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Postprint / Postprint
Zeitschriftenartikel / journal article

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This is a pre-copy-editing, author-produced PDF of an article accepted for publication in **European Sociological Review** 2003, 19(3):267-280 *following peer review. The definitive publisher-authenticated version is available online at*

http://esr.oxfordjournals.org/cgi/content/abstract/19/3/267

Time and Money: An Empirical Explanation of Behavior in the Context of Travel Mode Choice with the German Microcensus*

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Whereas variance in preferences is a central explanation for human behavior in the social sciences, economists traditionally avoid using preferences to explain behavior. Rather, change in behavior or different kinds of behavior are explained solely by differences in the economic restrictions imposed on an individual. Whereas restrictions have been analyzed as monetary constraints in traditional economics, Gary Becker has broadened this term. In his work, he tried to integrate "time" – the non-monetary restriction- into the economic constraints. In our paper we test empirically the effects of monetary and time restrictions on the travel mode choice of a representative sample of the German population. We do this by means of testing some hypotheses from Becker's work on microcensus data from Germany. These data include the following variables: travel mode choice, distance of travel, time of travel as well as some additional socioeconomic characteristics. Results of introducing these additional socioeconomic variables will also raise the question if it is really true, that only monetary and time costs matter.

* This is a pre-final version which was later accepted and published by Oxford University Press under the reference: Davidov, E., P. Schmidt and S. Bamberg (2003).Time and Money: An Empirical Explanation of Behavior in the Context of Travel-Mode Choice with the German Microcensus. European Sociological Review, 19(3), 267-280.

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1) Introduction.

In the empirical social sciences, preferences have a key role in explaining behavior. Psychologists use the term “attitude” rather than “preference” as a construct, which explains behavior. They evaluate the positive or rather negative attitude of individuals towards an object. For example see Ajzen/Fishbein (1980) and Ajzen (1991), or its implementations, as for example in Bamberg and Schmidt (1998).

Sociologists use socio demographic characteristics as well as different opportunity structures and differing historical conditions to explain behavior. They believe, that not only historical, social and political conditions impose restrictions on behavior. Rather, personal and socio demographic characteristics play also an important role (see for example, Semyonov, Lewin-Epstein and Davidov (2002) for the explanation of differences in housing values among immigrants to Israel).

What is obviously common to social scientists is the way individuals are analyzed. Individuals are basically perceived as different human beings with different needs and ambitions, thus with different preferences. These individuals face different alternatives, acquire different resources and choose the best alternative of behavior according to their both preferences and abilities.

Economists as well assume, that preferences play an important role in the explanation of behavior. The individual evaluates his alternatives of behavior, his restrictions and

the costs, and finally chooses rationally the best alternative according to his preferences. However, economists assume (in modeling as well as in practical empirical research) that all individuals have the same preferences. Thus, empirical research in economics is mainly concentrating in the differences of measurable monetary restrictions imposed, since according to this assumption only different restrictions will lead to different behavior (Stigler and Becker, 1977; Simon, 1985).

Simon (1985) and Opp (1999) argue, that human rationality is limited, and therefore one finds empirical evidence for violations of rationality. Simon suggests, that many of these deviations could be explained by taking into account the limitations of the human brain. Differences in choice could account for different tastes, different restrictions but also to different cognitive abilities, since we rather investigate a *Homo psychologicus* than a *Homo economicus.*

Opp (1998) and Simon (1985) call to pursue the hard work, which is often not done of testing rational action theory empirically. Furthermore, as Goldthorpe (1998, p. 52) has pointed out, in present-day sociology rational action theory and the quantitative analysis of large-scale data sets are pursued largely in isolation from each other (see also Blossfeld and Prein, 1998). This paper will try to bridge this gap by testing a rational action theory using a large-scale data set from the German microcensus of 1996.

In our empirical analysis, this criticism of economists on the manner social scientists try to explain behavior is taken seriously. We will test changes and differences in behavior in the context of the rational choice of travel mode, car or public transportation on the way to work. After a short description of the theoretical importance of monetary and time restrictions, we formulate empirically testable hypotheses about the influence of monetary and non-monetary restrictions on travel mode choice. In the next section, we test empirically these hypotheses using logit analysis. Finally we summarize the main findings and discuss the relevance for Becker's theory and for empirical tests of rational choice in general.

