THEORETICAL ANALYSIS OF MODAL CHOICE IN HUNGARY

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ABSTRACT

Due to its direct and indirect external impacts the transport sector has a crucial role in the economy and the environment,. Unfortunately, the natural evolution of technology processes in the sector are insufficient to tackle the environmental problems, therefore decision makers require efficient and effective policy tools to control the passenger transport demands, promoting less polluting transport solutions. Such an appropriate economic tool is road pricing which gives a correct price signal to the users. This article analyses the effects of implementing different road charges on modal choice in Hungary, as based on an equilibrium model. The results give a clear picture about the applicability of such a toll policy in demand management.

Keywords: *modal split, demand, control, tolling, externalities, market equilibrium*

1. INTRODUCTION

One of the most striking characteristics of the 20th century was the invention of the automobile for passenger transportation. There are over 700 million of these vehicles in circulation today around the world, the great majority of them with Otto cycle engines running on gasoline. Automobiles are an integral part of everyday life of the developed society. They reshaped the whole transportation system of mankind and represent a very significant share of the GDP of many countries. As developing countries grow and expand, the number of automobiles in the world will increase [1]. The number of vehicles per capita is filling up in industrialized countries, but is much smaller in today's developing countries (see Fig. 1). In China there are only 20 automobiles per 1000 people compared to 700 per 1000 people in the United States of America. In Hungary we had 300 passenger cars for 1000 people in 2006.

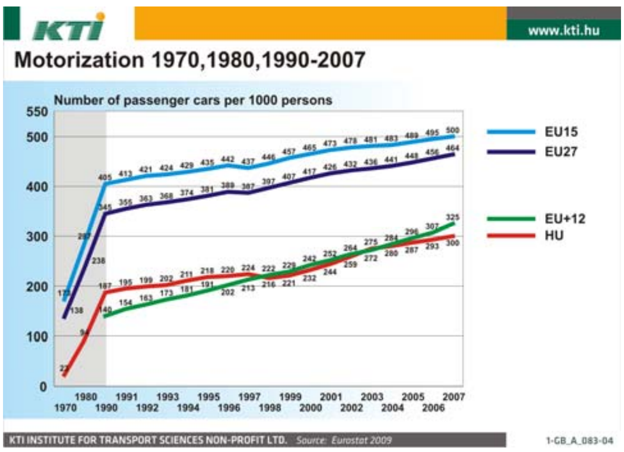

Fig. 1 Motorization in the European Union
(Source: KTI Trend database)

The consumption of gasoline necessary to run these automobiles is roughly 20 million barrels of crude oil equivalent per day, one quarter of the world petroleum consumption from which it is produced and, unfortunately, petroleum is to be found in relatively few regions of the world. Exports and imports of this commodity are the most important items in international trade and many countries are significantly dependent on petroleum imports.

It has been argued over the last 50 years that there is a clear relationship over time between GDP growth, trade of goods and passengers, and transport performances and transport-related investments. Theoretically, efficiency and productivity increase has priority in the economy, thus transport demands' correlation with the GDP may be reduced. However, recent experiences show that current policy tools are insufficient to change this trend.

Sustainable growth and development, as principal strategic aims project further growth in the national and international economies, parallel to increasing environmental pressure, therefore sustainable environment requires short term actions, using less or more efficient resources. The current mobility behaviour of population is in need of change towards a sustainable transportation system with better utilisation of alternative transport modes. This leads to lower dependency on fossil fuels and reduced harmful emission. Experiments show that fuel consumption based charges are effective tools in this challenge [2]. Our aim was to analyze the application of different toll measures in road transport in line with reforming the current pricing regimes [3] and the possibilities to control travellers in their transport mode choice with elasticity calculations, furthermore to model the modal and route choice as a human behaviour.

