EFFECTS OF THE INTERNAL CONSTRAINTS OF TRANSPORTATION SYSTEMS ON THE RELIABILITY OF FORECASTS

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ABSTRACT

The expansion of infrastructure networks and the benefits expected of these networks are subject to a number of system effects. At first, feedback effects appear which are often not taken into account by narrow spatial, temporal and causal system boundaries in the models currently in use and in the evaluation methods. Examples are the exclusion of inter-modal alternatives, of reactions to the settlement structures or of other concurring infrastructure projects.

Beside these system effects increasingly logistical functions can be observed in the trends of transport systems in industrial countries, arising from saturation tendencies.

Parts of the system or (depending on system boundaries) greater combined systems show logistical functions due to their capacity limits, limits in resources or endogenous limits like saturation trends (e.g. in the motorization level or the trip length). These saturation tendencies can be explained by both ecological and biological control systems.

The mobility behaviour of road users is characterized by increasing mileage. This behaviour is determined by the general (legal, social, energetical, etc.) framework. A large proportion of the driving forces for traffic behavior are unconscious. They are influenced by man's poor ability to grasp system effects.

Beside those effects which are immanent in any system as for example the law of diminishing marginal utility, increasingly new "system limits" for the mobility behavior – ultimately derived from resource limits – arise.

A more rational aspect is introduced by the availability of financial resources of households for transportation (public and private transport) – for example as a share oft the CPI (Consumer Price Index). This share in fact does not reach the 20 percent threshold for a number of reasons. The combination of increasing purchasing power and decreasing or at least stagnating energy prices virtually encouraged the transportation sector.

Until now, the significances of certain cost components in transportation have not been examined sufficiently. The last studies date from the time of the energy crises in the 80s.

Merely the effect of fuel costs has been analyzed in these examinations, though. Today private households have to face increasing costs in heating (heating energy), food and other categories at stagnating household incomes. Finally, even if only the lower 30 percent of income groups is affected, it will pose a significant challenge for the whole transportation sector.

These endogenous constraints of growth have to be included in simulations by the proper choice of elasticities in boundary situations. The impact of increasing energy costs and an estimate of the arising consequences will be shown by analyzing data from the Austrian Ministry of Transport. Based upon this data we risk a glance at possible scenarios for the U.S. and Austria.

Keywords: motorization, saturation tendencies, energy prices, motor fuel, oil price, household expenditures

INTRODUCTION AND PROBLEM DEFINITION

In recent years obvious saturation tendencies in the usage of infrastructures (traffic volumes) can be observed in developed countries in the form of logarithmic curve progressions. Forecast practice have used saturation tendencies for decades, as can be demonstrated by numbers of Shell forecasts, however these forecasts have always been exceeded. With regard to the personal motorized transport which originates from the successive improvement of supply of the new road infrastructure and the improvement of the standards for the quality of road transport control in both laws and guidelines. Until the mid-80s the combination of increasing purchasing power and decreasing, or at least stagnating energy prices led to an additional growth of traffic volume. Thus the growth may not be because of the improvement in structural and legal standards but also monetary incentives have changed the general conditions and caused the increase of personal motorized transport.

Saturation tendencies in the passenger traffic and in other parts of the transportation system can be observed in Europe, at least since the millennium. One of the reasons for this trend is the disproportional construction of road networks to the actual trends. In a developed road network every further construction is subject to a diminishing marginal utility. As the benefit of an infrastructure has to be justified by an adequate usage, the saturation tendencies have to be challenged. The current financial crisis and increasing crude oil prices in mind, one has to question the (financial) implications of these saturation tendencies. The growth of purchasing power along with the falling fuel prices (and the general low fuel prices in the U.S. due to the tax policy) has generated more and longer trips, resulting in a higher mileage.

Since the millennium a successive growth of fuel prices can be noticed compared to the purchasing power (and is sensed by most income groups). The growing transportation expenditures (esp. for private households) are becoming the restricting factor of further economic development and can, to some extent, explain crises e.g. in the U.S.

Therefore the effects of changes/increases of the households' expenses have to be assessed, distinguishing between the different income classes. In doing so both the access

to the automobile system (e.g. in the form of car ownership) and coping strategies (e.g. through the reduction of trip lengths) have to be studied.

For practical reasons we will use Austrian and German trends (which are quite analogous) as representatives for Central European trends, which we will compare to U.S. figures.

PREVIOUS FORECASTING AND ACTUAL TRENDS

Past and present forecasting practices (p.ex. by Shell) always included saturation tendencies (Figure 1). The predicted saturation levels were exceeded by far in the post-war years due to the excessive expansion of road networks and the improved conditions of the public transport. One can assume from the Figure 1 that the forecasted saturation levels match the actual ones from 1990 on, and that the Shell prognoses of the 80s have come true to a large extent. In Europe, one of the crucial factors for that are - amongst others – concentration tendencies, the rural mitigation and the improvement of public transport.
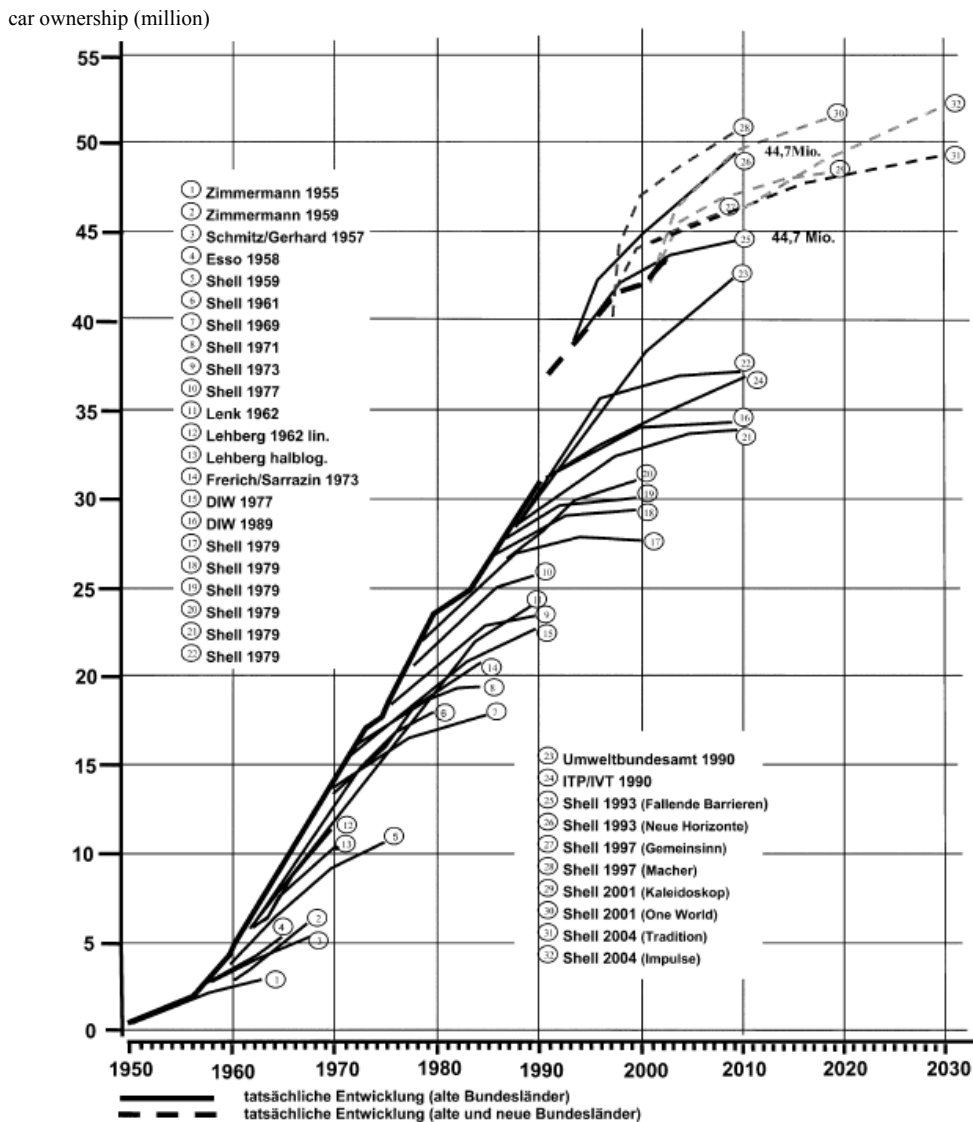

Figure 1: Predicted and actual trend of the motorization, Germany (Source: Steierwald et al. 2005)

The last decade has been characterized by declining growth rates and thus stagnating motorization levels. Beside the already mentioned reasons, there are mathematical ones: the increasing initial values for the computation of annual growth rates.

