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Explaining 'peak car' with economic variables: A comment

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Introduction

'Peak car' refers to the stagnation - or in some cases decline - in car travel in some high-income industrialized countries that has started in the early 2000s. Given the prevalence of 'predict and provide' approach in transport planning in most countries, peak car is quite important in the practical policy-making and road investment context. Following research at the beginning of this decade by various researchers - Millard-Ball and Schipper (2011), Goodwin (2011), Metz (2010, 2013), Newman and Kenworthy (2011) among them - it is now well accepted among transport researchers that we have had a 'peak car' phenomenon, whereby we observe a sustained reduction in per capita car travel in many western countries. Peak car authors primarily use the evolution of car travel per capita (PKT or VKT) over time to show graphically the stagnation or decline in car travel and offer various explanations as to why this may have happened. While most of these studies acknowledge that income and fuel price have some effect on per capita car travel, all also suggest that the recession in 2007/2008 and increases in fuel price during the years prior to that can only offer a *partial* explanation of the plateau in car travel and suggest other possible explanations of the slowdown, such as changes in lifestyle and attitudes (see Bastian et al. 2016 for a rapid summary). Peak car hypothesis is thus associated with a permanent change in lifestyle, attitudes and travel pattern in away from car travel. Although no statistical or econometric evidence is provided in these studies, the key argument - that the substantial slowdown in car travel started a few years before the recession and fuel price increases to have caused the plateau in car travel- is a strong one. Nonetheless a proper econometric evidence to separate out the effects of income and fuel price in this debate would have been useful to establish the peak car hypothesis beyond any doubt. The recent paper by Bastian et al. (2016, BBE hereinafter) sets to address this gap and - somewhat surprisingly - finds that the changes in income and fuel prices during the period are *sufficient* to explain the stagnation of car travel. In other words, BBE suggests that we have not observed any 'peak car' effect due to changes in lifestyle and travel pattern, rather the slowdown was due to the fuel price increases and the recession (and as such is possibly temporary in nature, rather than indicating a long term shift away from car travel). This conclusion goes against the collective wisdom of the peak car proponents and the analysis calls for further scrutiny.

BBE approach

BBE approached the econometric modelling of peak car through a remarkably simple model for aggregate travel demand by car, whereby car VKT per capita is regressed on GDP per capita and gasoline price, with all the variables in logarithms, their Eq. 1 reproduced below:

$$\ln(VKTpercapita) = \beta_0 + \beta_1 \ln(GDPpercapita) + \beta_2 \ln(fuel\,price) \quad (1)$$

The logical reasoning that BBE emphasized several times is simple yet useful in construct: "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" (p.248); i.e. if GDP and fuel prices can explain (i.e.

predict) the plateau in car travel in the countries investigated, then the 'peak car' hypothesis could be disproved. They ran the regression on data from six industrialized countries (USA, France, UK, Sweden, Australia and Germany), generated the parameter estimates (which are also respective elasticities given the functional form of the model), used those parameter estimates to predict car travel in those countries and compared the predictions with the observed data, especially in the context of early 2003 to 2014/2015. They find that their "deliberately simplistic models, ..., are able to predict the plateau and decrease of car travel with quite remarkable accuracy" (p. 248).

The logic in BBE is correct, however, the execution has an important flaw. BBE estimated their econometric model on the whole sample of data between 1980 to 2014. This means the data from the 'peak car' period in question is already used during parameter estimation, and therefore these parameter estimates are already altered to specifically fit the occurrence of 'peak car' as best as possible. As such there is some circularity in the modelling representation of their logical reasoning. Clearly, *predictions from a model that include the data from the 'peak car' period must not be used to understand the ability of the model to predict 'peak car'*! It is also vital during forecasting that the predictive accuracy of the model is tested using out-of-sample predictions.

The solution

There are several approaches to get around of the limitation of BBE in predicting 'peak car'. The first one can be acquired from one of the comments in BBE: "a hypothetical forecaster in the 1990s, 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" (p.248). We need to tweak that statement a bit and switch it to a question format: whether a hypothetical forecaster in the late 1990s or early 2000s, equipped with the elasticities *from only 'existing' data on car travel* and with perfect foresight of future GDP/capita and gasoline prices, would have been able to predict the 'peak car' phenomenon? If the answer to this question is yes, then the peak car hypothesis can be somewhat refuted, as in BBE. The modelling approach would be exactly the same as BBE, except that the data from which the parameters are estimated must not include the peak car period (post 2003). Once the parameters or elasticities are estimated on the sample from 1980 to 2003, they can then be used to predict the car travel post 2003 and compared with real observations. In essence, this is similar to the well-established 'intervention analysis' in the time series literature (Box and Tiao 1975).

