MODELLING AND FORECASTING CAR OWNERSHIP IN ROMANIA'S COUNTIES USING BASS DIFFUSION MODEL

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1. INTRODUCTION

It is generally believed that economic development through increased income, diversification of workforce, smaller households and changes in lifestyle has been the primary cause of growing car ownership. An indicator of increased population mobility, growth in the number of motor vehicles represents also a driving force towards increased congestion (Wegener, 1996). Land-use and transportation are dynamically subjected to external influences, such as changes in politic regime, economy, demography, technology and sometimes culture. The sudden or slow changes that are occurring at a point in time determine endogenous changes within the components, and therefore, induce complex behaviour in the transportation system. Moreover, if the changes occur without being a result of a forecast or a regulation in policy (to respond to unwanted effects), the behaviour could be unexpected. Also, the mitigation of observable negative effects (environmental) becomes a complicated and assiduous process.

The scope of the study is to bring contributions to the understanding the changes within the transportation system as result of economic development in post-socialist countries in the last 25 years. Given that car ownership is important to transport and land-use planning and its relationship with energy consumption, the environment and health, the objective of this research is to develop a methodology for modelling and forecasting car ownership levels in Romania, using the Bass diffusion model (Bass, 1969). This paper intends to provide recommendations to overcome the negative effects of sharp increase of motorization by giving better chances to relevant actions. Therefore, the structure of this research is structured as follows. Section 2 provides insights for current research determinants, such as historical background and worldwide models for studying and forecasting car ownership. Section 3 lays out the data and the methodology suited for available information and further, in section 4 we compute the forecasting based on the model results and assumed evolution

for model independent variables. Finally, we discuss the results, acknowledge the modelling critical issues and foresee possible solutions and future research directions worth following for the study of car ownership in Romania.

2. MOTIVATION OF THE RESEARCH STUDY

For a better understanding of the grounds which this study was based upon, first we need to explain the historical context. For countries in Central and Eastern Europe, exposed to political system such as communism for prolonged period of time during the 20th century, the transition from central planning towards a free-market economy has brought significant changes in the way individuals travel and the means by which goods are transported. Significant increase in private motorization caused re-orientation of modal preferences (Judge & Kaminski, 1996) and national transport infrastructure, such as road and rail, was overall distressed due to lack of investment and appropriately maintenance (European Conference of Ministries of Transport, 2004). In the following paragraphs we lay out the historical background which triggered the increase in car ownership levels. Subsequently, we will make a short description on models estimating and forecasting car ownership levels to forego the modelling methodology developed in this paper.

2.1. Historical background

The communist party gained power over Romania in 1946, bringing nationalization of privately owned factories, shops and hotels. Financed by international creditors, the country faced rapid industrialization the next years, and newly developed apartment blocks at the fringes of Romania's big cities accommodated the continuous forced migration from rural areas (Cook, 2001), phenomena that lead to a 40% increase in urban population (Scrieciu, 2011). Initially, automobiles could only be owned by institutions, but later on, if specific conditions satisfied, individuals were granted access to owning automobiles. The energy crisis in 1970s brought drastic austerity measures so that the acquired tremendous foreign debt was to be paid at the cost of population wellbeing. Basic food, electricity, hot water and gasoline were rationed. Each car was entitled to 20 litres per month and travel restrictions were imposed (Ofrim, n.d.). The international isolation of Romania ceased in December 1989 when the revolution burst and removed the Communist regime and settled its way towards prosperity and freedom, associated with capitalism and democracy (Cook, 2001).

2.2. Models for estimating and forecasting motorization levels

There have been several studies worldwide that employed economic development for explaining the growth of vehicle ownership. Due to automobile ownership important role in transportation and land-use planning, a large degree of attention was granted in travel demand analysis. The literature on automobile ownership has taken both aggregate and disaggregate modelling approaches. Earlier studies used the historical evolution of car ownership in several developed countries and found that it followed an S-shaped curve (Dargay & Gately, 1999; Dargay, Gately, & Sommer, 2007; Tanner, 1962), showing three stages in building up the considered automobile fleet: accumulation, maturity and slow-down. The aggregate forecasting methodologies were based on cross-sectional data (Button, Pearman, & Fowkes, 1982), time-series data (Romilly, Song, & Liu, 1998) or a combination between the two (Dargay & Gately, 1999). Aggregate models do not consider household of individual characteristics and as a result, recent forecasting methodologies have focused on a disaggregate approach. In a similar manner, disaggregate studies deal with cross-sectional data (Train, 1980), pooled time series data (MVA Consultancy, 1996) or panel data (Hanly & Dargay, 2000).