The trend of declining growth rates can also be observed in the motorization level of the Austrian provinces (Figure 2). The growth rates are already below 1 %, resulting in the stagnation of the total motorization level. In Vienna, even an absolute decline can be found.
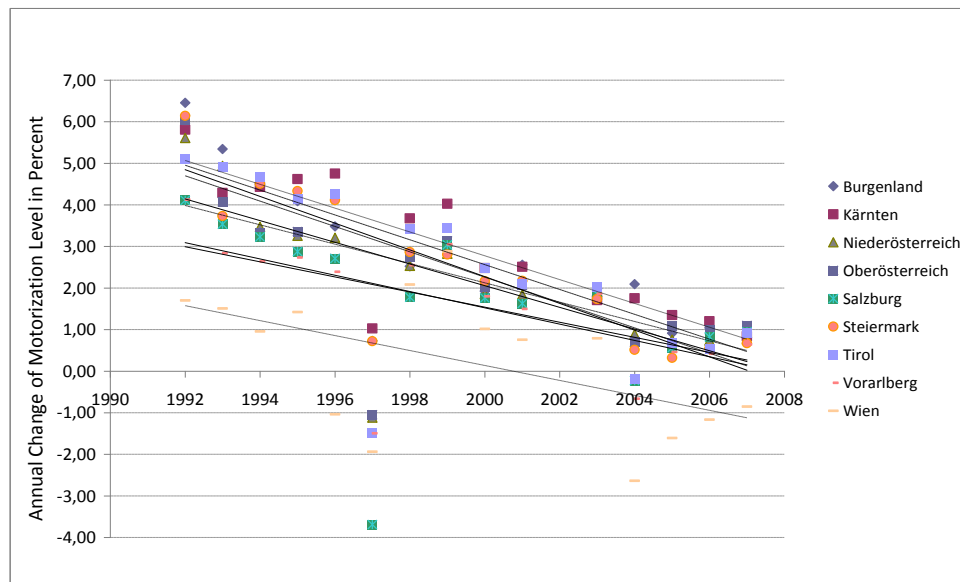

Figure 2: Annual change of motorization level, Austrian provinces (Source: Statistik Austria)

DEPENDENCIES (STRUCTURES, ALTERNATIVES, COSTS)

The influence of the settlement structures, the availability of alternatives etc. on motorization are known. It is also commonly appreciated that every newly built section of road is subjected to a diminishing marginal utility – especially in countries with an already dense grid of infrastructure. The expansion of alternatives to the personal motorized transport such as railways diminishes the additional utility of every proposed road building measure.

As already mentioned, the expansion of infrastructures and the increasing purchasing power of households are the main drivers of the growth of motorization levels over the past decades, and they are the cause of the underestimating forecasts that occurred until the end-90s.
The additional utility gained through the construction of infrastructures in developed countries in the past decades was reduced by a range of measures, e.g. the construction of parallel and concurring infrastructures, and it appears to approach saturation level. The purchasing power of an average household grew in this time period, while the energy prices remained nearly stable.

CAR OWNERSHIP AND PROSPERITY

A comparison of countries shows a significant (R^2=0.7) relationship between GDP and motorization level (Figure 3). However, the different socio-political systems around the world conceal this connection.
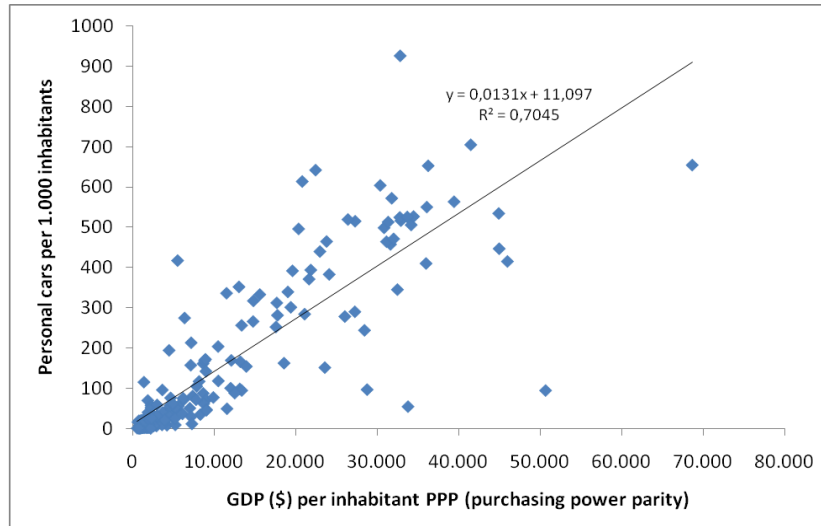

Figure 3: Correlation between GDP/inhabitant (PPP) and motorization level (cars/1.000 inhabitants); All Countries
(Source: Verkehr in Zahlen (2005); http://www.welt-in-zahlen.de)

Europe is characterized by relatively similar political (capitalistic) systems. The countries of the former Soviet Union still have weaker purchasing power, but the trend is already traceable: growth in the purchasing power which leads to an increased motorization level. Nonetheless, even at this aggregation level the saturation level is between 600 and 700 cars per 1000 inhabitants. This lower motorization rate, in comparison to the US can be explained by denser settlement structures, better public transport systems, and the different approaches in transport policies (first described in Newman & Kenworthy 1989; see also Bühler & Kunert 2008).
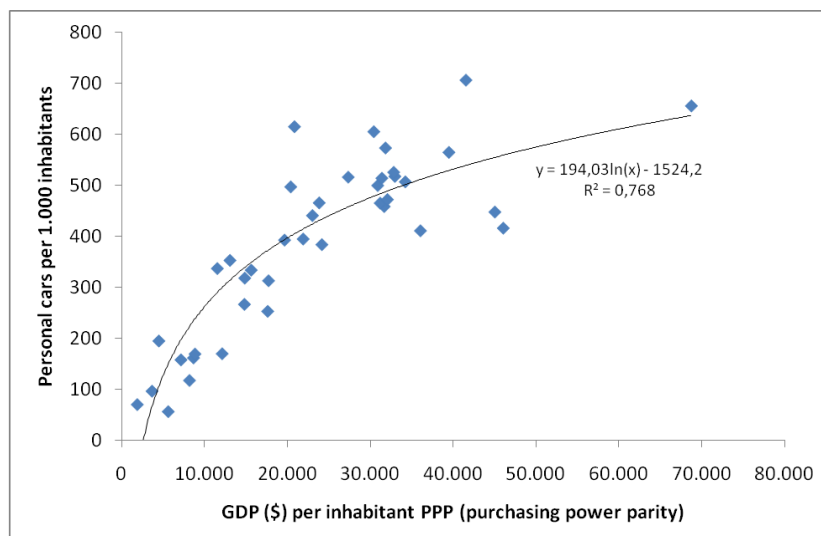

Figure 4: Correlation between GDP/inhabitant (PPP) and motorization level (cars/1.000 inhabitants); Europe
(Source: http://www.welt-in-zahlen.de)

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The overlap between the built and the organisational factors as well as energy prices drifting by increasing purchasing power requires the inclusion of those parameters into future forecasts.

Special attention has to be paid to two aspects:
- The availability of the car
- usage of the car (modal split and the travel distances)

TREND IN THE U.S. AND IN EUROPE/AUSTRIA

Trend in the U.S.

The trend of the Consumer Price Index shows an average annual growth rate of about 4 percent (about 3.5 percent in Austria).