2. THE THEORETICAL INVESTIGATION

Let us assume that there are three different routes (as a part of a graph) on the transport network. One with high capacity and high service level offered (interurban motorway, marked with purple), another one with low capacity and low service level (trunk road crossing cities and towns, marked with yellow), lastly a direct railway line (marked with red) – see Fig. 2. These alternatives bear different user costs and travel time needs; these resistance factors will be inputs of the objective function. Basic situation is that both routes are free of charge for the users. First we examine the impacts of a standard charging system (vignette system for example – taking into consideration the wear and tear costs) on the road with high capacity and service level, then similarly the effects of an air pollution cost sensitive one. These charges also influence the outs of the objective function. Consumer responses to changes in mobility prices are often measured by elasticity. When the price of road transport has been changed, the utility function of travellers consequently has also been changed. Higher transport prices affect demand for transport through two main channels. First, consumers respond by changing their route and secondly, they change their mode of mobility. In our case those people who need to reach the destination within a limited time period, and thus have a higher value of (travel) time will pay the toll [4]. Those who want to reach the destination with small expenses will choose the road with lower capacity and lower service level, free from any tolls.

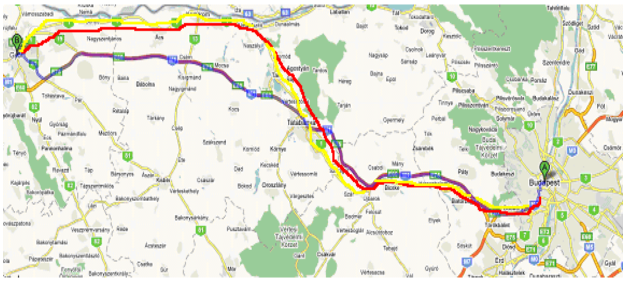

Fig. 2 Investigated area Budapest – Győr
(Source: www.googlemaps.com)

In macroeconomical sense we modelled the decision about route choice. We tried to build up a model based on utility functions and analyze the results. Practical uses of supply and demand analysis often centre on the different variables that change equilibrium price and quantity based on the fundamental model of Marshall [5], represented as shifts in the respective curves (Fig. 3). In the literature both affine and nonlinear approximations of the demand and supply curves are in use. The authors of the present paper apply affine approximation for this purpose that is reasonable within more or less narrow intervals. Comparative static of such a shift traces the effects from the initial equilibrium to the new equilibrium.

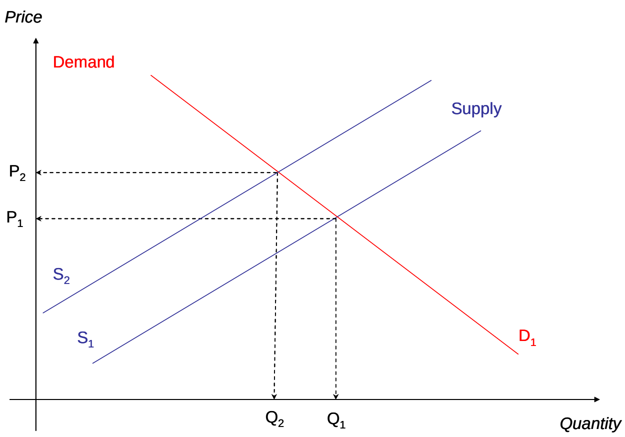

Fig. 3 Change in the supply curve [6]

We had an unwanted left-ward shift in supply that decreased quantity. With increasing road prices the traffic is decreasing so even higher service level has been reached. Due to the increased paying obligations, less people want to travel on the higher service level road and part of the traffic is diverted to the free of charge route. In the diagram, this increases the equilibrium price from P1 to the higher P2 and lowers the traffic from the Q1 to the Q2 value. The lower service level road runs through cities and towns. The increased traffic volume on lower service level road causes substantial damage to the infrastructure and the environment, and to the cities and citizens. To lower the damage caused, the traffic volume needs to be lowered. For this reason, diversified distance based road toll system should be introduced also on this road, internalizing the externalities of air pollution focusing on the polluter pays principle, to ensure that the diverted traffic turns back to the high service level road. After introducing the distance based toll regimes on both routes, road transport becomes more expensive, so some people will shift to public transportation modes, so traffic volume on the road will be less. Mathematically the demand function can be described as:

$$x_t = a_t \cdot p_t + \alpha_t \quad (1)$$

where: x_t – the demand for the road, p_t – the price in time t, t – the time period, $a_t<0$ and $\alpha_t>0$, these parameters are determined by tools of econometry.