There are other approaches: one can separate the sample in pre- and post- peak car event, run two regressions and test the equality of parameter estimates using a Chow test. ITF (2013) followed this approach in their panel for eight countries. However, given only 11 years of data availability since 2003, there is a lack of data in the second time period for this method to be robust enough. Other advanced tests for parameter stability can also be used. Using dummy variables to indicate the peak car period (Eq. 2) or interacting dummy variables with income and fuel price for peak car period and estimating the new model on the entire dataset are other possible approaches.

$$\ln(VKTpercapita) = \beta_0 + \beta_1 \ln(GDPpercapita) + \beta_2 \ln(fuel\ price) + \beta_3 Dummy04 \qquad (2)$$

Essentially, any econometric technique that can test the presence or absence of a structural change in the relationship between car travel, GDP and fuel prices around 2003 can possibly be applied. In order to remain true to the BBE logic, we primarily follow the first approach, but also estimate Eq. 2.

Results

We run regressions for three countries out of the six in BBE in this paper. We do not include Germany because of the shorter time period available after unification to estimate anything meaningful; Australia because of the anomalous results reported by BBE; and Sweden because its peak car event is not clear (one stagnation in early 1990s another coinciding with the recession in 2008, which would require a more sophisticated analysis). The data used for estimation are from 1980 till 2003. Results of our estimation (hereinafter WB1) is presented in Table 1. Also presented are the estimation results from the full sample (1980 to 2014/2015), which are the same as BBE. Clearly, our models fit the data marginally better, despite a smaller number of observations.

Table 1. Parameter estimates (t-stat in parentheses) for intervention model (Eq. 1)

	USA		France		UK	
Estimation period (model reference)	1980-2003 (WB1)	1980-2015 (BBE)*	1980-2003 (WB1)	1980-2014 (BBE)	1980-2003 (WB1)	1980-2014 (BBE)
GDP per capita	0.752 (23.7)	0.713 (32.3)	1.200 (46.7)	1.084 (49.4)	1.160 (30.7)	1.072 (32.2)
Fuel price	-0.109 (-3.97)	-0.140 (-9.8)	-0.187 (-5.7)	-0.313 (-11.0)	-0.323 (-6.2)	-0.374 (-8.4)
Constant	1.756 (6.8)	2.097 (19.9)	-0.029 (-0.1) #	1.082 (7.42)	0.897 (3.3)	1.579 (9.1)
Model diagnostics						
Adjusted R2	0.979	0.968	0.993	0.986	0.976	0.973
N	24	36	24	35	24	35
Naive trend model R2	0.955		0.980		0.912	
Prediction during 2003-2015						
RMSE	2.120	1.418	3.234	0.764	5.408	1.954
Relative RMSE	1.21%	0.79%	1.94%	0.46%	2.13%	0.76%
Relative average error	3.00%	0.17%	6.31%	1.00%	6.87%	1.76%

All parameter estimated statistically significant at 99% except for #

* marginally different from BBE, as data includes 2015

The more important result is the prediction performance. Figs. 1-3 presents the actual evolution of car VKT per capita and predictions from WB1 and BBE models, while Table 1 also includes the RMSE, relative RMSE and relative average error (the latter two defined in BBE) for the post-2003 period. Our model (WB1) predictions diverge further from BBE predictions during post-2003 for all three countries, which is expected since BBE includes peak car observations during estimation. For post-2003 period, our predictions continue to diverge substantially from the actual VKT observations. While the inception of the US slowdown is reasonably captured by our model, the prediction and actual observation keeps on diverging afterwards. For France and the UK, the observed plateau in car travel is missed by our model predictions. This indicates that on an aggregate level, fuel price and income were *not sufficient* to predict the peak car in these three countries, which is the opposite of BBE's findings. This does not mean income and fuel price are not important determinants of car travel - they still affect car travel, but could only partially explain the recent stagnation in car travel in these countries, as the peak car proponents accept. The very high adjusted R2 values (above 0.95) in both BBE and WB1 do not actually mean much in terms of explanatory power: such high R2 is fairly common in time series econometrics and even a naive regression with only a time trend can explain 95%, 98% and 91% or the variations in car VKT for US, France and UK respectively.

