 0.5.

In Figure 2 we find indications that the sensitivity to fuel price has increased while the sensitivity to GDP has decreased. Still, the elasticities obtained with our simplistic model on the 1980-2015 time period are well in line with elasticities from earlier periods (as long as there is sufficient variability in data) and also with the more advanced models in the literature that existed well before the year 2000.

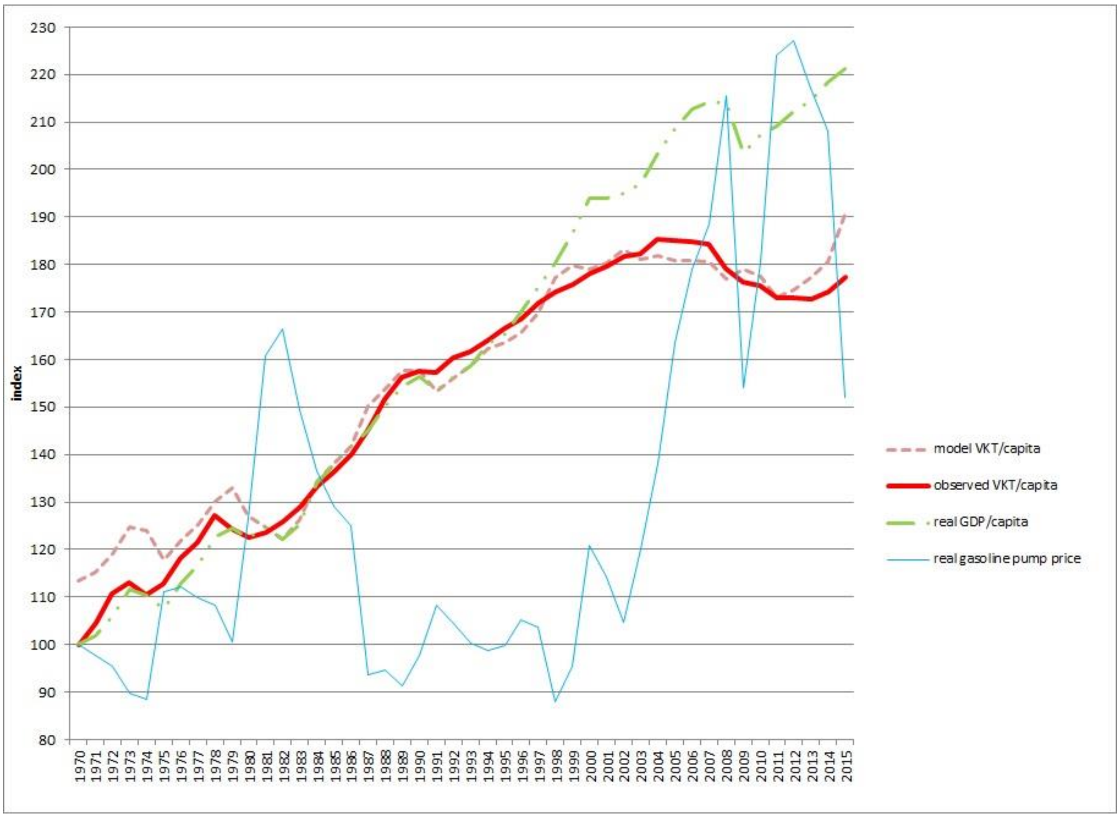

Figure 1. United States indices of real annual gasoline price, real GDP per capita, observed VKT per capita and predicted VKT per capita. The model index curve is fitted to minimize the distance to the observed VKT per capita index line over the modelled period (1980-2015), and does therefore not exactly match observed VKT/capita in 1970 (and similar for the subsequent figures).

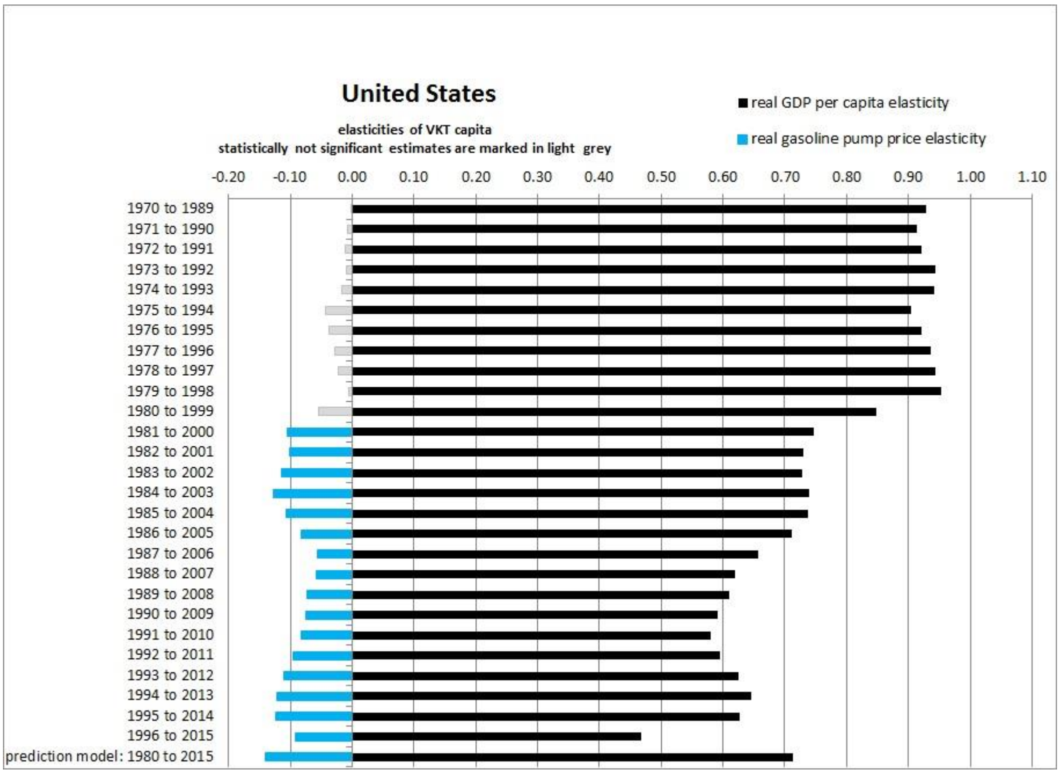

Figure 2. United States model estimation results: elasticities of VKT per capita for real GDP per capita and real gasoline pump price. Estimates which are not statistically significant are colored grey.