3. DATA AND METHODOLOGY

The methodology for the estimation of the parameters and for the forecast of car ownership adopts a simple Bass Diffusion Model. The model was estimated using cross section time-series data on vehicle ownership in Romania's 42 counties and consists of population evolution, vehicle ownership as well as economic development by means of gross regional product (GRP). Our analysis spans since the beginning of the 1990s until the recent years. We were constrained by the scarcity of studies in the field of urban transportation planning in Romania and were limited to data from the Romanian National Institute of Statistics and Eurostat. The next two paragraphs will present the data and theoretical framework for the methodology constituting the core of this research.

3.1. Motorization evolution in Romania

Over the last 25 years, the number of personal cars in Romania has been increasing from 1.54 million in 1990 to 5.92 million in 2014. If such trend continue, Romania will face increased energy consumption, traffic congestion and pressure on the hinterlands of expanding urban areas. The national car ownership level – 200 vehicles/ 1000 inhabitants in 2014 – is still below

compared to the average car ownership level in the developed countries. While there has been a general increase in motorization rate for Romania as a whole (see motorization evolution – Figure 1), there are considerable differences in ownership at a more regional and local level. The objective of this research is to develop and apply a model to generate forecasts across Romania's counties, by taking into account evolution of population, gross regional product and historical car ownership data. Romania is divided into 41 administrative areas and the municipality of Bucharest, the capital. Due to geographical layout and similar economic development, Bucharest municipality data were aggregated with the county inside which is located. Between 1996 and 2002 there is no data collected at regional level, being aggregated at national level. In order to have a more consistent database, we obtained values of the missing data by means of regression analysis for each of Romania's counties. On a national scale, the maximum level of car ownership is reached in the capital city, rising from approximate 100 cars / 1000 inhabitants at the beginning of the 1990s to more than 430 cars/ 1000 inhabitants in 2014 (Figure 1).

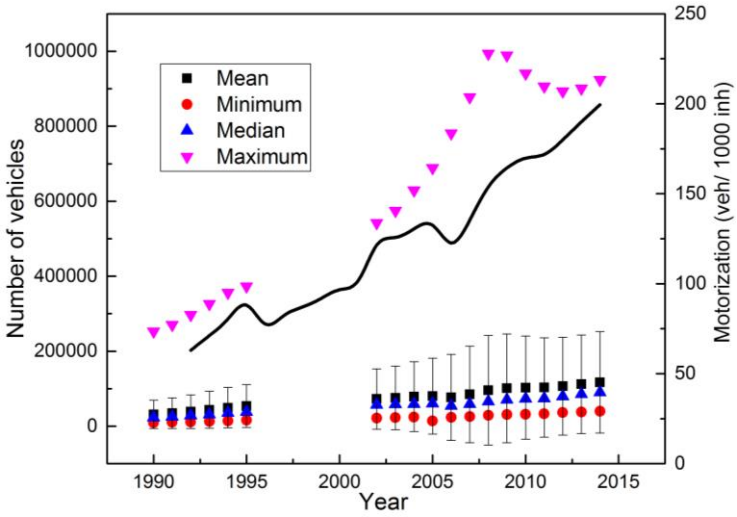

Figure 1: Summary statistics - county level

We note a greater variability among the counties after year 2000, possibly explained by the regional differences. In 2004 Romania joined North Atlantic Treaty Organization (NATO), followed by the adherence to the European Union (EU) in 2007, which brought a boost in economic growth in certain parts of the country and that could have determined a different status over investors' plans for Romania, especially Bucharest and its hinterlands. To illustrate such differences, Figure 2 reveals statistics on the evolution of GRP at county level.