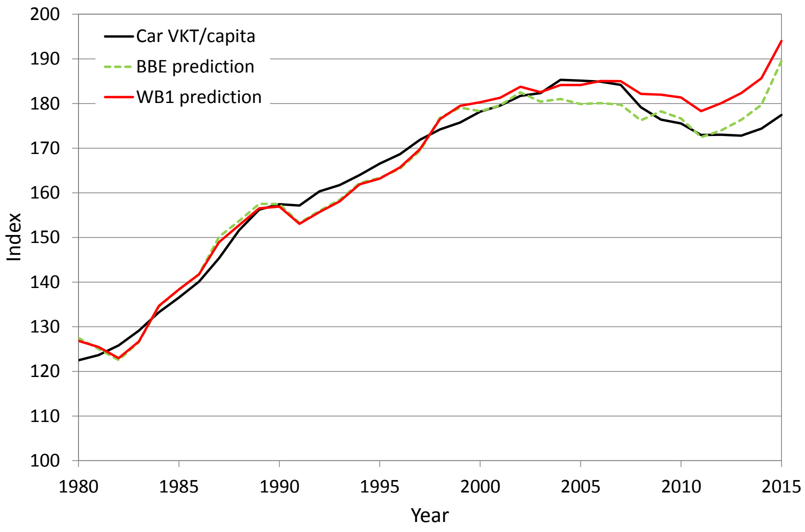

Fig. 1 Comparison of model predictions with actual VKT data in the US

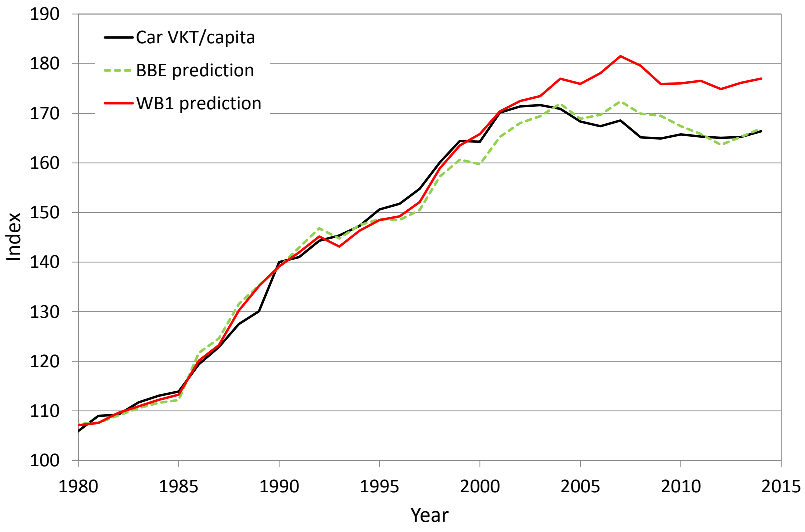

Fig. 2 Comparison of model predictions with actual VKT data in France

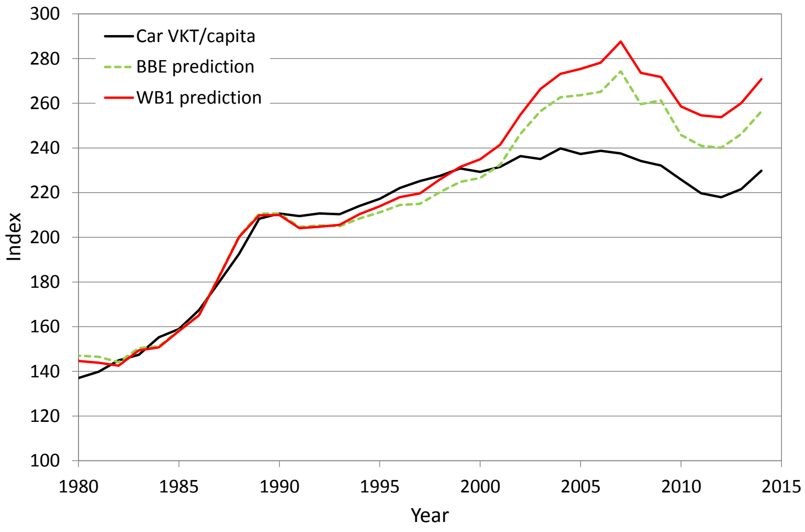

Fig. 3 Comparison of model predictions with actual VKT data in the UK

In the dummy variable approach (WB2) of Eq. 2, we include a dummy variable for post-2003 observations as an additional explanatory factor in the model. This time, data from 1980 to 2014/2015 is fully utilised for estimation, as in BBE. Note that the research question is different in this model, what we ask is: taking all the data together, whether - on average - there was a substantial divergence in car VKT from the regular trend from year 2004. If car travel had indeed reached a plateau around 2003, then we expect the dummy variable to be negative and statistically significant. Regression results for all three countries are presented in Table 2, along with the corresponding BBE estimates. For France and the UK, the dummy for post 2003 observations are indeed negative and statistically significant, indicating there was an 'additional' reduction in car VKT per capita in these countries that cannot be explained by income and fuel price; i.e. the peak car hypothesis cannot be rejected in these cases. However, for the US the dummy variable is statistically insignificant, indicating - on average - there was no statistically significant reduction in car VKT in the US during that period. As such it is questionable whether 'peak car' had indeed occurred in the US: this finding supports BBE results for the US. Note that the BBE models are 'nested' in the respective WB2 models, and we can use the likelihood ratio tests to choose between the models. For France and the UK, WB2 is statistically better, while for the US, WB2 is not statistically better than BBE. Although the dummy variable approach still uses post-2003 data for estimation as in BBE (which was our main point of contention), we do not use this model for prediction and the modelling philosophy is different from BBE. However, we believe the ‘intervention’ model is still more elegant in philosophy.

Table 2. Parameter estimates (t-stat in parentheses) for dummy variable model (Eq. 2)

	USA		France		UK	
Estimation period (model reference)	1980-2015 (WB2)	1980-2015 (BBE)*	1980-2014 (WB2)	1980-2014 (BBE)	1980-2014 (WB2)	1980-2014 (BBE)
GDP per capita	0.731 (21.1)	0.713 (32.3)	1.188 (50.0)	1.084 (49.4)	1.153 (35.2)	1.072 (32.2)
Fuel price	-0.127 (-5.0)	-0.140 (-9.8)	-0.211 (-7.9)	-0.313 (-11.0)	-0.304 (-7.7)	-0.374 (-8.4)
Dummy for post-2003	-0.014 (-0.7)		-0.055 (-5.8)		-0.068 (-4.33)	
Constant	1.946 (7.67)	2.097 (19.9)	0.137 (0.7)[#]	1.082 (7.42)	0.845 (3.85)	1.579 (9.1)
Model diagnostics						
Adjusted R2	0.967	0.968	0.993	0.986	0.983	0.973