4.2 France

In France, taxes currently constitute more than half of gasoline pump prices (EIA 2014). Therefore French gasoline pump prices are approximately twice as high as US prices, and much less volatile. Estimating the model on French data for the period 1980-2014, we get a gasoline price elasticity of -0.31 and a GDP per capita elasticity of 1.08 (Table 1). The model closely predicts the observed VKT per capita over the entire period (Figure 3 and Table 2); in particular, the model predicts the plateau and decrease in VKT after 2003.

Estimating models on rolling 20-year subsets of the data indicates some decrease in the GDP/capita elasticity over time (see Figure 4), just as for the US. Gasoline price elasticity estimates are low when the estimation period includes the sudden price drop 1985-1986. For post-1985-periods, on the other hand, elasticities are in line with earlier and more advanced studies (for example, Drollas (1984) reports a short-run gasoline price elasticity for France of -0.44). There is no clear trend over time in the gasoline price elasticities for time periods starting after 1985. The effect on the estimates of including the years 1985-1986 may be due to an effect that Dargay and Gately (1997) call imperfect price reversibility, meaning that the VKT does not seem to respond to large and sudden gasoline price drops as much as to large and sudden gasoline price increases. A similar effect can be observed for the 2008-09 gasoline price drop.

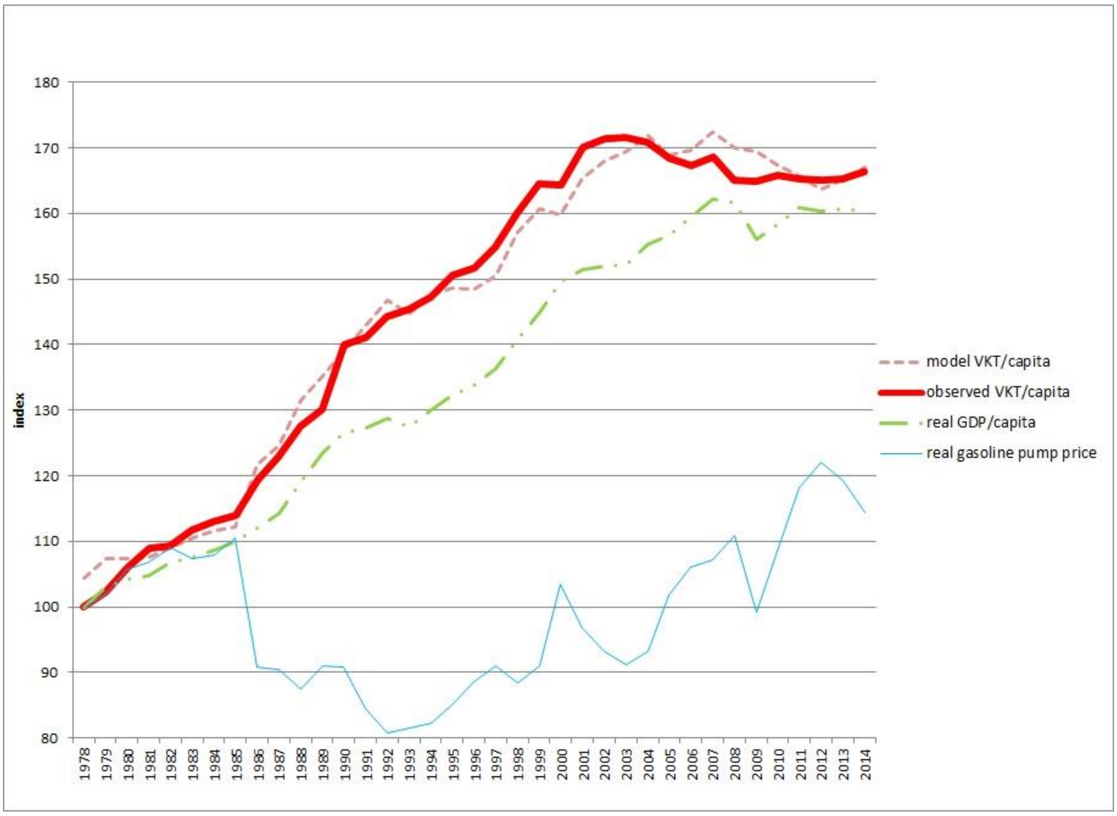

Figure 3. France: indices of real annual gasoline price, real GDP per capita, observed VKT per capita and predicted VKT per capita

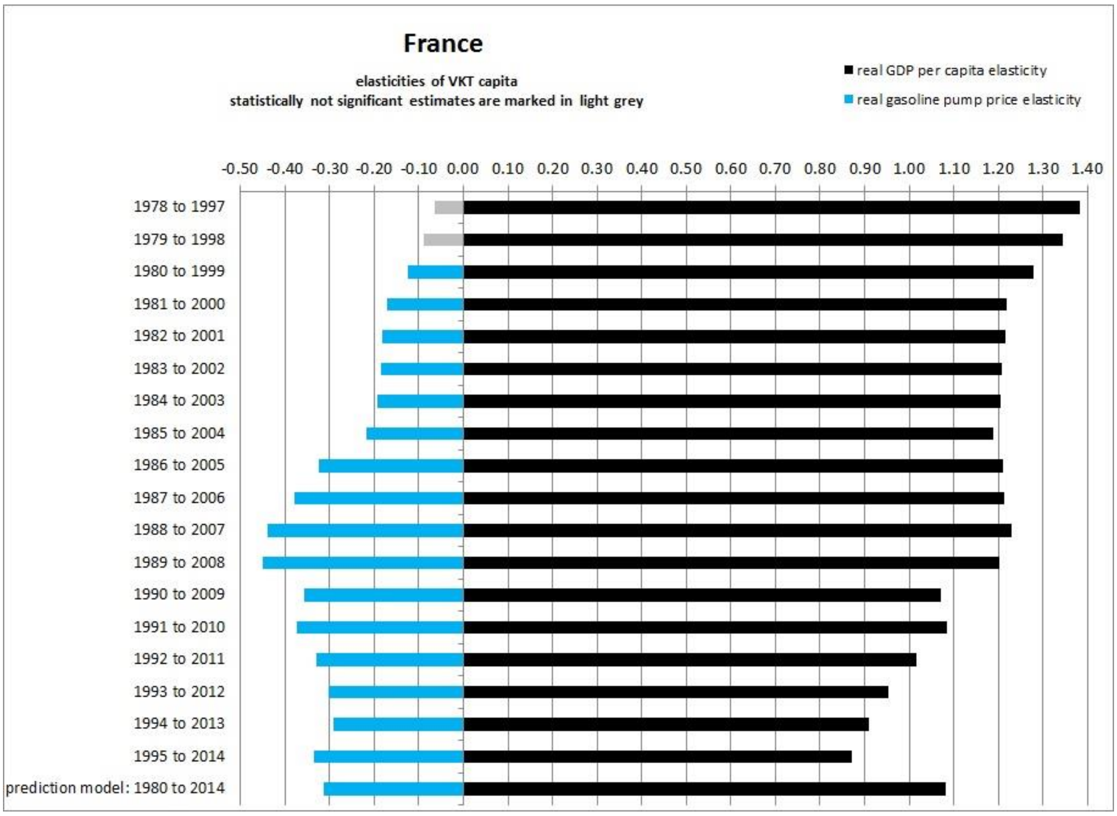

Figure 4. France model estimation results: elasticities of VKT per capita for real GDP per capita and real gasoline pump price.