The financial crisis in the year 2007 and 2008 can be traced in all countries to a certain extent. Problems for the private households arise from lower growth rates (namely the CPI) as well as from disproportionate growth of the energy prices, e.g. (see Figure 5)

During the past decades, the average share of transportation in the total budget of private households has only slightly increased – due to the growth of nearly all expenditure categories – and still ranges from 15 to 16 percent. While the share of "transportation" remained below 16 percent until the end of the 90s, it rose from 16.6 percent in 2001 to 17.7 in 2007.

At the same time, the share of "housing" increased from 40.5 percent (2001) to 42.4 (2007).
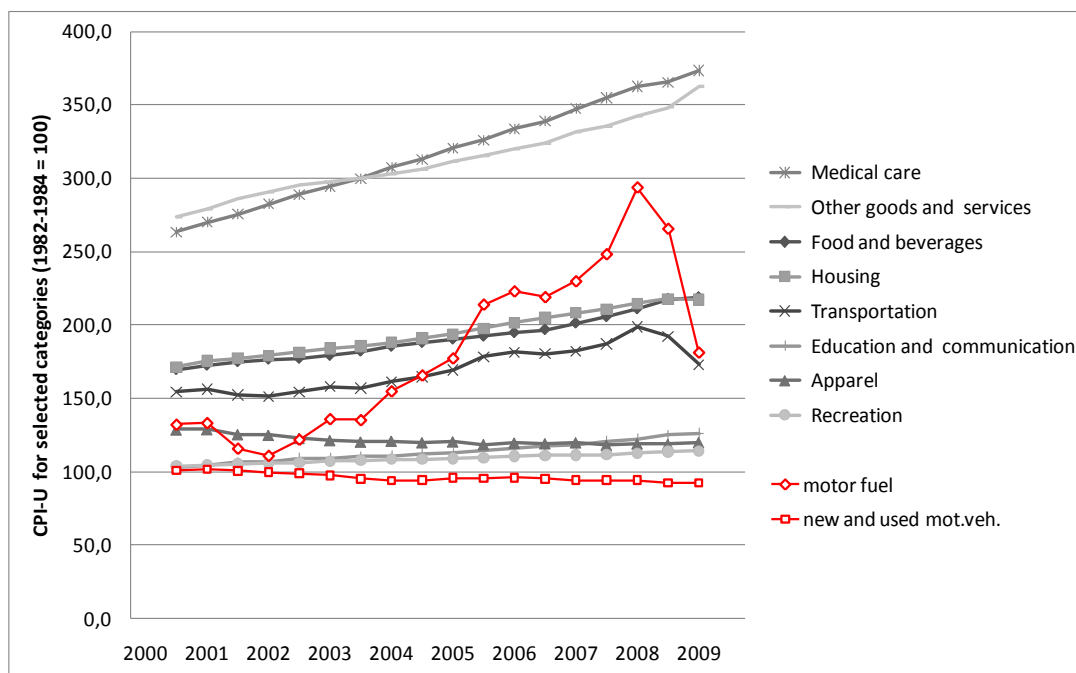

Figure 5: Trend of selected expenditure categories index (half-year, basis = 1982-1984) (Source: Consumer Price Index for All Urban Consumers (CPI-U): U.S. city average, by expenditure category and commodity and service group, CPI-U; US Department of Labor)

A detailed view at the "transportation" category shows that the share of "motor fuel" in the total expenditure has more than doubled from 2.6 percent in 2001 to 5.5 percent in 2007 (Figure 6). A compensation mechanism within the expenditure category "transportation" can be observed, aiming at the perpetuation of the total share. The index of the category "private transport" only increased by 1,3 percentage points between 2001 and 2007.
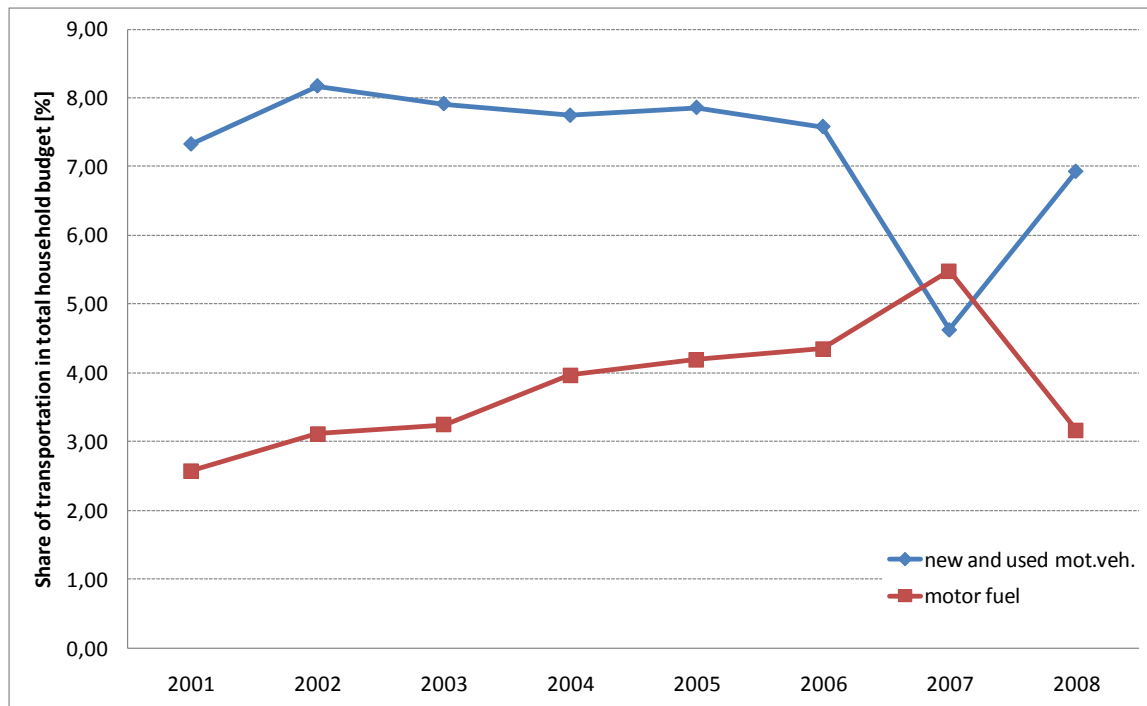

Figure 6: Share of expenditure categories in the total household budget (Source: Consumer Price Index for All Urban Consumers (CPI-U): U.S. city average, by expenditure category and commodity and service group, CPI-U; US Department of Labor)

The growing share of the "motor fuel" expenditures in the total household budget since 2001, and the rocketing of fuel prices in 2007 have been compensated by a reduction in the purchase of new and used vehicles. The re-decline of fuel prices in 2008 reversed this trend as the share reached the 3 percent level previously held in 2003. In return, the expenses for the purchase of vehicles rose again. Nonetheless, there is a long-ranging declining trend in this category since 2002.

The expenditure share of "transport" is correlated to parameters like settlement density, city size and the availability of alternatives (e.g. in the public transport sector). Therefore different settlement structures have to be compared with reference to the "transport" expenditures.