In the example above, there has been a decrease in demand which has caused a decrease in (equilibrium) quantity. We should take into consideration that the roads behave like concurring products and the decrease of demand for one will increase the demand for the other only if the rest of the circumstances remain constant.

Mathematically the supply function can be described as

$$y_t = \beta_t + b_t \cdot p_{t-1} \quad (2)$$

where: y_t – the supply of road, t-1 – time period before time period t, $b_t>0$ and $\beta_t<0$, these parameters are determined by tools of econometry.

It is well known that market equilibrium is reached when demand x_t and supply y_t are equal. For every time period t there is an equilibrium that can be described with

$$\begin{aligned} a_t \cdot p_t + \alpha_t &= b_t \cdot p_{t-1} + \beta_t \\ a_t \cdot p_t &= b_t \cdot p_{t-1} + (\beta - \alpha)_t \end{aligned} \quad (3)$$

We reach the final market equilibrium when $p_t=p_{t-1}$. Therefore, we get

$$\hat{p}_t = \left(\frac{\beta - \alpha}{a - b} \right)_t \quad (4)$$

where: $\hat{p}_t$ – final market equilibrium price.

On this basis Eq. (4) is the determination of the equilibrium at which the demand exactly meets the supply. The actual price differs from the market equilibrium price by

$$\tilde{p}_t = p_t - \hat{p} = p_t - \left(\frac{\beta - \alpha}{a - b}\right)_t \quad (5)$$

where: $\tilde{p}_t$ – the difference between price in time t and final market equilibrium.

At this time the market equilibrium can be described as:

$$a_t \cdot \tilde{p}_t = b_t \cdot \tilde{p}_{t-1}$$
$$\tilde{p}_t = \left(\frac{b}{a}\right)_t \cdot \tilde{p}_{t-1} \quad (6)$$

where: $\tilde{p}_{t-1}$ – the difference between price in time period before time period t and final market equilibrium.

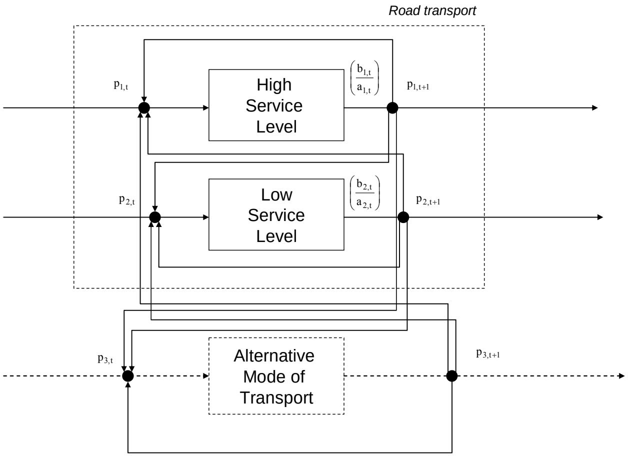

Fig. 4 Cybernetic model of market equilibrium with concurring products [7]

With the above mentioned model (Fig. 4) we tried to analyze the effects of concurring routes and modes in Hungary. As the outputs have an effect on inputs, the meaning of the fat dots in the figure above is the connection point of loops to the input.

3. METHODOLOGY AND RESULTS

As a consequence of the explosive growth in the volume of vehicle traffic the analysis of the demand for the vehicular traffic becomes more and more important. The traffic characteristics of an existing transport relation are being shaped during years [8]. The topic of this article is the revealing analysis of the vehicular relations connecting Budapest and Gyor, building on the traffic data for year 2006. In order to internalise the externalities – at least the environmental part – we divided the vehicle fleet into environmental categories (EURO1 and below, EURO2, EURO3, EURO4, and EURO5 and better) and we categorized them according to cylinder capacity (up to 1399 cm^3, 1400-1999 cm^3, from 2000 cm^3 – Fig. 5). The aim of the group formation is to estimate the complex environmental pollution.