4.3 United Kingdom

UK company car use declined substantially after 1995 in conjunction with several company car taxation changes (Le Vine, Jones, and Polak 2013). To limit distortion by these policy changes, the UK models and analysis presented here consider only privately owned cars' VKT per capita changes for the period after 1995[4].

Estimating the model on UK data for the period 1980-2014 results in a gasoline price elasticity of -0.37 and a GDP per capita elasticity of 1.07. The model predicts the observed VKT per capita very well from 1980 (see Figure 5), except for the period 2001-2004 where VKT for private cars grow somewhat less rapidly than the model would suggest. Specifically, the model accurately predicts the drop in VKT from 2004 and the subsequent increase from 2012.

Comparison of estimates for rolling 30-year periods (see Figure 6) shows that the elasticity with respect to GDP per capita tends to decrease over time, similar to the results for the US and France[5]. Similar to France, gasoline price elasticities become very low when the sharp price drop (1975-1979) is included – again, a sign of imperfect price reversibility. For time periods starting later than 1980, estimates vary very little over time, and are better in line with more advanced elasticity estimations. For our purposes, it is particularly interesting to note that the elasticities estimated on the time periods 1980-2003 and 1980-2014 are very close.

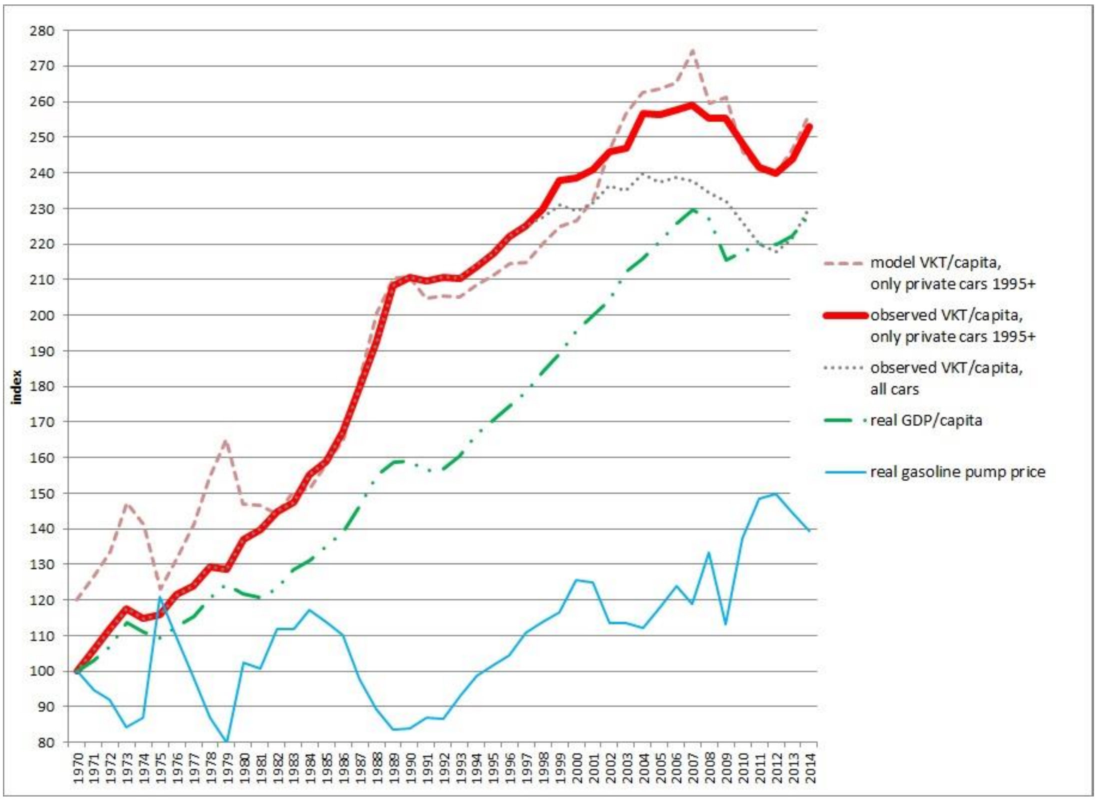

Figure 5. United Kingdom indices of real annual gasoline price, real GDP per capita, observed VKT per capita and predicted VKT per capita.

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[4] VKT per capita changes for privately owned cars are based on the national travel survey statistics presented in Le Vine et al. (2013). Their research finds only limited evidence of substitution from company to private cars.

[5] Models estimated on 20-year periods that include either the 1990s or 1970s do not produce reasonable gasoline price elasticities, because during these periods GDP/capita and VKT/capita are nearly perfectly correlated. Hence, we present models estimated on rolling 30-year periods.