In Figure 7 structures with more than 1.5 million inhabitants (size A) are compared with non-metropolitan (less than 50,000 inhabitants, size D).
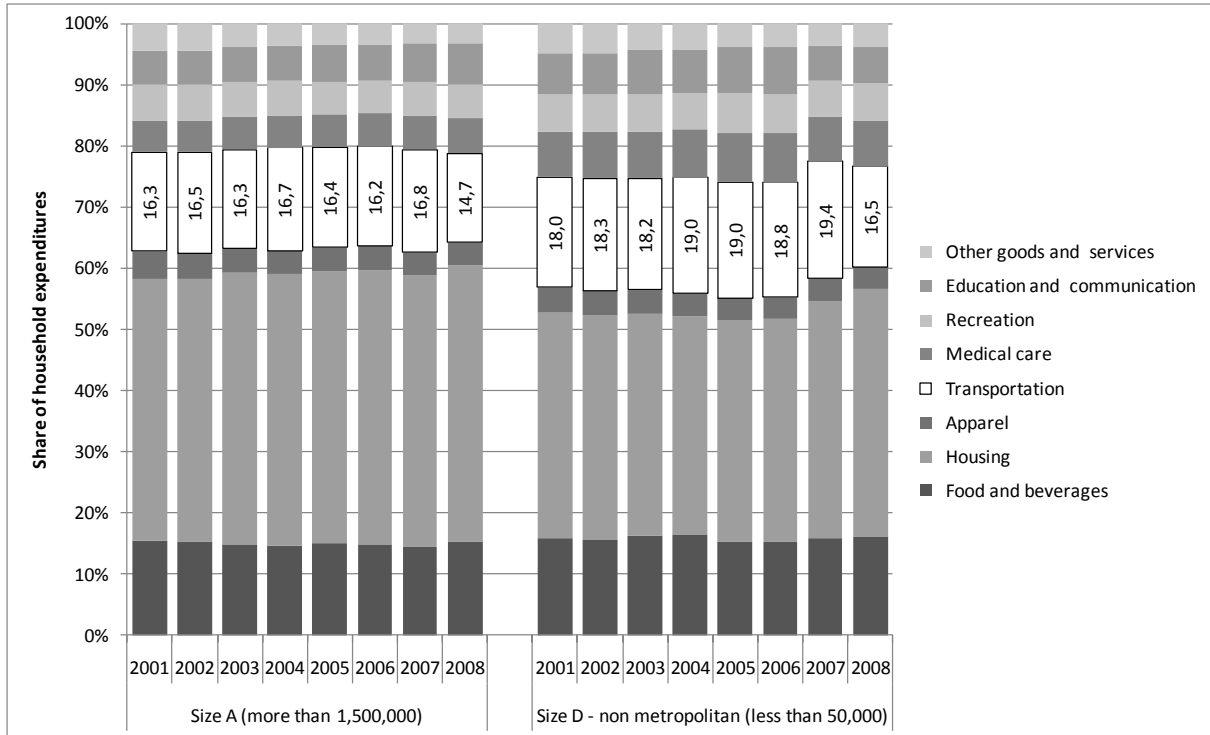
Figure 7: Relative share of expenditure categories in total household budget, different settlement structures (Source: Chained consumer Price Index for All Urban Consumers (C-CPI-I): U.S. city average; Month Dezember; U.S. Department Of Labor)

For reasons of clarity we will assume that larger cities show higher densities than smaller cities, i.e. size A is denser than size D. Proof for this assumption can be found in the US Census Bureau data (see Table 1).

In accordance with the urban and regional planning theories, the rural housing costs are lower than those in built-up areas. The difference comes to about 4.9 percentage points. However, the share of this category in rural areas has increased by 3 to 4 percent in 2007 and 2008 (compared to 2006). Strangely, the share for "medical care" is also about 2 percent higher than in cities.

Size of Urban Areas	Mean Average	Median	Cases
Over 5,000,000	4,788	4,611	3
2,500,000 - 4,999,999	3,358	3,094	11
1,000,000 - 2,499,999	3,130	2,724	22
500,000 - 999,999	2,415	2,162	34
250,000 - 499,999	2,197	1,977	55
100,000 - 249,999	2,087	1,880	131
50,000 - 99,999	1,941	1,777	195
Under 50,000	1,766	1,529	3,158
Overall: Unweighted	1,816	1,583	3,610
Weighted Average	2,404		3,610

Table 1: Size and average density of Urban Areas, US, 2000. Source: http://www.demographia.com/db-uzasizedens.htm on the basis of US Census Bureau data

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The share of "transportation" expenditures in the total household budget is of particular interest. It amounts to 14.7 percent in rural areas, being 16.5 percent in urban surroundings (+ 2.2 percentage points). Especially, the higher mileage in the personal motorized transport caused an increase in energy expenditures. The share of "motor fuel" has risen continuously from 2000 on, from 2.3 to 5.0 percent in cities (2001-2007), and from 3.1 to 6.7 percent in rural areas (+3.6 percentage points). These growth rates are in the same magnitude as those in the category "housing".

Therefore the compensation effect due to increased fuel prices occurs in higher magnitude in the rural areas in comparison to urban areas. Figure 8 also shows that the share of public transport increased more in the cities. (Compensation via the change to public transport is only possible in these areas.)
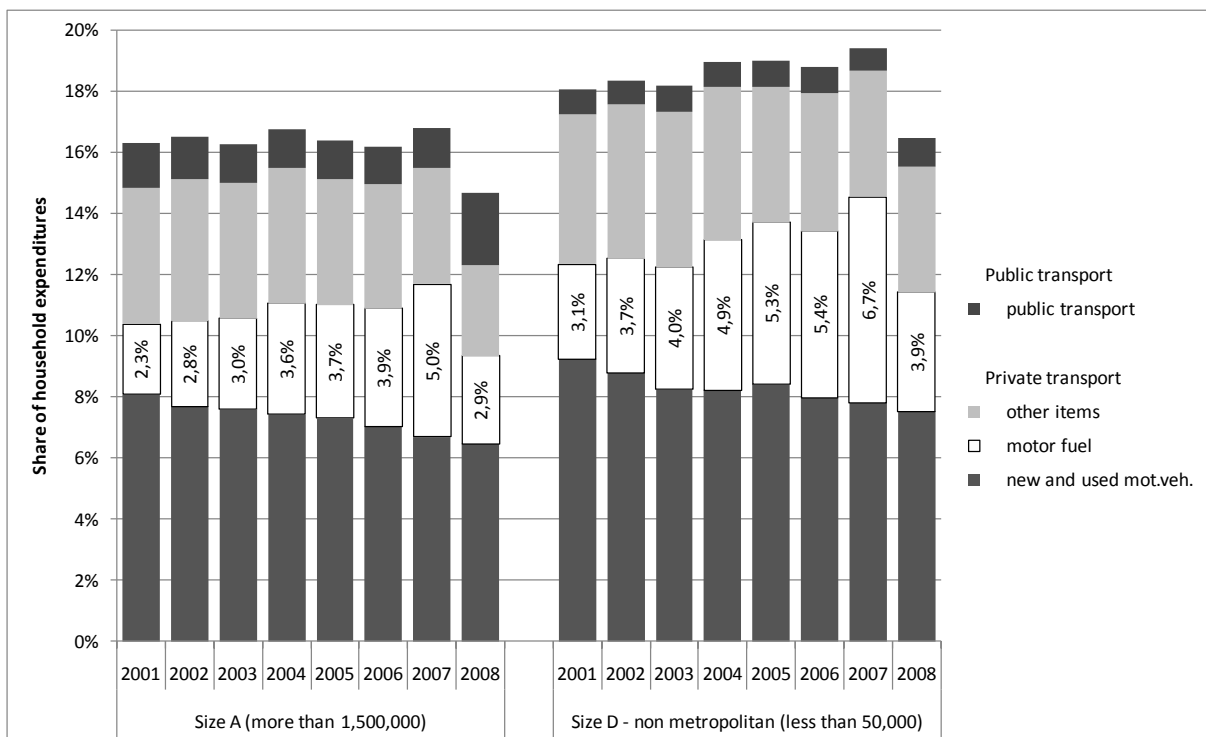

Figure 8: Absolute share of expenditure categories in total household budget, different settlement structures (Source: Chained consumer Price Index for All Urban Consumers (C-CPI-I): U.S. city average; Month Dezember; U.S. Department Of Labor)

The problems in the U.S. have arisen from the transportation as well as the housing at an equal level. Thus the elasticities in the transport sector are directly linked to the trends of the prices in other expenditure categories.