N	36	36	35	35	35	35
Likelihood ratio test	0.48 (p=0.49)		16.54 (p<0.001)		25.84 (p<0.001)	

All parameter estimated statistically significant at 99% except for [#]

* marginally different from BBE, as data includes 2015

Conclusions

In this comment piece we set out to test the recent finding that income and fuel prices were sufficient to explain the recent downward trend of car travel in some western countries and, by deduction, 'peak car' is only a transient phenomenon. We argue that any econometric model designed to predict the occurrence of peak car must not include data from the peak car period. Our corrected 'intervention' type models - still entirely within the BBE logic in spirit - appear to show that economic variables such as income and fuel prices were *not* sufficient to explain the stagnation in car travel in the three countries, although they still remain important predictors. Our finding for the UK and France is clearly in line with the mainstream literature that advocates peak car hypothesis. More importantly, even BBE did find evidence in support of saturation car use (a possible explanation for peak car) when they turn their interest on the stability of model parameter over various decades and mention: "saturation is part of the peak car literature and in this sense our results support this literature" (p. 249). For the US, however, the results are mixed: while we do find a visual divergence between our 'intervention' model predictions and actual car VKT per capita, the dummy variable model statistically shows no substantial reduction in VKT post-2003 in addition to what can be expected by changes in income and fuel price during that period. Taken all three countries together, our results are therefore still inconclusive. A perfectly valid conclusion could also be that peak car may have happened in the UK and France, but not in the US.

How confident should the readers be in these revised results? While our 'intervention' and 'dummy variable' approach is superior in modelling philosophy to BBE, the econometric models here and in BBE are both too simplistic and still have some vital caveats. Especially, time series data, as used here and in BBE, are more often than not non-stationary (see Wadud et al. 2009), and any regression with non-stationary variables will be spurious, unless they are cointegrated. The same may be the case here, too. Also, as hinted by BBE, controlling for asymmetric responses to income and fuel prices following Kahneman and Tversky's (1979) prospect theory may be required as per Wadud (2014, 2015) or Dargay and Gately (1997). It would therefore be useful to check whether these advanced modelling approaches could provide a more robust conclusion in favour of or against the peak-car hypothesis.

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