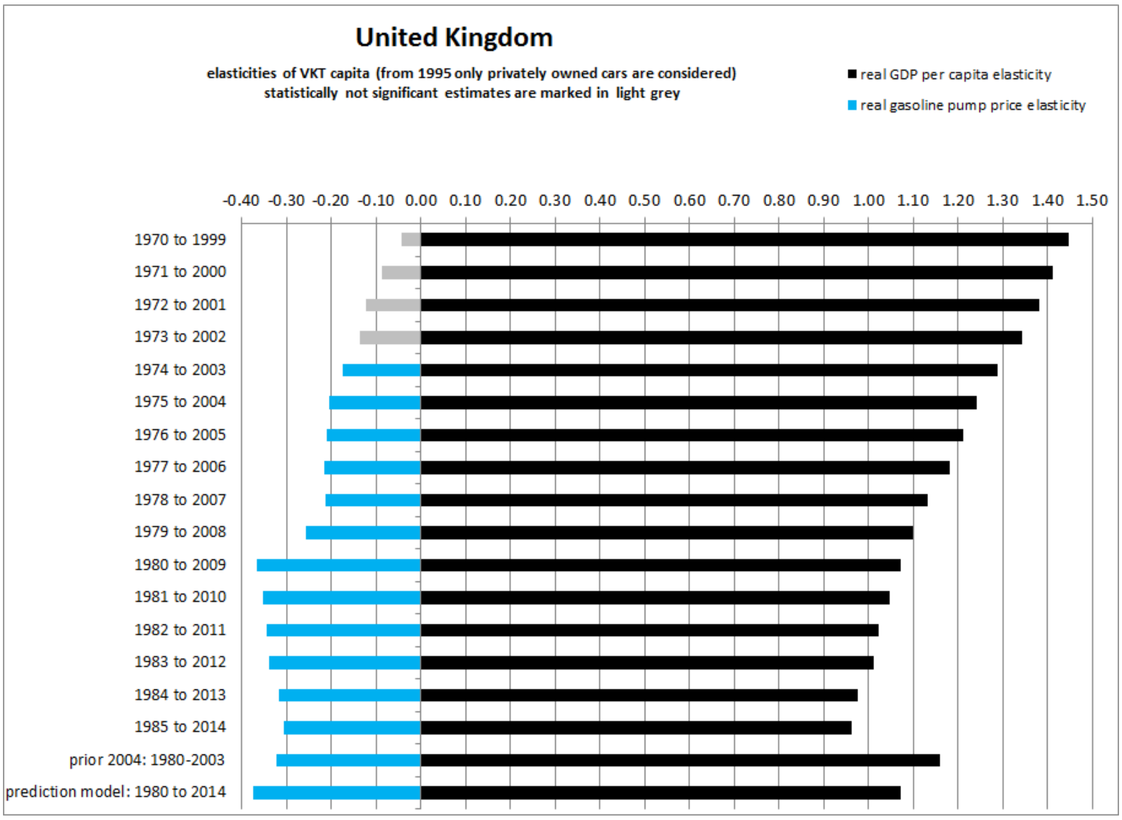

Figure 6. United Kingdom model estimation results: elasticities of VKT per capita for real GDP per capita and real gasoline pump price.

4.4 Sweden

Estimating the model on data from Sweden for the time period 1980-2014 gives a gasoline price elasticity of -0.23 and a GDP/capita elasticity of 0.63. The model predicts the observed VKT per capita fairly well, although it over-predicts the reaction to the decrease in GDP in the early 1990's. In particular, the model predicts the plateau and subsequent decrease in VKT/capita during the 2000's. The estimated elasticities are in line with more advanced studies for earlier periods; for example, Sterner and Dahl (1992) estimate short-run elasticities of -0.30 (gasoline price) and 0.51 (income) for Sweden, using data for the time period 1960-1985.

From 1970 to the mid-1990s, Swedish GDP and VKT are highly correlated and gasoline price elasticities are not statistically significant in our simple model. Comparing rolling estimates for rolling 30-year periods (Figure 8), gasoline price elasticities are broadly stable over time. The GDP/capita elasticities appear to be somewhat declining over time, just as for the other countries.

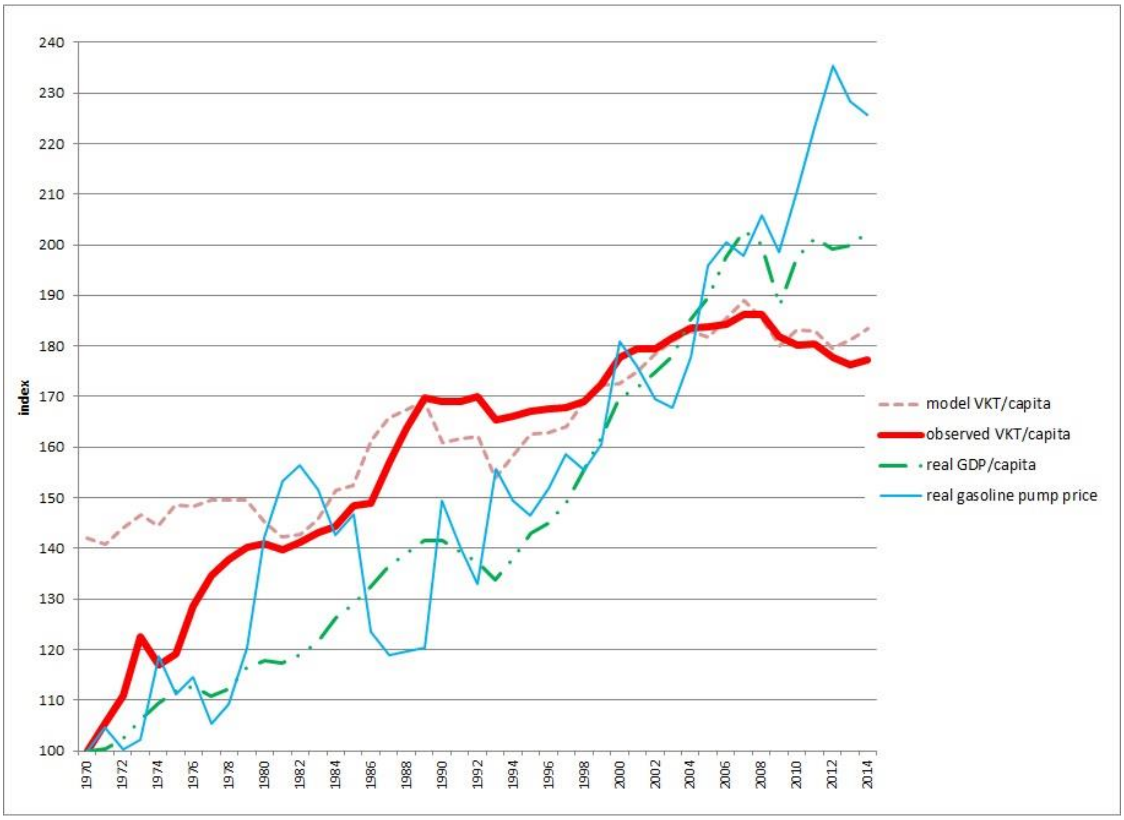

Figure 7, Sweden indices of real annual gasoline price, real GDP per capita, observed VKT per capita and predicted VKT per capita