The connection between the shares of "transportation" in the household budget, the density of settlements and the population has already been demonstrated above. In general the share of expenditures for energy in the total household budget is higher in the U.S. than in European countries. Comparing the energy expenditures in dense settlement areas in Austria and the U.S. in 2005, the share in the U.S. is 7.8 percent, while only 3.7 percent in Austria (Figure 9). In sparsely settled areas the share in the U.S. amounts to 10.1 percent and to 5.3 percent in Austria. Relative differences in both countries average to about 30 percent higher energy expenditures in the areas with low population density.
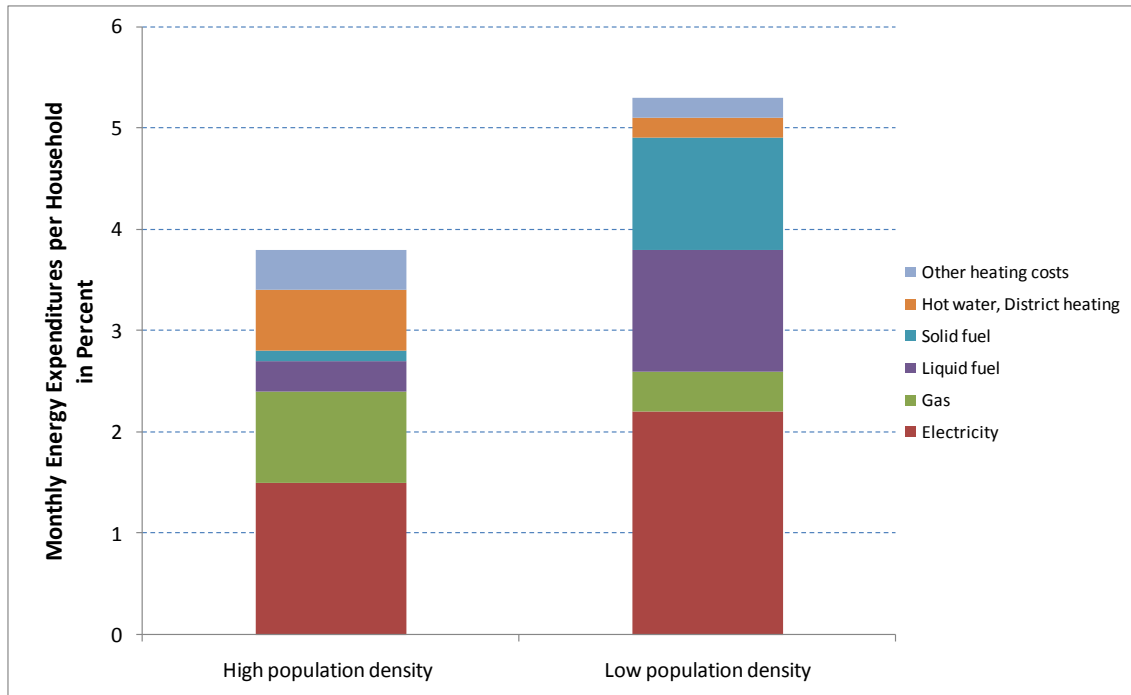
Figure 9: Monthly share of energy expenditure; comparison high/low population density (Source: Konsumerhebung 2004/2005, Austria)

The role of income / purchasing power in forecasting

As already shown in the first part of the paper, there exists an explicit connection between the income/purchasing power and the ownership of cars. (Therefore the increasing purchasing power – along with extensive infrastructure construction – is one of the main reasons for the exceeded forecasts in recent years.)

The distinct correlation between the expenditures in transportation sector and the purchasing power can be demonstrated in the U.S. as well as in Austria.

Arithmetically speaking the first quartile of private Austrian households has only 43 Euros (per month) for the purchase of vehicles at their disposal. The share of "fuels" in the total transportation budget amount is rather constantly about 50 percent, which is equivalent to about 36 Euros for these households. The consequence – as shown in Figure 10 on the right – is the low ownership level of cars. 60 percent of the households of the first quartile have no car, as well as 25 percent of the second quartile.
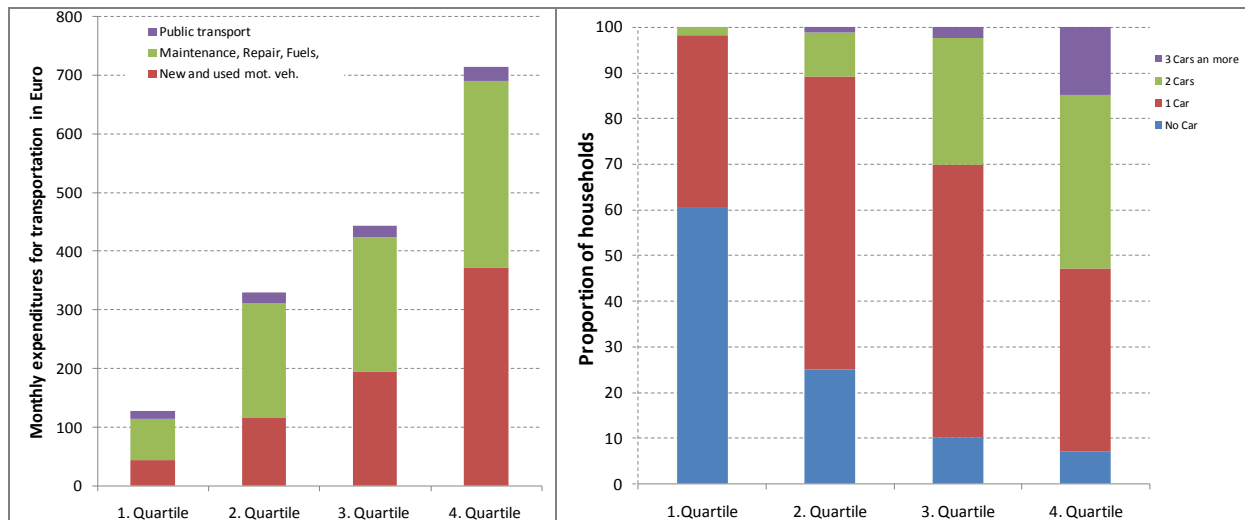
Figure 10: Left - Monthly average expenditures of private Austrian households for transportation, quartiles; Right – Percentage of car ownership, quartiles (Source: Konsumerhebung 2004/2005, Statistik Austria)

The correlation to the monthly expenditures for "vehicle purchase" as well as the total "transportation" expenditures are characterised by a high quality of regression. The negative exponential connection to the expenditures for the "purchase of vehicles" indicates disproportionately high spending for purchase of vehicles in the upper quartiles of income (Figure 11).
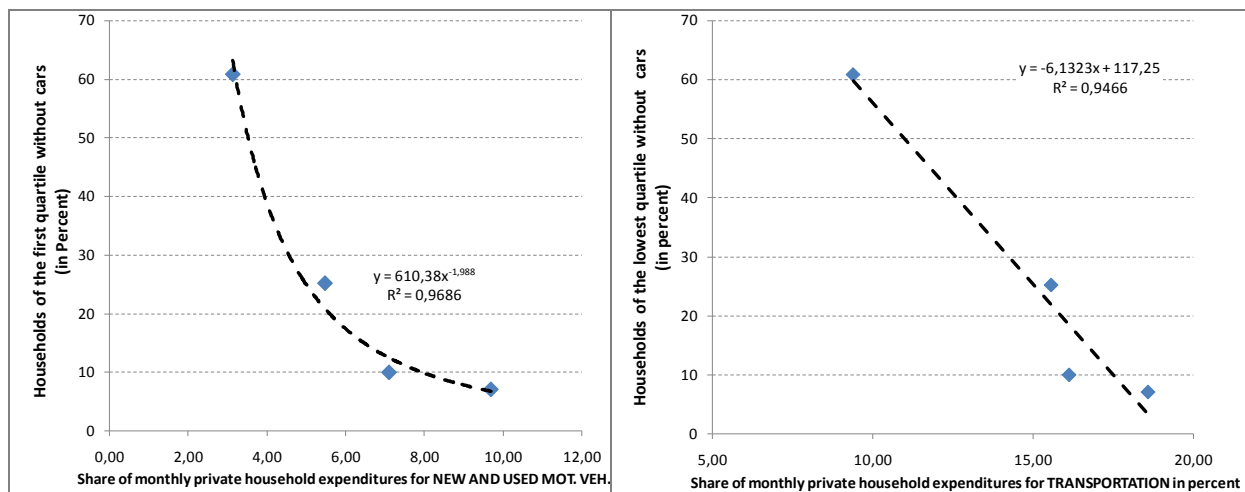

Figure 11: Left - Percentage of households without cars in relation to the share of expenditures for "vehicle purchase", quartiles; Right – Percentage of households without cars in relation to expenditures for "transport", quartiles (Source: Konsumerhebung 2004/2005, Statistik Austria)

This results in quite diverse general conditions for households, and implies diverse forecasting approaches. While the upper income classes apparently underlie the diminishing marginal utility concerning the purchase of vehicles, income is the restricting factor of car ownership for the low income households.