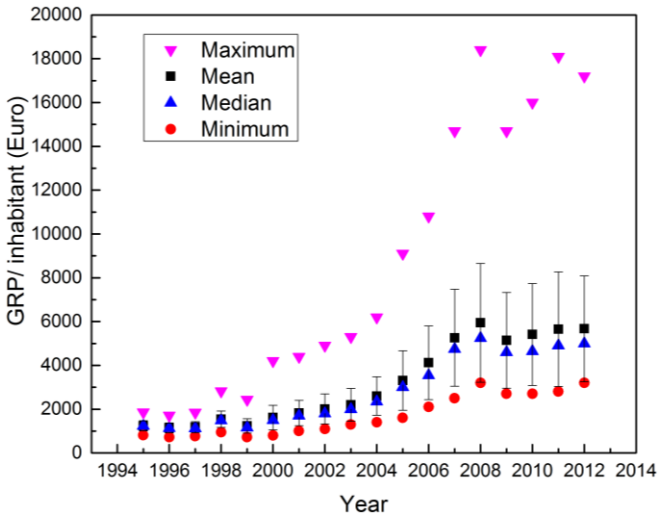

Figure 2: GRP summary statistics - county level

The maximum level is represented by GRP per capita in Bucharest, which is nowadays higher than the EU average and three fold the Romania's average, contributing to almost 25% to Romania's gross domestic product (GDP) (Ionescu-Heroiu, et al., 2013b). The next section lays out the theoretical framework for the methodology that was established to achieve current research objectives.

3.2. Bass model

Developed by Bass (1969), the model was used in forecasting market innovation diffusion of new products. When a new product is introduced on the market, there are two potential adopters: the innovators and the imitators. The former adopt the new product independently of other individuals in the social system, while the latter ones are influenced in acquiring the product by the pressure of the social system (word-of-mouth communications and observation). The theoretical principle that lays at the core of innovation diffusion states that "the probability that an initial purchase will be made at time T given that no purchase has yet been made is a linear function of the number of previous buyers." In mathematical terms,

$$P(t) = p + \frac{q}{m} Y(t) \qquad (1)$$

where $P(t)$ is the probability of purchase at time t, $Y(t)$ is the number of previous buyers, m is the total number of buyers, p and p are the coefficient of innovators and imitators, respectively. The number of innovators decreases with time, while the number of imitators increases to a peak and gradually drops due to market saturation. The base model is expressed as:

$$S(t) = \left(p + q\frac{V_{t-1}}{P_{t-1}}\right)(P_{t-1} - V_{t-1}) \quad (2)$$

Where, $S(t)$ represent the increment of car numbers at time t, V_{t-1} is the number of cars at time $(t-1)$ and P_{t-1} represents the maximum assumed number of vehicles, as in the saturation level.

3.3. Current research methodology and results

The regression model used has the following structure:

$$y_i = \beta X_i + \epsilon_i, \quad \epsilon_i \sim N(0, \sigma^2) \quad (3)$$

Therefore, y_i follows the normal distribution, but with mean equal to βX_i. In this way, we can define the likelihood function:

$$L = f(\beta X) = \frac{1}{\sqrt{2\pi}\sigma}\exp\{-\frac{(y^* - \beta X)^2}{2\sigma^2}\} \quad (4)$$

The unknown parameters can be estimated by maximizing the log-likelihood function in equation 9, written and implemented in GAUSS econometric software, version 3.2.32.

$$LL = \ln\big(f(\beta X)\big) = -ln\sigma - 0.5\frac{y^* - \beta X}{\sigma} \quad (5)$$

The estimated parameters are the coefficient of innovation p, coefficient of imitation q and gross regional product (GRP) effect g_e (expressed in thousand Euro). Table 1 displays the results of the non-linear regression model. The R^2 values indicate that the data appear to be in good agreement with the model.

Table 1: Bass model parameters

Parameters	Low GRP		High GRP	
	Estimate	t-value	Estimate	t-value
p	0.0073	6.787	-	-
q	0.0345	5.008	0.0733	8.158
g_e	0.0019	2.101	0.0032	3.742
R^2	0.325		0.567	
LL	-8.189		-9.744	

Two groups of counties were identified taking into account the average GRP of Romania, as delivered by Eurostat and which is 6200 Euro/ inhabitant. The innovation parameter for high GRP counties returned negative at first estimation, therefore was eliminated from the model formulation and the

remaining parameters were re-estimated. The imitation and GRP effect parameters for both low and high GRP counties are significant and seem to be in good correlation with the annual growth of car ownership and scale of GRP, respectively. The model assumes that the saturation level is achieved when the total number of vehicles equals the number of working adult population.