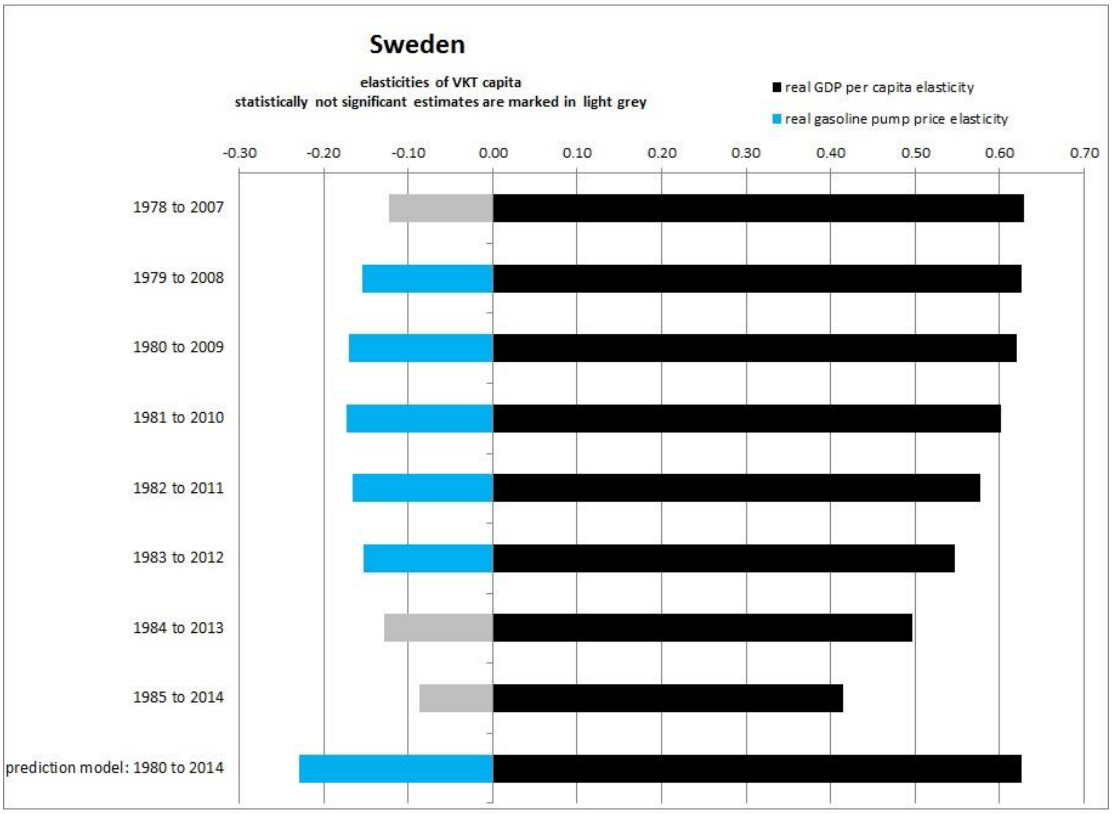

Figure 8, Sweden model estimation results: elasticities of VKT per capita for real GDP per capita and real gasoline pump price

4.5 Australia

In Australia taxes make up approximately one third of the gasoline pump price (EIA 2014), which makes the country more comparable to the United States than to Europe with respect to gasoline price levels.

Estimating the model on Australian data for the time period 1980-2013 results in a gasoline price elasticity of -0.36 and a GDP/capita elasticity of 0.41. This model predicts the observed VKT somewhat less well than in the previous countries. However, it correctly predicts that VKT/capita essentially stops growing after 1998, and decreases during the period 2004-2008 due to the rapid gasoline price increase (similar to the other countries). However, the model fails to capture the continuing decrease in VKT/capita after 2008.

We have two tentative explanations why the model fit is worse for Australia than the other countries: data issues and immigration. The Australian method of estimating VKT statistics makes it difficult to capture short term VKT variations: Travel surveys and fuel sales data are combined to estimate VKT for different vehicle types, interpolation is used for missing travel survey years, and some smoothing is applied to achieve believable trends over time (Bureau of Infrastructure 2011, 17). Our data series ends in 2013. However, the 2014 Survey of Motor Vehicle Use (Australian Bureau of Statistics 2015) indicates that the total VKT grew by 6% from 2012 to 2014, which would correspond to a 2% growth in VKT per capita, breaking the previously declining trend.

However, a second possible explanation of the poor model fit is the marked increase in immigration since the mid-2000s. Total VKT actually increases through the 1990's and 2000's; the reason that VKT/capita falls is that population grows faster than VKT, especially in later years (after 2005). Net immigration accounts for approximately 60% of Australia's population growth of 1.8% annually (Australian Bureau of Statistics 2013). Immigrants from outside the Anglo-Australian cultures are less likely than Australia-born residents to own and use cars, particularly during their first years in Australia and even after controlling for income and demographic factors (Klocker et al. 2015).

Australian VKT and GDP are highly correlated from 1978 to the mid-1990s, and the estimated gasoline price elasticity for this period is not significant. Comparing estimates over rolling 30-year periods (Figure 10) we see that gasoline price elasticities are broadly stable over time, while there is a slightly decreasing trend in the GDP elasticity.