The gross income of the high income households has increased by 17 to 20 percent in the last decade. The middle income groups (average of 3rd to 6th decile) gained only 7.4 percent in this period, while the low income households (1st and 2nd decile) lost on average 5.2 percent of their gross income (Figure 12).
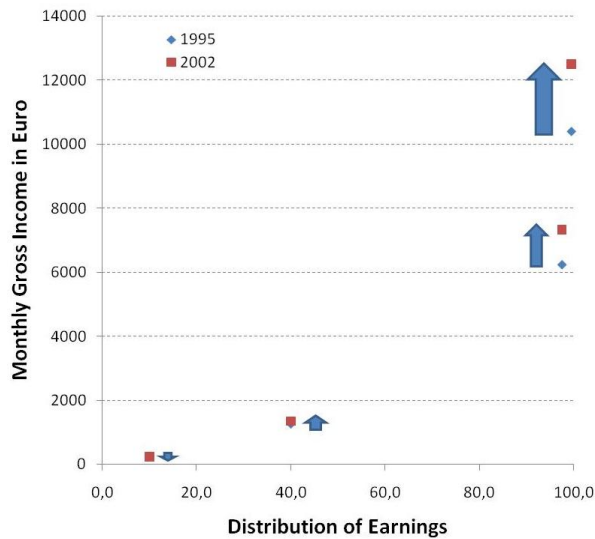
Figure 12: Gross earnings of distinct income classes, 1995-2002 (Source: Lohnsteuerstatistik, Statistik Austria)

The future trend of purchasing power will therefore be of utmost importance for the forthcoming forecasts.

The share of the transport increasingly rises with higher expenditure classes (Figure 13). However only the households in the top decile of expenditures exceed the share of 20 percent (either private households with immense capital income or captive drivers – e.g. commuters without alternatives to the car). The share for transportation of all other income groups is in some cases well below 20 percent.
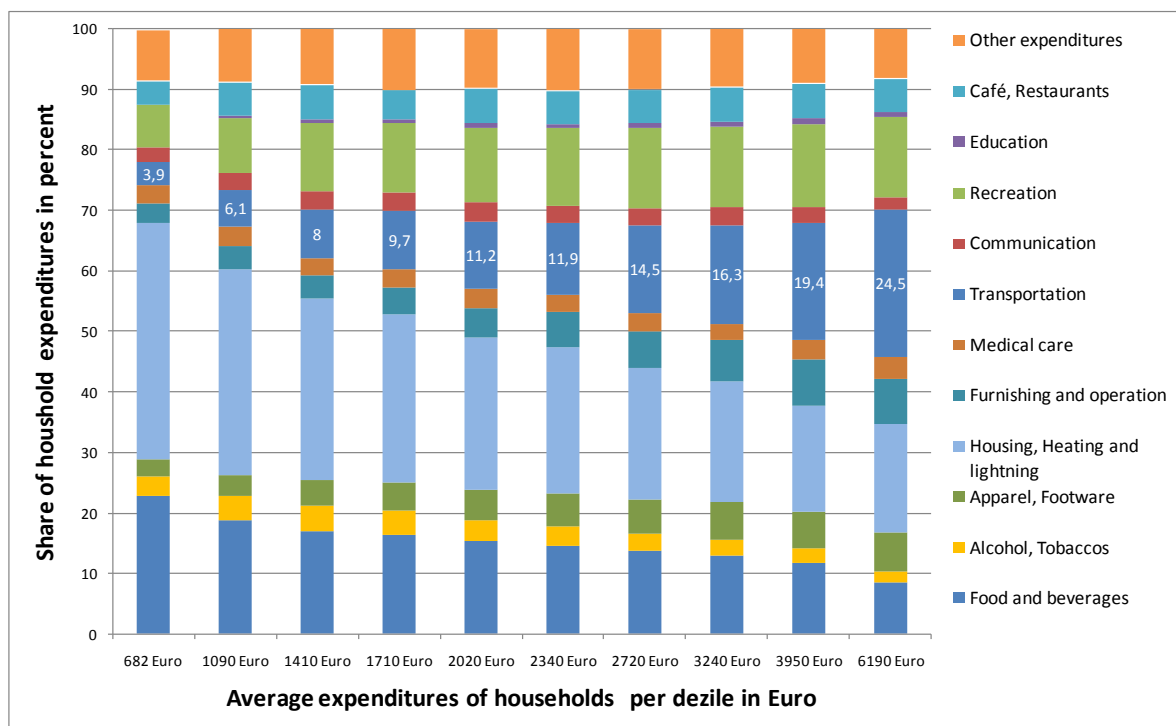

Figure 13: Share of household expenditure categories, deciles (Source: Konsumerhebung 2004/2005, Statistik Austria)

TRENDS AND FORECASTS

The trends of Consumer Price Indices show similar patterns in the U.S. and in Europe (e.g. Austria) (Table 2). The annual growth rates between 1958 an 2009 are calculated to 4.03 percent in the U.S. and 3.47 percent in Austria. Depending on the inclusion of the year 2009, the trends differ between 2.57 percent (2000 to 2008) and 2.83 percent (2000 to 2009) in the U.S. and between 1.94 and 2.12 percent in Austria, resp. Considering only the growth rates between 2008 and 2009 leads to 0.48 percent in America and 0.46 percent in Austria.

	Period	INDEX	Annual rate of growth (%)
USA	1958-2009	100,0-748,6	4,03
	2000-2008	595,9-745,0	2,83
	2000-2009	595,9-748,6	2,57
	2008-2009	745,0-748,6	0,48
Austria	1958-2009	100,0-568,5	3,47
	2000-2008	478,3-565,9	2,12
	2000-2009	478,3-568,5	1,94
	2008-2009	565,9-568,5	0,46

Table 2: Consumer Price Index, average employee household, growth rates (CPI-U, VPI) (Source: http://stats.bls.gov/data/inflation_calculator.htm)

The progression of the overall index is one of the main problems of the future trends. Figure 14 illustrates the trend as well as an extrapolation of the growth rate 2008-2009 (financial crisis) as a worst case scenario.
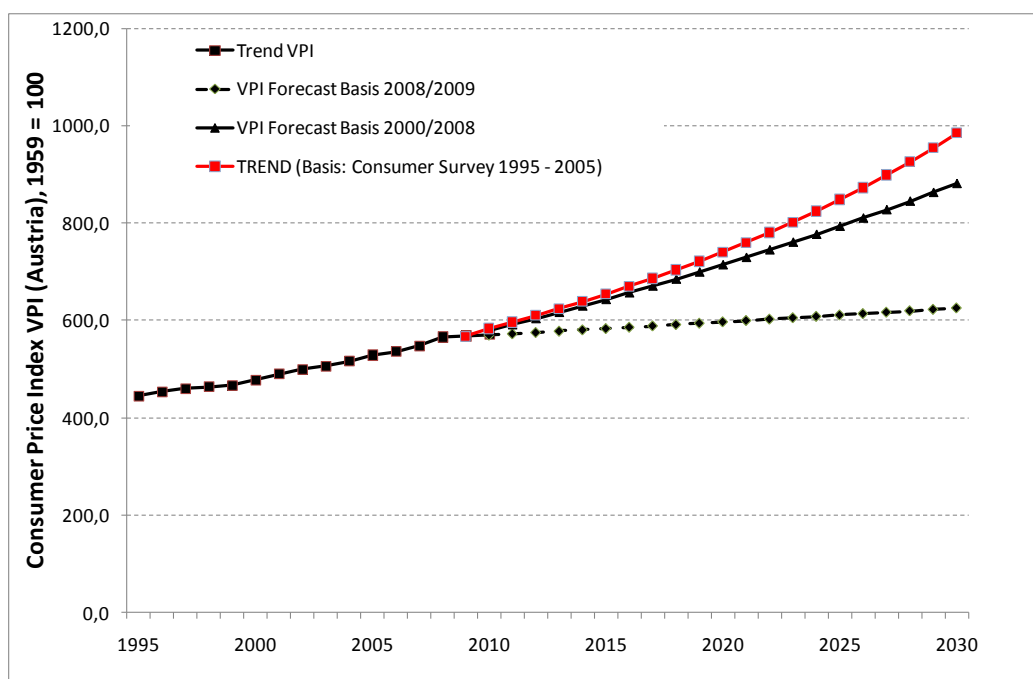

Figure 14: Trend and forecasts of the Austrian Consumer Price Index (VPI) (Basis: Konsumerhebungen 1993/1994, 1999/2000, 2004/2005) (Source: Konsumerhebungen, Statistik Austria)

A simulation of different inflation scenarios indicates that the price trends of various categories (of the consumer surveys) between 2000 and 2005 follow the growth path, which corresponds to the trend of the CPI solely. In other words – even when extrapolating the moderate inflation rates (especially of the energy prices) between 2000 and 2005, a steady

growth of incomes is necessary. Reductions of the total index will inevitably cause immediate economization and compensation needs in certain expenditure categories.