2) Theoretical Background

Micro- and macroeconomic theories deal intensively with the influence of the attribute "price" on the economic behavior. Price is the value that a vendor receives in return to his product from the buyer or the customer, since the price of this product presumably represents its quality. During the purchase, the buyer must use financial means from his income in the size of the price of the product. People can buy products whose prices cannot exceed their total income. Hence, the influence of the attribute "price" on the economic behavior rests on the income restriction.

In the context of traditional consumer theory (Deaton&Muellbauer 1980; Maier&Weiss 1990; Varian 1984), the monetary prices of the different means of transportation constitute determinants of the choice of transportation by individuals. Consequently, private car users could be persuaded from the economic perspective to

use more ecological public means of transportation by using the “price” instrument. Measures such as gasoline taxation or road taxation are expected to reduce the use of the private cars. Alternatively, reductions of the prices of public transportation by means of a monthly ticket or a reduced student ticket for instance are expected to increase the use of public transportation.

So far several studies have shown that neither the pure factor of price nor that of income have a significant effect on the decision of the used means of transportation (Domencich &McFadden 1975; Hensher & Dalvi 1978; Held 1982; Ben-Akiva & Lerman 1985; Erke 1990; Molt 1990; Bruederl & Preisendoerfer 1994; Diekmann 1994). Alternatively, these studies have shown, that factors such as duration of travel, socioeconomic and socio-demographic characteristics such as age, family size, gender, education and professional status have a strong influence on the means of transportation choice. Apparently, the explanation of the choice of means of transportation lies not only on one context such as the monetary costs and the income. These critics of the economic approach to explain behavior point out, that it is easier to explain the choice of travel mode on the basis of empirical findings by individual differences in motives, norms and sociological characteristics which can all represent preferences, than by differences in financial restrictions.

According to Becker (1965), the weakness of traditional consumer theory to explain behavior rests not on the lack of consideration of differences in preferences, but on the lack of consideration of other non monetary restrictions in addition to the

monetary restrictions. Becker suggests, that “time” becomes a clear factor and resource, when households are considered not only as consumers, but also as producers. Households produce basic commodities (Becker, 1965), such as “a nice apartment”, “leisure-time experiences” or “healthy nourishment”, in which they comply with cost-minimization rules of producer’s theory, and use “time” as an input. The price of the basic commodity, which is produced in the household, is regarded as the sum of the price of this product in the market and the price of the invested time.

How can time be quantified? Time is limited, and has a value for every consumer, which evolves from its scarcity. Differently from money, time is a resource, which cannot be saved, but rather reallocated. Time can be spent by doing specific activities rather than doing other ones. Becker divides the time one has to “working time” and “non working time”. Since in recent years the non-working time has grown in many countries, the allocation and efficiency of it have become more important for economic welfare than that of working time. Only a limited part of the non-working time is spent for necessary activities such as eating and sleeping. When the income increases, the opportunity costs of the time increase as well, because every hour spent on leisure rather than work becomes more expensive. A reaction to such an increase might be for example saving time of preparing food by buying ready made (and sometimes more expensive) food products.

In Becker’s words, “households will be assumed to combine time and market goods to produce more basic commodities that directly enter their utility functions. One

such commodity…depends on the input… and time. These commodities will be called Zi and written as

$$Zi=fi(xi, Ti)\text{……..}(1)$$

Where xi is a vector of market goods and Ti a vector of time inputs in producing the ith commodity… when capital goods such as… automobiles are used, x refers to the services yielded by the goods" (Becker 1965, p. 495). Fi is the individual production function[1]. As Becker points out (p. 510), "The transport field offers considerable opportunity to estimate the marginal productivity or value of time from actual behavior". In our case, fi could be referred as the production function of traveling to work (Zi), where time (Ti) and market goods such as traveling in public transportation means or in the private car are the inputs (xi) of the function. People "combine time and market goods via the "production functions" fi to produce the basic commodities Zi, and they choose the best combination of these commodities in the conventional way by maximizing a utility function" (Becker 1965, p. 495).

In this way, Becker constitutes a substitution between money and time. Time is money and money is time. By using time, money can be saved, for example by repairing problems in the water canalization by oneself, and by using money time can be saved, for example by inviting a plumber to do that job. In this manner, time has value that can be expressed by money, and alternatively money has value that can be expressed by time.