4. MOTORIZATION FORECASTING

In proceeding on the long term forecasting of motorization in Romanian counties, we need to predict the evolution for the model variables, the number of adult working population and GRP per capita. Nowadays Romania's country population is smaller by 4 million people compared to 1990, due to decline in birth rate and external migration and the suburbs around Romanian major cities have gained around 300,000 inhabitants (Ionescu-Heroiu, et al., 2013a). This phenomena is triggering factor for rapid pace of motorization, as longer commuting trips are generated (Gakenheimer, 1999). Taking into account Romanian historical population data, negative birth rate and ageing population (Jemna, Pintilescu, & Turturean, 2010), we have assumed that the overall population is constantly decreasing, at a rate specific to each region. There are three counties in the north-east of Romania in which the evolution is positive. Those counties are among the ones with low GRP, large population and low percent of urbanization (48%, 44% and 43%, respectively). According to the World Bank, Romanian economy has been growing at an average rate of 3.5% per year in the last 14 years (World Bank, n.d.). Taking into account that the country average GDP is among the lowest in the European Union (European Commission, n.d.), we decided to maintain this average growth rate, under the assumption of continuous investments and long term technological innovations. Figure 3 reveals the forecasted car ownership evolution curves for the two groups of counties. Note that the scale is different, due to high car ownership in the capital.

The graph shows that the pattern of growth follows an S-shaped curve. Each curve's inflection point represents the peak of private car acquisitions for each county. For the high GRP counties, the saturation starts to spread around the year 2035, while for some of the low GRP counties, under the assumptions of low increase in GRP, in conjunction to high working population numbers, saturation level appears to be farther in time.

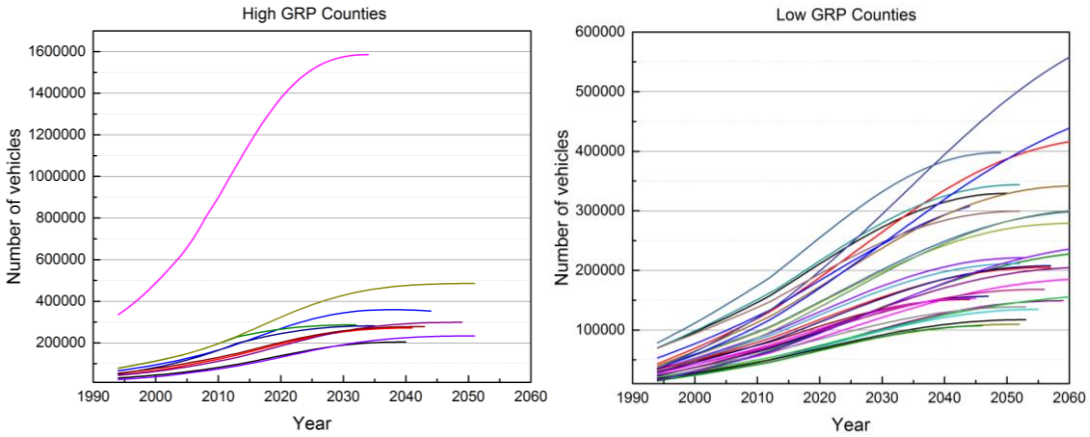

Figure 3: Evolution of vehicle ownership for Romania counties

Obtaining the accumulated number of vehicles for each county might seem a valuable result, it does not account for the motorization rate (cars/ 1000 inhabitants), a measure used by the developed countries as an indicator of economic development and environmental issues in research literature (Dargay, Gately, & Sommer, 2007; Wu, Zhao, & Ou, 2014). According to data, most developed countries reached a saturation level between 400 and 800 cars per 1000 inhabitants (World Bank, n.d.). The process of accumulation begins slowly, matures and grows rapidly and slows down in time due to saturation. When applied to developing countries, Gakenheimer (1999) argues that motorization is far from saturation point and that the peak of acquiring of vehicles is not visible. Figure 4 reveals the modelled GRP dependant motorization rate for low and high GRP Romanian counties.