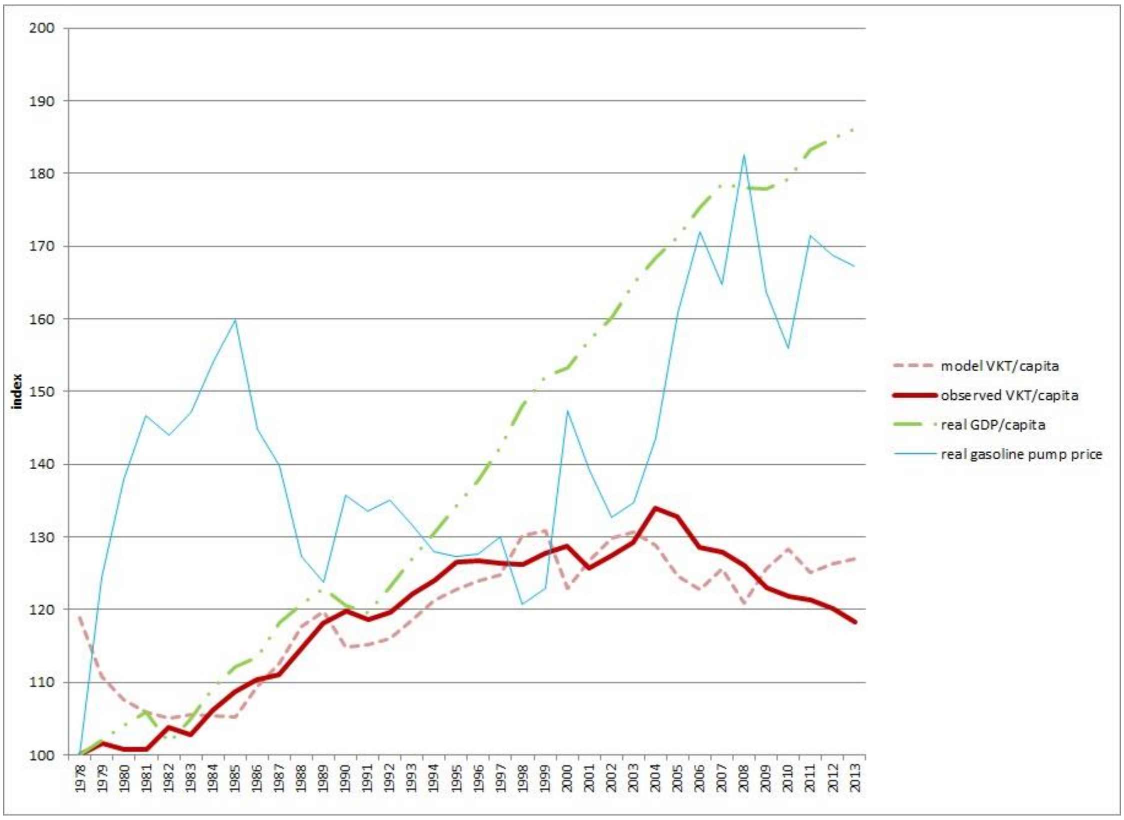

Figure 9, Australia indices of real annual gasoline price, real GDP per capita, observed VKT per capita and predicted VKT per capita

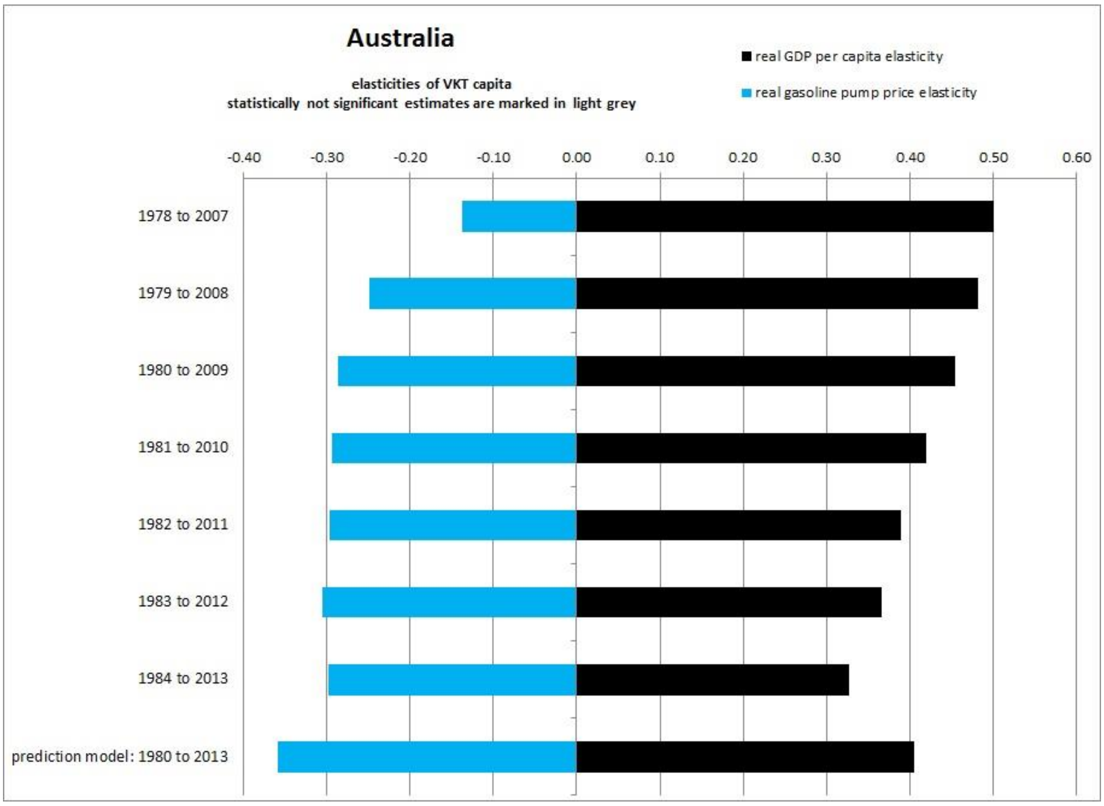

Figure 10, Australia model estimation results: elasticities of VKT per capita for real GDP per capita and real gasoline pump price.

4.6 Germany

German VKT per capita increased rapidly from 1989 to 1994 when East Germany and West Germany were reunified. This was mainly due to radical changes in the East German economy; for example, queuing times of over a decade for East German new-car buyers disappeared. For this reason, drawing conclusions regarding the drivers of the car use trend in Germany is unreliable; but in the interest of completeness and comparison, we report the data and estimates anyway.

Estimating the model on data from Germany 1994-2012 gives elasticities of -0.18 (gasoline price) and 0.94 (GDP/capita), but the gasoline price parameter is not significant (t-statistic 1.41). The model still closely predicts the observed VKT per capita (see Figure 11). However, this does not say much, since the development of both GDP/capita and VKT/capita are essentially only linear trends.

Interestingly, there is no downward trend in German VKT per capita since 2003, despite a 30% increase in real gasoline prices until 2012. The strong and quickly recovering German economy is a possible explanation. Additionally, in 2009 sales of new cars reached their highest point since the re-unification. This was due to a temporary counter-recession policy, which subsidized purchases of private new cars in exchange for scrapping old cars (German Economic Research Institute Berlin 2011, 23). Finally, the German method of estimating VKT statistics appears insensitive to short term variations in observed VKT (just like the Australian data using a similar method).[6]