Future trends in price increases will be highest in category "housing" and "transport" due to their highest share of energy expenses.
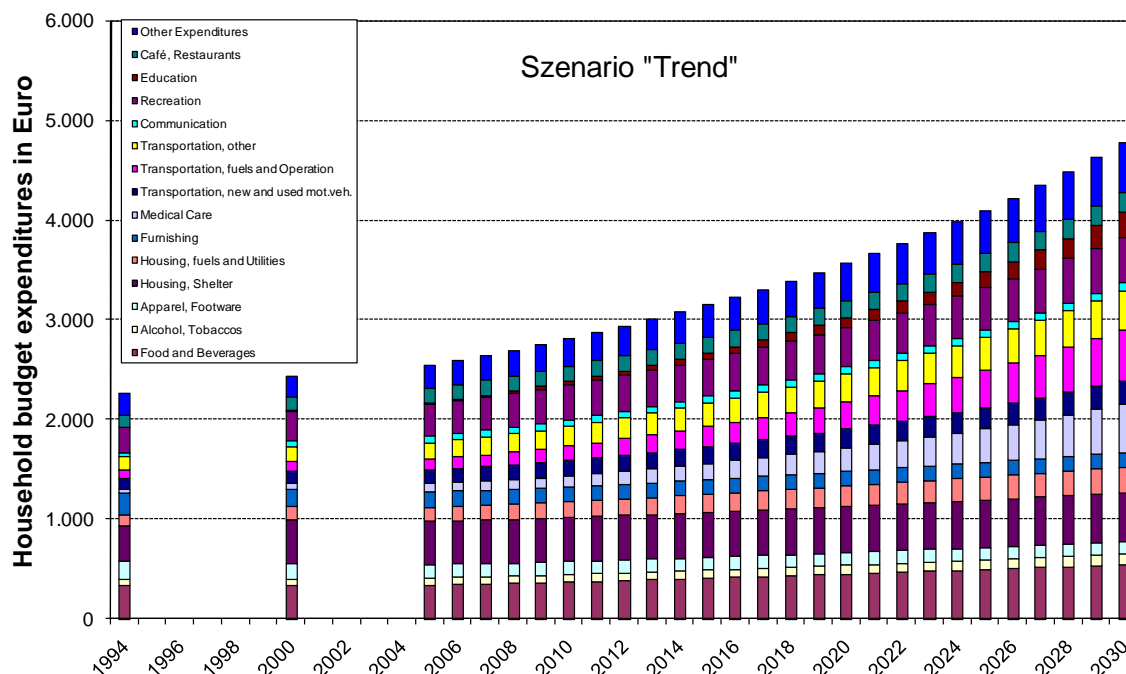

Figure 15: Evolution of average absolute household expenditure categories (Source: Basis of the trend scenario, Konsumerhebungen 1993/1994, 1999/2000, 2004/2005)

The "Trend" scenario (Figure 15) is based on the price trends for all expenditure categories collected in the Austrian consumer surveys in 1993/94, 1999/2000 and 2004/2005. The energy prices remain unchanged for the trend forecast as they showed no significant change during the observation period. Furthermore, no price declines were included in the forecast although observed in the categories clothing, shoes or household equipment.

	1995	2000	2005	2010	2015	2020	2025	2030
TREND (1995-2005)	14,34	15	16,12	17,7	19,2	20,8	22,4	23,9

Table 3: Calculated share of transport in total household expenditures, "Trend" scenario

The share of transportation in the total household budget will rise from about 17.7 percent in 2010 to 19.2 percent in 2015 and will exceed 20.0 percent from 2020 on (Table 3). From 2020 on the calculated expenses will be slightly above the trend of the overall index. As long as the index trend corresponds to the incomes on the long run, this scenario seems feasible. But if the growth of the incomes is weakened by some crisis in the financial sector, the private households will have to face serious problems and compensation needs.

In another scenario, the inflation trends of the years 2005 to 2009 were used as the basis for the forecast (Figure 16). The annual progression of the energy price index came to about 3.76 percent in this period (electricity 4.97 percent, gas 6.11 percent, crude oil 12.8 percent, domestic fuel oil -3.1 percent).

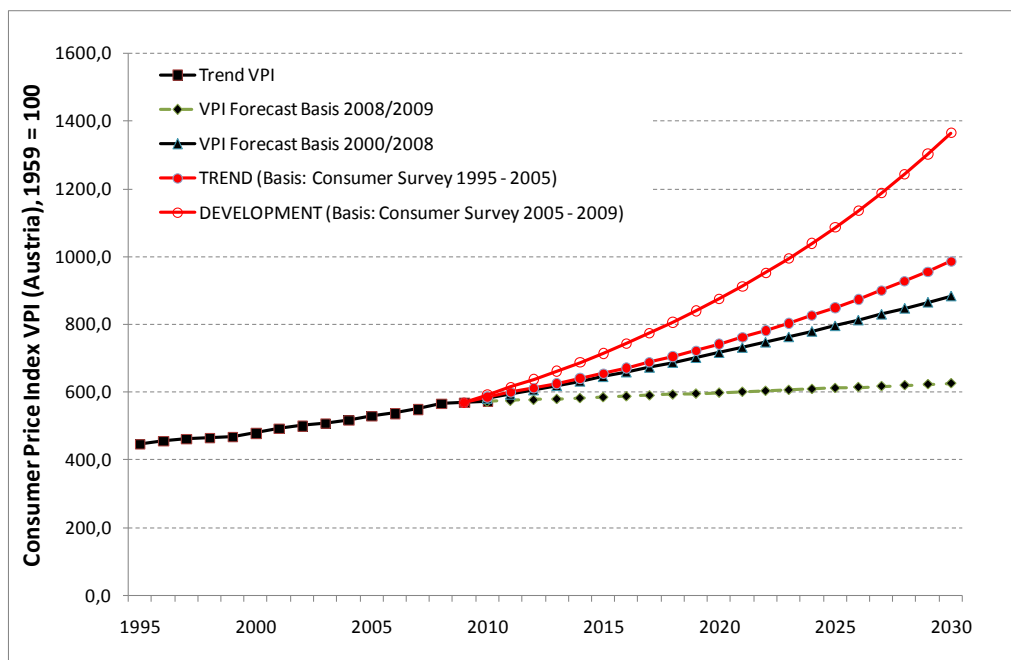*12th WCTR, July 11-15, 2010 – Lisbon, Portugal*

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Figure 16: Evolution and trends of the Austrian Consumer Price Index (VPI) ("Trend" Basis: Konsumerhebungen 1993/1994, 1999/2999, 2004/2005, "Development" Basis 2005-2009) (Source: Konsumerhebungen, Statistik Austria)

The forecast of the basis in the period between 2005 and 2009 produces increased shares of the transportation in the total household budget, which overshoot 20.0 percent in 2015 and 24.0 percent in 2020 (with considerable needs for compensation) (Table 4).