The vehicle flow of the two routes has been simulated by the authors: M1 motorway (high service level) and trunk road no. 1 (lower service level) according to cylinder capacity and environmental standard grouping. The simulation covered three different scenarios:

- first: no change to the current pricing system,
- second: constant level external road charge is applied on both roads,
- third: external road charge is diversified.

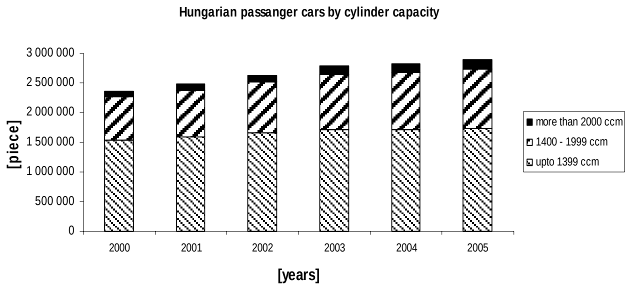

Fig. 5 Hungarian passenger cars by cylinder capacity (Source: Hungarian Central Statistical Office; own research)

The results of the simulation can be found in Table 1, Table 2 and Table 3.

Table 1 Model results (first scenario)

2006	Travel	Normal	
	Time [h]	Cost [th. HUF]	Passengers [mil.]
Bus	1,833	1,700	0,730
Motorway	1	5,006	7,760
<1300 ccm			
<1999 ccm			
>2000 ccm			
Trunk road	1,5	2,632	2,599
<1300 ccm			
<1999 ccm			
>2000 ccm			
Rail	2	1,600	4,019
Total			15,108

Table 2 Model results (second scenario)

2006	Static	
	Cost [th. HUF]	Passengers [mil.]
Bus	1,700	1,400
Motorway	8,756	6,980
<1300 ccm		
<1999 ccm		
>2000 ccm		
Trunk road	3,632	2,338
<1300 ccm		
<1999 ccm		
>2000 ccm		
Rail	1,600	4,390
Total		15,108

Table 3 Model results (third scenario)

2006	Diverse	
	Cost [th. HUF]	Passengers [mil.]
Bus	1,700	1,772
Motorway		6,548
<1300 ccm	7,818	3,845
<1999 ccm	8,756	2,346
>2000 ccm	9,693	0,357
Trunk road		2,193
<1300 ccm	3,382	1,288
<1999 ccm	3,632	0,786
>2000 ccm	3,882	0,120
Rail	1,600	4,596
Total		15,108

The modal split of the corridor demonstrates a great road sector dominancy in the first case, the main reason is its relatively cheap time advance compared to the others sectors. The amount of surplus in user costs is lower than absolute value of differences in travel times.

The application of external cost charges on road sector modulates the previous results. Implementing fixed rate, external cost based road tolls causes remarkable realignment of modal split, from the road towards the public transport sector, dominantly on the bus transport, thanks to its comparative gain to the rail transport. The relative cost advance of individual road transport had been limited.

Diversification the environmental tolls according to the passenger cars' EURO category and cylinder capacity significantly improve the competitiveness of public transport, because the estimated share of more polluting cars is relatively high, therefore their user cost increased over the average.

Having simulated the expected value of the vehicle flow, the results show that in the first case nothing changed. In the second case – where we added constant level tolls to the vehicle flow on the M1 motorway and trunk road no. 1 – the passenger flow using trains and buses increased, to the contrary the passenger flow of the road and motorway decreased. In the third case – applying the diverse tolling measure formed by the complex environmental groups, taking into account the cylinder capacity and EURO classification of vehicles – the passenger flow of the motorway and the road decreased and the passenger flow using the trains and buses decreased. The results are demonstrated in Figure 6.