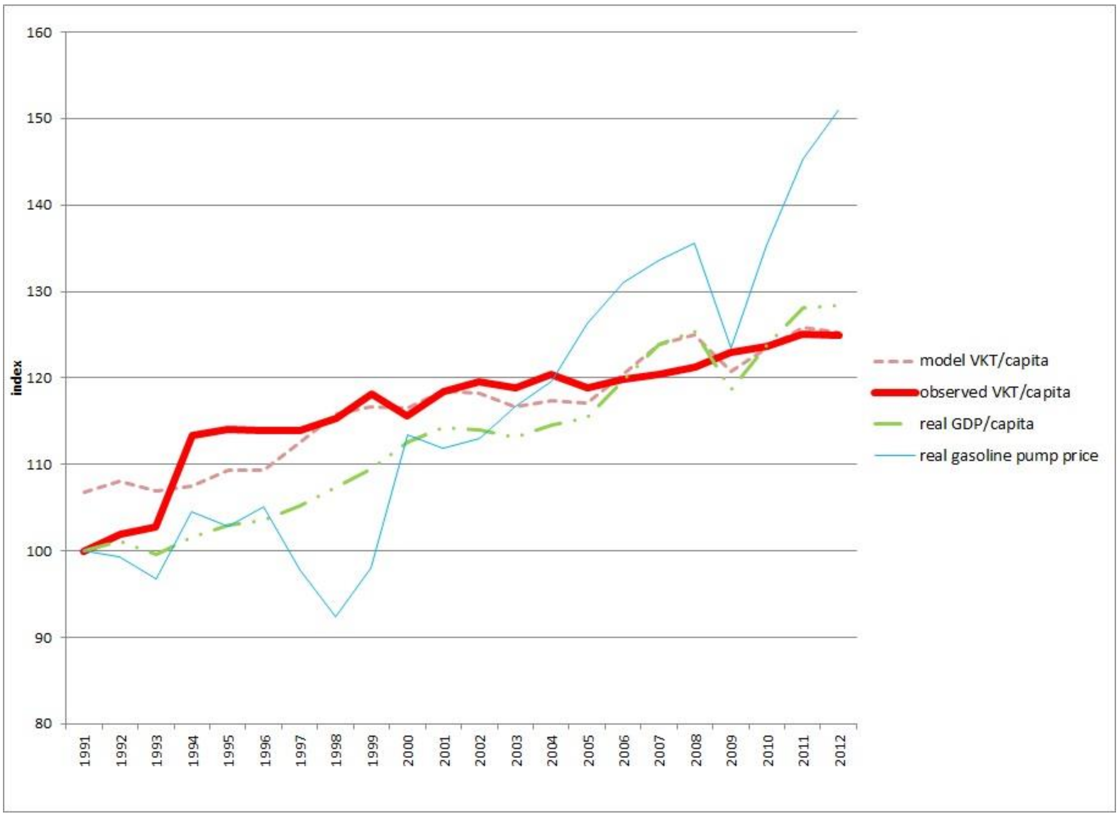

Figure 11, Germany indices of real annual gasoline price, real GDP per capita, observed VKT per capita and predicted VKT per capita.

[6] Until 2013 the German VKT modeling approach was based on multiplying car registration counts (by vehicle and owner class) with the average distances driven from a 2002 mobility survey (German Bureau of Statistics 2011, 12,14,23).

4.7 Summary

The simplistic models with only gasoline price and GDP per capita are able to predict VKT per capita remarkably well in all the studied countries. In particular, the simplistic model predicts the plateau and decrease of VKT/capita in the 2000's, and also the very recent upturn in VKT/capita in 2014. The possible exception is Australia, where VKT/capita has decreased more in very recent years than predicted by the model – but even there, the model is able to capture the development reasonably well. Growing immigration from non-Anglo-Australian countries and data issues are possible explanations.

Table 1 summarizes estimation results. The elasticities in the simplistic models are well in line with results from more advanced studies. In particular, they are in line with studies made well before the development in the 2000's was observed. This means that a hypothetical forecaster in the 1990's, equipped with these elasticities and with perfect foresight of future GDP/capita and gasoline prices, would have been able to predict the "peak car" phenomenon with quite decent accuracy.

Table 1. Estimation results.

	Intercept		log(gas price)		log(GDP per capita)		No obs.	R^2
	Estimate	*t value*	**Estimate**	*t value*	**Estimate**	*t value*		
US (1980 – 2015)	2.10	*19.90*	**-0.14**	*-9.80*	**0.71**	*32.27*	36	0.97
France (1980 – 2014)	1.10	*7.42*	**-0.31**	*-11.01*	**1.08**	*49.38*	35	0.99
UK (1980 – 2014)	1.58	*9.07*	**-0.37**	*-8.41*	**1.07**	*32.15*	35	0.97
Sweden (1980 – 2014)	3.13	*19.64*	**-0.23**	*-4.14*	**0.63**	*10.92*	35	0.87
Australia (1980 – 2013)	4.57	*16.08*	**-0.36**	*-5.62*	**0.41**	*11.22*	34	0.80
Germany (1991 – 2012)	1.18	*2.18*	**-0.18**	*-1.41*	**0.94**	*4.18*	22	0.76

There are indications of declining elasticity with respect to GDP per capita in all the countries, possibly related to saturation of car use and ownership in the highest income segments. There are also some indications of increasing gasoline price elasticities over time, as gasoline price levels increase, and especially during periods of rapid price increases. That the gasoline price elasticity seems to depend on the price level was noted by Goodwin et al. (2004). There are also observations consistent with the imperfect price-reversibility described by Dargay and Gately (1997).

Table 2. Relative prediction errors.

	Time period	*1980-2014*	*1980-1990*	*1991-2002*	*2003-2014*
US	Relative RMSE	0.3%	0.6%	0.5%	0.5%
	Average relative error	0.0%	0.7%	-0.6%	0.0%
France	Relative RMSE	0.3%	0.6%	0.6%	0.4%
	Average relative error	0.0%	0.5%	-1.3%	0.8%
UK	Relative RMSE	0.5%	1.0%	1.0%	0.5%
	Average relative error	0.0%	1.5%	-3.2%	1.9%
Sweden	Relative RMSE	0.5%	1.2%	1.0%	0.5%
	Average relative error	0.1%	2.4%	-2.9%	0.8%
Australia	Relative RMSE	0.6%	1.0%	0.8%	1.2%
	Average relative error	0.1%	1.1%	-1.2%	0.3%

The RMSE:s in Table 2 are quite small: the models are actually able to predict the outcome quite well, much better than a simple trend line, for example. The average relative errors indicate that the models tend to overestimate traffic slightly in the 1980's and 2000's, but slightly underestimate traffic in the 1990's. Perhaps most interestingly in our context, there is no sign that the models perform worse in the 2000's than in the earlier decades.

5 CONCLUSIONS

This study explores whether the standard economic variables GDP per capita and fuel price can explain the plateau and decrease in VKT per capita observed in many rich industrialized countries since the beginning of the 00's. If these variables cannot explain these trends, then the observed decline in car travel could be driven by changes in lifestyles, attitudes and preferences[7]. That, in turn, could have potentially far-reaching consequences for transport policy and transport forecasting. Generally, it would be good news for transport policy makers: the problems generated by car traffic would to some extent solve themselves.

However, our results indicate that GDP per capita and fuel price are in fact able to explain most of the trends in VKT per capita. Our deliberately simplistic models, yielding elasticities well in line with (and, in fact, mostly lower than) literature and data preceding the development in the 2000's, are able to predict the plateau and decrease of car travel with quite remarkable accuracy. This holds for the United States, France, the United Kingdom, Sweden, and to a slightly less extent Australia. We have also presented data for Germany, where there are no signs of a plateau in VKT, but the German development is more difficult to model using time series data due to the reunification in 1990. (The poorer model fit in Australia and Germany might be due to the method of generating aggregate VKT data in these countries.)