Implications for the use of transportation

According to Becker's paper, we suggest to regard transport as a production process, in which a household combines "market commodities" that are restricted by his income, and time that is restricted as well, in order to maximize his utility. The total cost of transport is thereof the sum of the direct cost (the monetary cost) and the indirect cost (the time expressed by monetary units).

Since the direct monetary costs of daily transport are usually relatively small whereas they are time consuming, the total cost of transport (which includes the time-cost component) will significantly change and be influenced by the duration of travel. We will demonstrate it with an example, given by Bamberg (1996). Let us assume that traveling a 15 km way to work lasts 50 minutes with the bus and 20 minutes with a private car. The costs for using the bus are 18 cents per kilometer, and for the private car are 36 cents per kilometer. If a person earns 10 Euros per hour, his costs using the bus would be 11 Euros and for using the car 8.7 Euros although the direct monetary costs of using the car are higher. In such a case the monetary costs themselves would not be a good explanation for the travel mode choice, but the duration of travel or the velocity could very well be one.

As mentioned before, several studies have shown that socio-demographic and socioeconomic variables have an influence on the choice of travel mode. Whereas

these studies suggest, that these effects represent differences in preferences of different individuals, Becker suggests that they reflect differences in the money and time restrictions. Now we will refer to some possible effects according to Becker between socio-demographic characteristics and travel mode choice mediated by the time use.

- The effect of income on travel mode choice.

According to Becker, basic commodities produced by a household cost more when they are more time consuming. Following this, change in the time cost of such a product would produce a stronger increase in the total cost of a product. People would tend to substitute in that case the time consuming product with the product with higher direct monetary cost, which is less time consuming, especially if their income increases.

Public transport, which is usually more time consuming, becomes more expensive in relation to the car when the income per hour increases, even though the monetary costs of the bus and the car remain the same. With a higher salary, one will continue to use the bus if either the duration of bus travel decreases or its direct cost decreases to compensate for the increase of the time price. Otherwise, one would substitute the time consuming public transportation with the time saving car.

This can explain the increase in the last years of both income and gas use. The increase in income has caused a substitution from the time consuming public

transportation to the time saving private car. Education, age and professional status can all be reflected in the income, and therefore serve as indirect effects on the travel mode choice. In that sense, higher education, and an age range somewhere after schooling and somewhere before retirement can all reflect higher income and a higher tendency to use the car[2].

- The effect of gender on travel mode choice.

The finding that women use the bus more frequently than men could be explained by time costs of the members of the household. The one who earns the highest amount of money per hour is the one from the point of view of efficiency, who should lose the least time for transportation, because transportation time is most expensive for him. Therefore the members of the household would let him use the car, assuming there is only one car in that household. If only one of the people in the household takes part in the labor market, it would be most efficient that he/she would use the car, because his/her transport costs would be the highest. Since in Germany there are still many women who earn less than men (see for example Diekmann, Engelhardt and Hartmann, 1993), it is clear that his time cost would be the highest, and therefore he would be the one to use the car.

- The effect of marital status on travel mode choice.

Another implication of Becker's paper is the influence of marital status on travel mode choice. The finding that married people tend to use the car more than the public transportation can be explained by different time costs. Being married usually

involves activities that singles are not obliged to do, such as spending time at home together with the partner or taking care of other members of the household. These obligations consume time, and thus time outside of work spent by married people becomes scarcer, and more valuable. Traveling with the car becomes cheaper relatively to the time consuming bus, and therefore car becomes their preferred choice[3].

We believe this is not a full explanation, and in order to better account for the processes involved in the choice of travel mode one has to build bridge assumptions (Kelle & Luedemann, 1998). Bridge assumptions (or auxiliary hypotheses in Simon, 1985) reflect mechanisms, which relate socio-demographic characteristics, such as gender, marital status and age to behavior, and in our case to travel mode choice. They may serve as additional explanations to the one offered by Becker relating to time costs and income differences. As considering only time and monetary costs as valid restrictions is typical for the narrow version of rational choice (Opp, 1999), offering other explanations serves the wide version of rational choice as a theoretical basis to explain behavior. However, our critique on Becker's approach is empirically oriented, and we will suggest such alternative bridge hypotheses, which reflect a wider version of rational choice in the discussion section.