	1995	2000	2005	2010	2015	2020	2025	2030
DEVELOPMENT(2005-2009)	14,34	15	16,12	18,1	21	24	27,4	30,3

Table 4: Calculated share of transport in total household expenditures, "Development" scenario

When looking at the effects of price increases in the energy sector it makes sense to distinguish between the different income classes (Table 5).

TREND (1995-2005)	1995	2000	2005	2010	2015	2020	2025	2030
10	7,92	8,28	8,90	9,9	10,9	11,8	12,6	13,4
25	11,31	11,82	12,71	14,1	15,5	16,8	18,1	19,1
50	14,34	15,00	16,12	17,7	19,2	20,8	22,4	23,9
75	15,14	15,82	17,02	18,9	20,8	22,5	24,1	25,6
90	16,85	17,62	18,95	21,7	23,1	25,7	26,9	28,5
DEVELOPMENT(2005-2009)								
10	7,92	8,28	8,90	10	11,6	13,3	15	16,7
25	11,31	11,82	12,71	14,3	16,1	19	21,4	23,9
50	14,34	15,00	16,12	18,1	21	24	27,2	30,3
75	15,14	15,82	17,02	19,1	22,2	25,4	28,7	32
90	16,85	17,62	18,95	21,2	24,7	28,3	31,9	35,6

Table 5: Comparison of "Trend" and "Development" scenarios, calculated share of transport in household expenditures, cumulative frequencies

It is not reasonable to judge the findings without considering the purchasing power trends at the same time. Also the absolute amount of money at the households' disposal has to be taken into account, not the relative share. Thus a 15.0 percent share of transportation in the total budget of a low income household is not feasible because of increasing expenditures in other categories (heating, commodities, etc.). Therefore this income/expenditure class will have to face adjustments from 2015 on, and will have to develop some household-tailored

coping strategies. Austrian surveys indicate that in order to save expenses one primarily cuts vacation costs, and already tertiary reduces car use and automobile mobility (Source: Generali Study)

Cutbacks in the car-oriented mobility sector may imply the reduction of the purchase and repair expenses of vehicles, the switch to cheaper transportation alternatives (see fig 7 and 8 for an example from the U.S.) mainly to public transport in the urban areas, and/or the reduction of the average trip lengths.
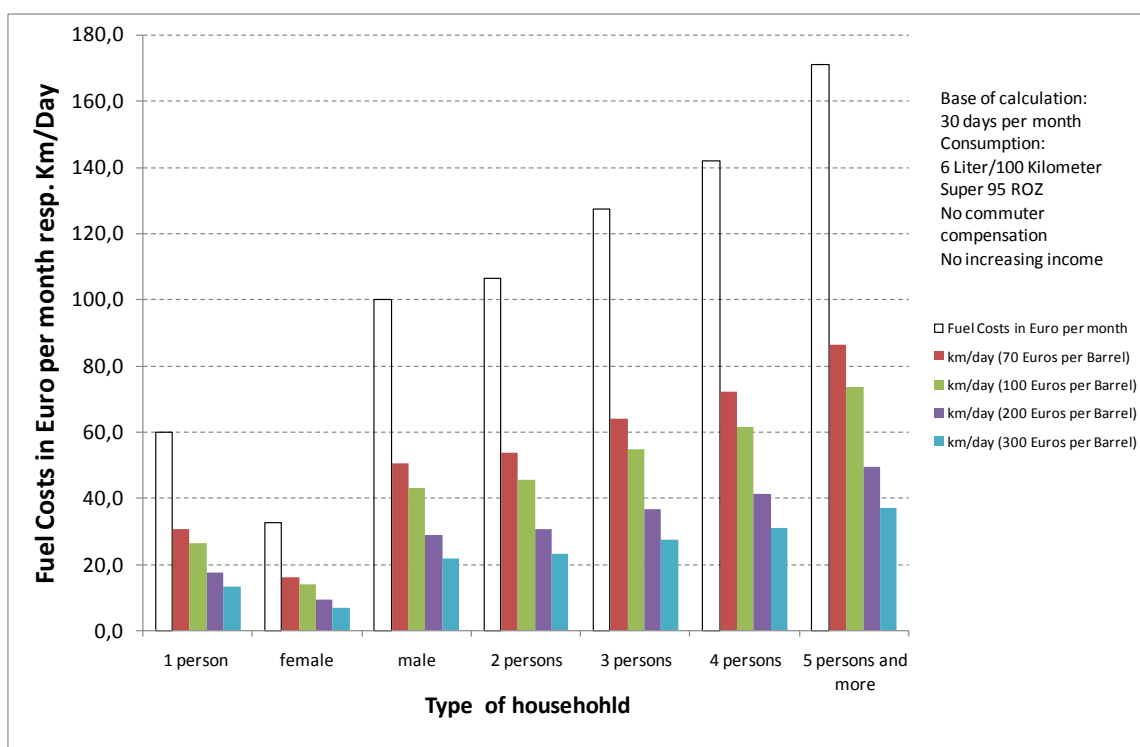

Figure 17: Calculated trip lengths per day for a variation of fuel prices (Basis: variation of the crude oil price between 70 and 300 dollars per barrel (Source: own illustration)

On the basis of the present crude oil prices and past peak prices of 150 dollar per barrel, an estimation of the oil price between 200 and 300 dollar per barrel is realistic. Price trends that exceed this threshold are not reasonable at the present time because they would result in a decline of the demand and thus in the fall of the prices (cp. financial crisis in mid-2008).
Fig. 17 shows the dramatic necessity of limitations in the trip lengths for households of different sizes. As a consequence destination changes could be thinkable for households living outside of cities. Commuters of long distances in Europe are affected as well, even though to a much lesser extent than in the U.S.

According to Austrian surveys (see also Köppl S., Wüger M. 2007) the elasticities of the transportation expenses are well above those for housing. "Vehicle purchase" holds the highest elasticities within the transportation sector, irrespective of income, population density or of car ownership. This connection can also be found in the U.S. The lowest elasticities regarding the purchase of vehicles are obviously found in households that possess no car at all. Concerning the operational costs (motor fuel, repair) the elasticities are much lower.

The elasticities in the transport sector closely correspond to the trends in the other expenditure categories. Moreover, a clear system boundary can be observed in the form that the average household share for "transportation" hardly exceeds the 20.0 percent bound. Within the threshold range, which is different depending on the income classes, the elasticities of expenses are shifting. Therefore the elasticities that are relevant for certain situation have to be based on precise groups of households (clusters).

CONCLUSIONS

Since the millennium a successive growth of fuel prices compared to the purchasing power can be noticed (and is sensed by most income groups). The growing share of transportation expenditures is becoming the restricting factor for further traffic development, and in succession of the economic development.
The analysis of U.S. data shows that the strategy of reducing the costs of an own house by building well outside the cities is being increasingly impeded by rising fuel prices. The share of "housing" in the total expenditure budget in rural areas is about 5 percentage points lower than that in urban areas. However, the "pure" share of the "motor fuel" has increased by 3.6 percentage points between 2000 and 2007. At the same time the "housing" expenses ascended. These growth rates are of the same order of magnitude as those in the category "transport", which indicates that the critical developments can be traced back to these two sectors equally.

The analysis of the income classes reveals the different access to car-oriented mobility. There is a significant correlation between the disposable income and vehicle ownership.
From the households' point of view (and subsequently of the public budget) the stagnation of incomes and an increase of the energy prices can only be dealt with compensation. Due to the fact that not only the energy expenses in the transport sector but also the expenses in all other sectors (housing, wealth) will rise, one can assume that the share of transportation will remain quite stable. The compensation strategies, e.g. via the reduction in the purchase of vehicles, are traceable.

The observed saturation tendencies of the past decades in the developed countries can be explained by an already dense grid of infrastructure. Thus every newly built section of road is subject to a diminishing marginal utility, not to forget the influence of the settlement structures (urbanization tendencies), availability of alternatives, etc. The expansion of alternatives to the motorized individual transport such as railways also diminishes the additional utility of every road building measure. These effects are intensified by the financial restrictions of the private households, which will strengthen the stagnation tendencies in the developed countries even more.

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