[7] The changes could also be driven by various planning policies that are difficult to track at an aggregate level, such as spatial planning or parking policy. For some reason, however, this explanation seems to have attracted less attention in the peak car debate.

However, finding correlations between variables in times series does not prove causality, of course, so we should be precise with what our conclusion is. The logic is this: *if* economic variables *could not* explain recent downward trends in aggregate car use, *then* that would have meant that the trends must have been caused by something else, and this "something else" could be changes in lifestyles and attitudes. What we show is simply that the first part of this syllogism is not true: economic variables *can* in fact explain these recent trends. Of course, this does not rule out the existence of alternative explanations (this is true for any econometric model); nor does it imply that there are no changes in lifestyles or attitudes (of course there are), or that other variables do not affect travel patterns as well (of course they do). However, we can conclude that economic variables are *sufficient* to explain the aggregate trends in car use.

It should be emphasized that our results are not at all inconsistent with the reported changes in travel behavior and attitudes of various socioeconomic groups, for example that young people tend to postpone getting a driver's license and a car, or that the elderly (especially women) tend to drive more than they used to do. Nor do our results contradict that there are many other factors which also affect travel demand in general and driving in particular. Aggregate trends and the trends of individual groups are different degrees of resolution; it is like the difference between looking at waves and looking at the tide. The driving pattern in different socioeconomic groups, the waves, may evolve differently over time. Some of these changes may cancel each other out, while others do not. Obviously, there have been very large changes in society and the preconditions for car travelling in all decades during the entire post-war era: new youth culture, increased female labor participation, forming of families later in life, older people becoming healthier and wealthier, higher shares of university education, urbanization and ICT. Some of these changes are reflected in (or caused by) changes in GDP, while some are not. Our analysis, just like any aggregate analysis, simply suggests that general variables such as GDP per capita and fuel price tend to pull the *sum* of all these trends in a specific direction, just as the moon pulls an unruly sea in a specific direction. For example, it is likely that the increase in car driving among the elderly had been even larger had not the fuel price increased so much in the last decade; and it is likely that economic downturn and high fuel prices amplified the trend among young people to postpone getting driver's licenses and cars.

Likewise, our results are not inconsistent with observing attitude shifts such as cars becoming perceived as less important or attractive. It is possible that such attitude changes are partly *driven* by changes in behavior, rather than the other way around. Someone who opts out of car driving for economic reasons may simply adapt his attitude to car driving to be consistent with his behavior.

It seems to us that much of the literature that shaped the peak car debate has underappreciated the importance of fuel price increases that already occurred from 2003, instead focusing too much on the timing of the oil price peak in 2008. The fact that the peak car phenomenon happened around the same time in so many countries with substantial cross-national differences in driving distance per capita and demographic and cultural trends actually suggests that global parameters such as fuel price and economic downturn were key drivers. It seems unlikely that long-term societal changes in lifestyles and attitudes should appear simultaneously and exogenously in all countries. It should also be noted that trends in different subgroups go in different directions: much has been written about the decline in car use and license holding among the young (especially young men), whereas the increase in these variables among the elderly (especially older women) has attracted much less attention. At the time of writing, we can also observe simultaneous effects in the opposite direction: with the decline in fuel prices in 2014 and 2015, per capita driving distances increased in all four countries for which we have recent data.

There are indications of declining elasticity with respect to GDP per capita in all the studied countries, which is consistent with a saturation of car use and car ownership in the highest income segments. These segments have also received much of the income increases given the widening gaps in many countries. Saturation is part of the peak car literature and in this sense our results support this literature. Still, this trend does not seem to have started recently but has been going on for decades. Depending on how income increases are distributed in the future, the income elasticity might decline further, but the process seems to be slow. There are also some indications of increasing gasoline price elasticities over time, as gasoline price levels increase, and especially during periods of rapid price increases. That the gasoline price elasticity seems to depend on the price level was noted by Goodwin et al. (2004). There are also observations consistent with the imperfect price-reversibility described by Dargay and Gately (1997). Still, our most important conclusion is that the predictive power of these two variables has stayed rather constant over time. There are, as there have always been, other factors and changes in society that affect car use in different directions; but there seems to be no strong reason to suspect that transport forecasting would be less valid today than it used to be.

For transport and climate policy, our conclusion is a clear message that policy makers cannot sit back and hope that changes in lifestyles, preferences and attitudes will solve the problems with car traffic for us. Instead, it seems that policy measures will be necessary to curb the growth in car traffic. Nevertheless our results imply some good news for policy design: they reinforce the old result that drivers do in fact react to economic variables such as fuel prices.

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Appendix

The main data source is the OECD library, accessed 2015.08.30, http://www.oecd-ilibrary.org:

Real gasoline pump volume prices: Energy prices in national currency per toe – regular gasoline (unleaded from 1993), deflated by the consumer price index all items, as listed for each country in the OECD library

GDP per capita: Gross domestic product (output approach) - Constant prices national base year (as defined and listed for each country in the OECD library); Population all ages

VKT per capita: Road in million passenger-km passenger cars; Population all ages

The following data has not been sourced from the OECD library:

United States real gasoline prices 1970-2013: U.S. Department of Energy; http://energy.gov/eere/vehicles/downloads/fact-835-august-25-2014-average-annual-gasoline-pump-price-1929-2013-dataset

United States real gasoline prices 2013-2015: U.S. Energy Information Administration, accessed 2015.08.30; http://www.eia.gov/, 2015 values are predicted for August 2015-December 2015,

United States VKT: U.S. Department of Transportation, Federal Highway Administration, Traffic Volume trends May 2015, predicted values for June 2015-December 2015, http://www.fhwa.dot.gov/policyinformation/travel_monitoring

United Kingdom VKT: Road traffic (vehicle miles) by vehicle type in Great Britain, cars and taxis, Department of Transport Statistics, table TRA0101, https://www.gov.uk/government/statistical-data-sets/tra01-traffic-by-road-class-and-region-miles

United Kingdom private car VKT as share of all-car VKT from 1995: (Le Vine et al., 2013)

Sweden real gasoline prices: Swedish Petrol and Bio Fuel Institute, BF95 real gasoline, accessed 2015.08.30, http://spbi.se/statistik/priser

Sweden VKT 2002-2014: Transport Analysis Sweden, accessed 2015-09-16, http://trafa.se/vagtrafik/korstrackor/