In the literature we find studies based on regression analyses to explain travel mode choice. For example, Franzen (1997) showed based on environmental surveys in Germany (see below), that the difference in time and money costs of public

transportation and car rather than the absolute costs are better determinants of travel mode choice. He also found how important the factor "comfort" has been for the decision whether to choose public transport or car. However, these findings have not been based on a systematic development of a formal rational choice model in the form of a production function for example (see also Diekmann and Preisendoerfer, 1998), but are results of regression analyses. These findings have also not been applied to transform and improve a systematically developed rational choice model so that it will include these findings, and in this way serve as a better model. Therefore they may not necessarily link rational choice and large-scale data analysis.

Other sources of data to be considered for the purpose of testing a rational choice model are environmental surveys in Germany (e.g. Diekmann, Gautschi, Franzen and Preisendoerfer, 1996). There are some deficiencies in these surveys. First, they are not representative, and include a few thousand respondents. What is a little more bothering is the selection bias, as the response rate is less than 50% in some cases. In 1996, 1,095 out of 1,680 sampled households in former western Germany (65.2%) and 1,212 out of 1680 sampled households in former eastern Germany (72.1%) were actually analyzed. Indeed, in a comparison we have conducted between the 1996 environmental survey and our data from the same year, we have found significant differences in the travel mode choice (modal split), especially in the choice of car and car joining and in walking, which might severely affect computations. Some significant biases are also reported by the environmental survey in socio demographic characteristics. Variables, such as marital status, size of household (with significant

over-representation of one-person households), gender and education are heavily biased (for details see Diekmann, Gautschi, Franzen and Preisendoerfer, 1996 p.8-9). The advantage of the microcensus data is its representative sample of the entire population, and the fact that people are forced by law to participate and respond to the questions (a zero percentage of non-response), thus reducing selection bias. In this way we address the call for alliance between official data and rational choice and enrich the data analysis giving better data estimators. As our main goal was modest, trying to test Becker's rational choice model of time and money and do it with large-scale data analysis, we found the microcensus data most adequate for that goal.

Narrow models of rational choice, such as the elegant models suggested by Becker, are indeed clear and sharp in their theoretical explanation. However, they have not been extensively tested empirically, and therefore may not always suggest a thorough explanation as we find in our analysis because they may not be validated. Some other variables than those mentioned in some "narrow" rational choice models, like sociological variables such as gender and age (and possibly others we could not use here) may have strong additional explanatory power via additional bridge assumptions.

3) Data.

We will now report the analysis of the travel mode choice for the way to work of individuals with data obtained from the German microcensus. We will especially

focus on the possible effect of external restrictions, especially time restriction, rather than the influence of preferences, on the travel mode choice.

The German micro census collects data on individuals residing in Germany once a year, and contains a randomized 1% data of the total population (approximately 800,000 cases). Once in four years data about travel mode choice are collected, and the last available are from 1996 (for further documentation see Luettinger and Riede 1997; Schimpl-Neimanns 1998). We analyzed a randomized 1% of the data available from the German micro census because this was sufficient for our purpose. As we are interested to analyze travel mode choice of working people, we concentrate in our analysis only on people who go to work. As we can see in Figure 1, 61% of the people who travel to work use their private car and another 4% accompany them. About only 13% use public transportation (bus, underground, tram and train), 1% of the people use a motorcycle to go to work, 9% use their bicycle and approximately 11% walk to work.

Insert Figure 1 about here

As data in the German micro census on travel time and distance of travel to work is categorical[4], we had to convert these values into continuous values, and therefore presumed that each category had the middle value of its original category. In other words, for the variable “distance to working place” category 1 received the value “5 km”(3.1 miles), category 2 received the value “17.5 km” (10.9 miles), category 3

received the value “37.5 km” (23.3 miles) and category 4 received (arbitrarily) the value “60 km” (37.3 miles) (as there is no data available on the distribution of distances for those people reporting a bigger value than 50 km (31.1 miles)). For the variable “duration of travel to working place” category 1 received the value “0.08” (which equals to five minutes), category 2 received the value “1/3” (which equals to 20 minutes), category 3 received the value “0.75” (which equals 45 minutes) and category 4 received the value “1.25” (which equals 75 minutes) arbitrarily (as there is no data available on the distribution of time to work for those reporting a value “more than one hour”).