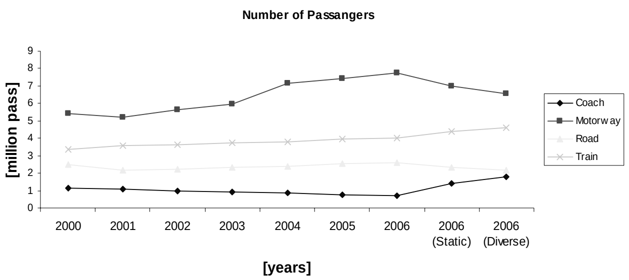

Fig. 6 Simulation of different toll strategies (Source: own research)

4. CONCLUSION

From the point of view of economics the main assumptions of the paper are based on Marshall's fundamental model. According to his model it is assumed that the operation of the economy is determined by the "equilibrium point", that is at the price at which the supply is equal to the demand. This paper consist of the application of Marshall's principles in a particular field, that is the control of road traffic by determining properly the prices to be paid by the various participants of the traffic driving various vehicles grouped according to the environmental categories.

Motorisation causes perceptible environmental externalities. The locally effective emission has been taken into account by the EURO environmental categories and the globally effective one has been taken into account by the piston displacement. In the course of our experiments we revealed that the use of standard road tolling regime enhances the usage of the road-system offering inferior, lower service standards, but this diversion leads to the discontent of the citizens living in the neighbourhood. Reducing greenhouse gas emission will cost money to the states and the society but the amounts required are clearly affordable. It is important to remember that climate policies can create many win-win situations. Reform and diversification of pricing systems will have to be one of the international community's top priorities over the coming decades to reach the desirable sustainability. There will be many difficulties and detour along the road towards building climate friendly economies.

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REFERENCES

[1] TANCZOS, K. – TOROK, A.: Impact of transportation on environment, *Periodica Polytechnica Transportation Engineering*, 2008, pp. 105–110.

[2] RUFOLO, A. M. – KIMPEL, T. J.: Transit's Effect on Mileage Responses to Oregon's Experiment in Road Pricing, Portland State University, Report, 2009.

[3] TANCZOS, K. – BOKOR, Z.: Analysing the conditions of adopting up-to-date transport pricing systems in Hungary. Paper published in Hungarian, *Review of Transportation Sciences*, Budapest, vol. 2, 2004, pp. 50–57.

[4] VARKONYI, D. – ZOLDY, M. – TOROK, A.: Road pricing and climate change at IV. TEN–T corridor in Hungary, *Travel Demand Management Conference*, Semmering, 16 July 2008.

[5] MARSHALL, A.: Principles of Economics. Principles of Economics, vol. 1, Macmillan, London, 1890.

[6] LANGE, O. R.: Intorduction of economic cibernetics – (in Hungarian), Közgazdasági és Jogi Könyvkiadó, Budapest, 1967, p. 237.

[7] PETRES, Z. – TOROK, A.: Analysis of biofuel based mobility in Hungary. *10th European Conference of International Association for Energy Economics*, Vienna, Sep. 2009, pp. 174–175.

[8] GILICZE, E. et al.: Mathematical tools and models in transportation – in Hungarian. Tankönyvkiadó, Budapest, 1971, p. 185.

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BIOGRAPHIES

Adam Torok was born in Budapest in Hungary, on January 18, 1981. He studied at the Budapest University of Technology and Economics. His employment experience included the KTI – Transport Research Institute Non Profit Ltd. in, Budapest, Budapest University of Technology and Economics. His special fields of interest included transport economics, environmental pollution and climate change. He is member of the Hungarian Scientific Association for Transport since 2003. He holds degree MsC in Transport Engineering, MsC in Transport Management and PhD of Transport Science.

Ferenc Meszaros was born in Budapest in Hungary, on December 13, 1978. He has graduated as MSc transport engineer and economic engineer from the Budapest University of Technology and Economics. He holds Ph.D. in transport sciences. He is married and has a child. He is employed by Budapest University of Technology and Economics since 2004, currently as senior lecturer. He is also actively involved in pricing issues as an independent consultant. He has been responsible for operative and scientific tasks in several 5th, 6th and 7th FP and further national projects. He is member of the ERTRAC-Hungary Energy and Environment Working Party, co-opted member of Committee on Transport Engineering of Hungarian Academy of Science, member of Hungarian Scientific Association for Transport. His main research areas are: transport policy, social costs and infrastructure charges.