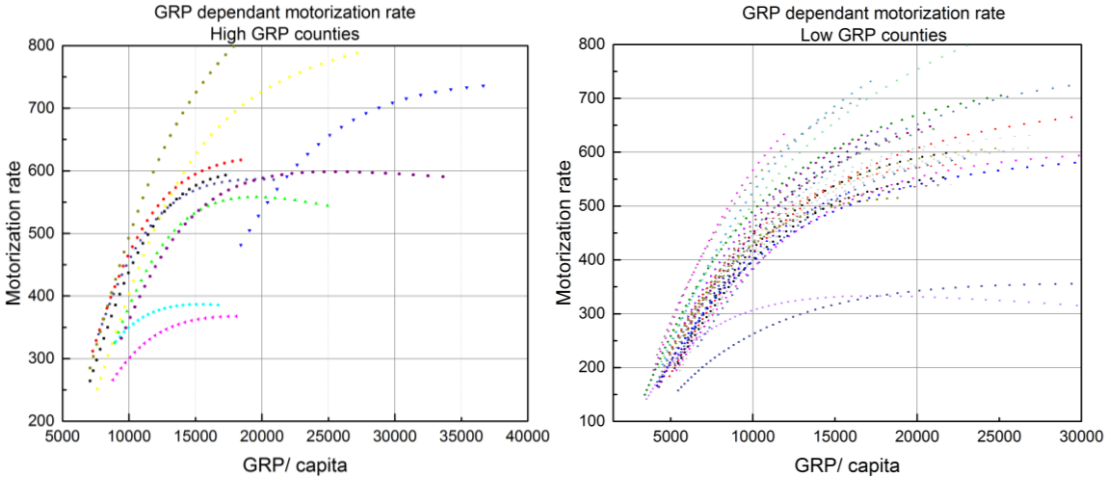

Figure 4: Forecast of GRP dependant motorization rate

The motorization rate was computed according to forecasted total population and the yearly cumulated number of vehicles obtained from Bass model. Under the assumed population and county GRP evolution, data shows that for high GRP counties, the saturation level of around 600 cars /1000 inhabitants is

achieved at a GRP average of 20,000 Euro per capita. This saturation is achieved within the period between 2040 and 2050. Similar relation is confirmed by Dargay et al. (2007), who observed the same pattern for the vehicle ownership level in advanced economies, using pooled-time series and cross-sectional data. The saturation point for low-income counties is to be achieved after year 2050.

5. DISCUSSION AND FURTHER CONSIDERATIONS

5.1. Model shortcomings

This section deals with probable source of errors in the modelling and the forecasting of car ownership. The population and GRP data aggregates at county level, with no distinction between rural and urban areas. It is important to stress out that higher levels of GRP and car ownership are to be encountered in urban areas, which might need additional data to make distinction between the two areas and improve the forecasting. We need to mention that car ownership forecasts were made under the assumptions of continuous GRP growth and population shrinkage. The saturation point for the personal vehicles was assumed to be the number of working adult population. On the long-term forecasting of car ownership we assumed a continuous decrease of working adult population, but there are no such kind of data in statistics. Another factors affecting personal options in car ownership are oil prices and adoption of electric vehicles or other types of personal mobility, which were not considered to be an influencing factor in any of the forecasted time frames. We are not aware on how the future policies on birth rate boosting or eventual workforce migration will influence the labour market and implicitly the car ownership.

5.2. Conclusions and further considerations

In this paper, we have developed a methodology for car ownership modelling and forecasting in Romania, using Bass diffusion model. The input variables were gross domestic product (GRP), historical evolution of car ownership and population data. In order to overcome the discrepancy in terms of the input variables, we have separated the data into two groups, low GRP and high GRP level counties and estimated the model parameters separately. The high significance of the parameters prompted us to forecast the car ownership levels while assuming socio-economic evolutions for each county. As growth mostly occurs in the urban environment, where personal income and workforce are higher than the ones in the rural areas, saturation levels in urban areas might occur earlier than predicted by the current methodology. Taking into account

the insufficient infrastructure supply available in the developing urban areas in order to sustain the continuous growth in car ownership, this would lead to rapid increase of congestion levels, if current growth patterns continue.

Big cities in developing countries are aware that cities in developed countries that went through rapid pace of motorization endured decline in mobility and accessibility, translated into congestion problems and derived social discontent, economic losses and environmental degradation. In this respect, the developing countries adopted technology, institutional management and experience (Gakenheimer, 1999). This transfer does not always work, due to cultural and social differences. In Romania, the percent of urban population has been slightly stable since 1995 (Avg.=50.5%, SD=1.02) and population data shows that more people are migrating towards the outskirts of big cities. As anecdotal evidence shows that major urban areas in Romania experienced increased levels of congestion within the last 15 years, there is evidence that emphasis should be put on the conscious planning of the urban areas. Therefore, it is the cities within the same country that should learn from each other's experience, and the situation in Romania seems promising for such issue. In this respect, cities from low GRP counties in Romania should learn from the bigger cities that have experienced rapid growth due to several reasons (geographical location, access to infrastructure, foreign investments etc.), but missed the opportunity to learn and act from the errors of the developed world.

The results of the car ownership forecast tool should not be taken as a proof of need to construct to satisfy the passenger demand traffic. Developed countries facing increased motorization rate considered other approaches to deal with the problems of congestion and focused on investing in alternatives to personal motorized mobility and appropriate policy measures. Policy makers should take the results of this paper as a time horizon for anticipating the negative effects of high motorization rate, leaving investments to increase capacity of road infrastructure as a last measure to consider.

6. ACKNOWLEDGEMENT

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