Our dependent variable is travel mode choice for going to work. In the data, people reported different means of transportation for their way to work, including for example underground, train, bus, private car (alone or as an accompany), bicycle and walking. We decided to define our dependent variable as a car user or as a public transportation user for the following reasons: (1) it is our main interest to check what could divert the mass of people using their private car into using public transportation, which is in most cases the available alternative, as jobs are in many cases not in a bicycle or walking distance; (2) we received unacceptable values for the “velocity” variable for bicycle users and people who walk. These velocities were much higher than reasonable for walking or for riding the bike. It could happen possibly because of inaccurate values either reported by the individuals (who are likely to be less aware of the time because they have no train to catch) or due to our arbitrary transformation which affected mostly the extreme values for time (walking

or riding the bike may have lasted longer than driving or using the train) and thus bringing inaccurate value for the velocity variable. Therefore, we decided to neglect bikers and people who walk; (3) car and public transportation users constitute the biggest group of travelers (approximately three quarters). As a result, our defined dependent variable is “car user” which is 1 if individual uses the car on his way to work, and zero if he uses public transportation, namely, underground, tram, train or bus (all other cases are filtered).

We calculated the “velocity” variable by dividing the “distance to work” variable with the “duration of travel to work” variable, thus creating an index, which incorporates both time and distance components. As it is the efficiency of the use of time rather than its absolute number, which reflects how costly or effectively time is used, we concluded that time costs would be best measured and represented as an empirical variable by the velocity of the means of transportation. Monetary costs are represented in this case as the opportunity costs of time.

The income variable was given in categories. Therefore, we followed the same procedure as for the variables “distance to work” and “duration of travel to working place” by taking the middle value of each category. For the last category (income is 3,750 Euros or more) we followed again what we had done before, and gave it a value of 4,000 Euros arbitrarily (as there is no data available for the distribution of income for the people earning more than 3,750 Euros). We calculated the number of hours worked per month by using the following procedure: we applied the available

variable “normal number of hours worked per week” and multiplied it by four (assuming 4 weeks of work per month). By division we received the “income per hour” variable. As the highest 20% earn 9,50 Euros per hour or more, and we are interested to know whether level of income has any effect on travel mode choice we created a dummy variable: “income 9,50 or more?” receiving the value of 1 for people earning 9,50 Euro per hour or more and 0 otherwise (it enables us to create an interaction variable multiplying it with the velocity variable).

We defined “age square” as the “age” variable given in the micro census data with the power of two. According to the data, young and old people tend to use public transportation more often than others, which justifies using a nonlinear variable for age. The “Higher education” variable receives the value 1 for people completing studies beyond high school, and 0 otherwise[5]. “Gender” receives the value of 1 for men and 0 for women “Velocity X income 9,50 or more” is the interaction term between the variables “velocity” and “income 9,50 or more?”. Thus, this variable will receive a velocity value only for people earning a high salary, and zero otherwise. In this manner, we can test whether higher velocity has a stronger effect on the tendency to use private car on people earning more per hour. The “Marital status” variable receives the value of 1 for married people, and zero otherwise.

4) Descriptive Overview

In the following section we give a short description of our data. As we intend to analyze only working people who travel to their working place either with a car or by

public transportation, all other cases are excluded. In that way, the number of cases reduces to N=1,742. Table 1 presents the average and standard deviation of the variables in the analysis.

Table 1 about here

As can be seen in Table 1, approximately 35% of the sample of working people earns 9,50 Euros or more, and about 82% use a car on their way to work. The average of the overall income per hour of working people in the sample is 9.17 Euros/hr. 61% of the working people are males and the same percentage of people are married, and approximately 20% of them have obtained higher education. The average age is 38.5. As expected, the average velocity of cars (43.1 km/hr) is significantly higher than the average velocity of public transportation on the way to work (30.1 km/hr). The average velocity in general is 40.7 km/hr.

Becker's theory implies, that any differences in income per hour between different socio demographic groups should be responsible for different choices of travel mode due to different time costs. Thus, before checking whether there is any effect of different socio demographic groups like gender or age on travel mode choice, we check whether these groups differ in income per hour in our sample. After all, it could be the different income they represent, which is responsible for the differences in travel mode choices and not the sociological groups. For this purpose, we test whether there is a significant difference in the variable "income 9,50 or more?"

between males and females, between married and unmarried, between people who obtained higher education and people who did not and between the different age groups. Later on we test if these groups differ in travel mode choice.

As table 1 describes, approximately 66% of the people who obtained higher education earn 9,50 Euros per hour or more, whereas only 30% of the people who did not obtain higher education earn that much. Significant differences in earnings are observed among the other groups as well. Whereas 41% of the married people and 44% of the males earn 9,50 Euros per hour or more, only 24% of the unmarried and only 20% of the females do so. As for the relation between age and income per hour, in a correlation analysis we find a significant 0.247 (N=1,672) correlation between the variable “income 9,50 Euro or more” and age, and a significant 0.225 correlation between “income 9,50 Euro or more” and the age with the power of two variable. Therefore, whereas different sociological groups are indeed correlated with income significantly and therefore representing different income groups, this correlation is not so high, and there is still some independent explanation for sociological factors and for income. We will return to this point in the multivariate analysis.

The next question we ask is if there is any significant difference in travel mode choice between different socio demographic groups. As can be seen in table 1, males and married people use a car on their way to work significantly more than females and unmarried (89% and 85%; 71% and 78% respectively). Different categories of the variable “higher education” and the variables “age” and “agesquared” show no

special pattern with their relation to the variable “car user”. Is the difference in car use within some of our socio demographic groups related to their difference in income, or rather to other traits imbedded in the socio-demographic group? According to Becker we ought to expect it to be related only to the difference in income and time costs. A multivariate analysis might give us an answer.

5) Multivariate Analysis.

In the following section we would test the hypotheses evolving from Becker’s theory[6]. We would expect to receive the following results:

(1) Due to the fact that resources are limited, we expect people to maximize their utility in their decision process, in such a way that they would choose a travel mode, which would waste the least out of their limited time and limited money. In our research we concentrate on the time restriction. As the “velocity” variable incorporates both the distance component and time of journey component, this would be our indicator of the time use, so that the higher the velocity, the more efficiently time is used. As cars are faster than public transportation, we expect people with higher income per hour to tend to use the more time efficient travel mode, namely the car. We also expect that the effect of velocity on choosing the car is stronger for the high-income group.

To put it precisely:

H1) we expect a positive and significant coefficient of velocity on car use;

H2) we expect the interaction term velocity X income 9.5 or more to have a positive and significant effect on car use.

(2) According to Becker's theory, there should be no direct effect of socio-demographic characteristics on travel mode choice, but only indirect via the time restriction. As different characteristics such as gender, age, marital status or education are expected to be reflected by different income per hour, different time costs are expected to take over, and be the main forecast for travel mode choice. However, as we saw the correlations between income and sociological factors are significant but not high, we suspect sociological factors by themselves have an additional explanatory power for travel mode choice.

To put it more precisely:

H3) we expect the variable gender to have a significant effect on car use after controlling for velocity and for velocity X income 9.5 or more.

H4) we expect the variable age squared to have a significant effect on car use after controlling for velocity and for velocity X income 9.5 or more.

H5) we expect the variable family status to have a significant effect on car use after controlling for velocity and for velocity X income 9.5 or more.

We test our hypotheses in a series of logit models using SPSS. In each model, the dependent variable is the travel mode choice: car or public transportation. The results are presented in table 2.

Table 2 about here.

In the first model we test whether velocity has any effect on travel mode choice. We find out a positive and significant relation between velocity and car use (.0305). Indeed, the higher the velocity, the higher the probability that the used travel mode is the car. This confirms once again our expectation, that car is the faster mean of transportation in our data. In the next step we are going to test, whether this has any effect on travel mode choice over different income groups.

In model 2, we test hypothesis 2, whether the interaction effect between velocity and the variable “income per hour 9,50 Euro or more” has a significant effect on travel mode choice. As table 2 presents quite clearly, both velocity and the interaction effect between income per hour and velocity have a positive and significant effect on travel mode choice (.0263, .0127 respectively). This means that the high-income group has a higher tendency to use the car than the lower income group.

Finally, we test whether socio-demographic characteristics have any effect on travel mode choice. In model 3, we add to the independent variables velocity and interaction between velocity and “income per hour 9,50 Euro or more” the variables gender, marital status, age with the power of two and higher education. As table 2 indicates, the results of model 3 contain several interesting points. First, velocity has a remaining positive and significant relation to car as the preferred travel mode. Second, all socio demographic variables except higher education have a significant direct effect on the dependent variable. In other words, males and married people are significantly more likely to choose the car to travel to work than females and

unmarried people. Age with the power of two indicates a small, negative and significant effect on the dependent variable. Namely, in younger and older ages it is less likely that people in our sample would use a car, but it is more likely they would do so when they are in a middle age. Obtaining higher education has no significant effect on travel mode choice.

Finally, after including socio demographic variables to explain travel mode choice to test hypotheses 3, 4 and 5, the interaction term between income per hour and velocity becomes insignificant. In other words, as higher and lower incomes are already reflected in several socio demographic variables, the effect of the interaction between high income and velocity becomes insignificant. Whereas the Cox & Snell R^2 was only between 5% and 6% in models 1 and 2, and it improved to 8.3% in the third model. The Nagelkerke R^2 was 8.6% in the first model, 9.5% in the second model and improved to 14.4% in the third model.

6) Discussion.

In this paper we have restricted ourselves to maintaining three goals. First, we suggested testing a well-established theoretical model of behavior of Becker, questioning whether time in addition to monetary costs affects behavior in the context of travel mode choice. Second, we tried to test Becker's theory by using large-scale data from the German micro-census of 1996. Third, we checked whether socio-demographic characteristics have any effect on behavior after controlling for economic restrictions. As Green and Shapiro claimed (1994), proponents of rational choice seem to be most interested in theory elaboration, leaving for later or others the

messy business of empirical testing. We tried to bridge this gap between rational choice theory and large-scale data analysis by testing an important rational choice model, which has not been seriously challenged so far.

Becker has been trying in his work to formulate a theory, which could explain any behavior, in the economic market, in choice of partners, in family relations and in social discrimination in the form of production functions. We have tried to test a special case in this theory, in respect with the decision whether to choose the car or the public transport on the way to work. As a theoretical framework, we drew out of his strongly and elegantly formulated theory testable hypotheses, in order to check how well his explanations work in a practical problem. Specifically we wanted to check if restrictions rather than preferences affect choices, and whether the effects of socio demographic characteristics, which may represent preferences in addition to time cost differences according to Becker, disappear, when objective restrictions as time costs are introduced in the empirical test. In formulating the hypotheses, we were confronted with the question how to model time costs. Velocity incorporates two important factors to compute efficiency of time use, namely the duration of travel and also the distance. As it is the efficiency of the use of time rather than its absolute number, which reflects how costly or effectively it is used, we concluded that it would be best measured by the velocity of the means of transportation.

As theoretically expected, there is a significant effect of the time cost, reflected by the interaction term between higher income and velocity, on the travel mode choice in

our sample of the German microcensus. As car is the faster mode of transportation, the more costly is the time, namely, the higher the income per hour, the higher the positive effect of higher velocity on the tendency to use the car on the way to work. This confirms the theoretical expectation of Becker, that time has a value, and thus an effect on choices in time consuming daily activities, and particularly also on travel mode choice.

However, we could not confirm the second implication from Gary Becker's work, that all socio demographic characteristics are reflected by different time costs. We suspected we would find a significant effect of some sociological characteristics on travel mode choice. In our findings, marital status and gender had a significant and overwhelming effect on travel mode choice. In addition, the interaction term of income per hour and velocity became insignificant[7]. Women, indeed, use more public transportation as well as unmarried people. We found no direct significant effect of education on travel mode choice, which may be explained by the fact that maybe it is indeed strongly reflected by differences in time costs between the different education groups. Age had a very small but significant effect on travel mode choice, reflecting a higher car use for the middle age group. It may as well be explained by the fact that time cost differences may well represent the different age groups. To check it, we ran an OLS regression of income per hour on the variables age squared and education, and indeed, both coefficients were highly significant. Although females and unmarried earn less money per hour than married people and males, their socio

demographic status overwhelmed the effect of their lower time cost on travel mode choice.

Indeed, in such a case, in order to have a better explanation of behavior, we must turn to other disciplines, and construct “bridge assumptions” (see for example Kelle and Luedemann, 1998). According to one of the interpretations, bridge assumptions (or auxiliary assumptions as termed in Simon, 1985) link a theory with observational terms, thus formulating alternative explanations. It would make sense here to suggest bridge assumptions between gender and marital status on the one hand, and the sociological processes, which account for the chosen travel mode on the other hand, as gender and marital status had an overwhelming effect on the travel mode choice. Indeed, one such explanation concerning gender could relate to differences in technical affinity between men and women (see for example Pasero et al., 2002 or Wajcman et al. 1994). A stronger technical affinity for men could account for an additional factor affecting a higher tendency of men to prefer the car as a travel mode regardless of their time costs. Another explanation concerning marital status could relate to the finding, that married couples tend to live in less urban areas, where public transportation use is less feasible or parking is less of a problem (see for example Lichtenberger, 1998, p.318 for the case of Vienna). In general, married people have also more children in the household than non-married. In such a case, a need for higher flexibility (which serves as an additional constraint) would affect a higher tendency to use the car. These explanations would serve as additional bridge assumptions to those of income and time cost differences between males and females

or married and unmarried people suggested by Becker. Additionally, they suggest according to Simon (1985) how other variables are related to preferences and utility. They could indeed bridge the gap regarding the influence of these socio economic characteristics on travel mode choice and serve as an additional plausible explanation for choosing a travel mode.

When we think of possible other explanations for the findings, we may suggest at least two. We received relatively low percentages of explained variance even in the third model. The highest explained variable we received was 14.4% (Nagelkerke). It may well be the case, that there are other economic and social-psychological factors, which may explain travel mode choice and nevertheless we did not include in our models since they were not in hand in the German data of the micro census[8]. An example of such a variable is the availability of a car. Many studies show, that car availability is a central variable in transportation research, and may reflect both the socio demographic characteristics that we included in the analysis and other ones. Indeed, males, married people and people in the middle age group tend to have an available car more than females, unmarried and young or old people (e.g. Hautzinger 1996). Once one owns a car or has one in hand, the tendency to use it is usually higher[9]. However, this problem cannot be easily solved outside a new design of the questionnaires. As users we can either employ the microcensus with all its obvious limits, or rather use another data set. However, we do not have any data set, which is equally suitable in Germany to fulfill and address the call of Goldthorpe (1998) for an alliance between official data and rational choice theory. The drawbacks (like a

selective sample) of other smaller surveys, such as the environmental surveys in Germany, have been previously discussed in this paper, especially their low response rate and their being far more biased than the microcensus data set. Future large scale data research might try to address these issues, like indeed some experimental studies already do by applying social psychological theories such as the theory of Planned Behavior to explain travel mode choice (see for example Bamberg and Schmidt, 1998, 2001) and testing them in smaller scales of data. In these studies, the explained variance is much higher. Another point, which we wish to mention, is that there might have been problems in the operationalization of the time costs. Maybe the arbitrary assignment of values for the extreme categories has led to inaccurate application of personal time costs. However, only 37 out of 1,742 had an income on the highest level, only 60 cases had a distance longer than 50 km and only 120 cases out of 1,742 needed more than one hour to go to work, and consequently the great majority of values used in the analysis are not arbitrary. Omitting cases with these extreme categories might cause another kind of bias to the data. As one of our main purposes was testing the theory, the data in hand was adequate to conduct an empirical test of the model.

Some practical implications can be drawn from our analysis, also as to what social groups are to be addressed in order to bring more car drivers to use public transportation. Apparently, it is quite a sociological question what makes people use public transportation, and what makes them rather use the car. These social mechanisms (such as place of residence or technical affinity) are to be explored more

deeply, in order to find the dynamic processes, which lead some groups to a more ecological behavior in respect to travel mode choice.

When we try to model a rational behavior, the question which model to choose and which factors to incorporate in the model relates quite often to whether rational choice should be modeled and tested in a narrow version in which only objective factors such as time and money are taken into account (Preisendorfer, 2000), or in a wide version, in which subjective social-psychological as well as sociological variables should be taken into account (Opp, 1999). Our critique on Becker's approach is indeed empirically oriented. However, Becker is considered as a proponent of the hard (narrow) rational choice version according to Opp. As there are other versions of rational choice, such as the wide one as Opp defines it, it could be that the model of Becker is not sufficient. Indeed, Simon (1985) criticized Becker of making a lot of untested assumptions, but those criticisms were ignored. Our work demonstrates quite clearly, that behavior might be influenced by many different factors and explanations via bridge assumptions. It is an empirical question to be tested which factors are relevant, and whether narrow or wide rational choice is the right behavioral model. As we want to get as close as possible to a good explanation of behavior, we can conclude that for a synthesis, instead of constraining a model only to objective economy oriented explanatory factors, one should let it include in advance different theoretically based explanations from different disciplines to be tested empirically.

Figure 1: Distribution of travel mode on the way to work of the sample-modal split[10] (N=2,343)

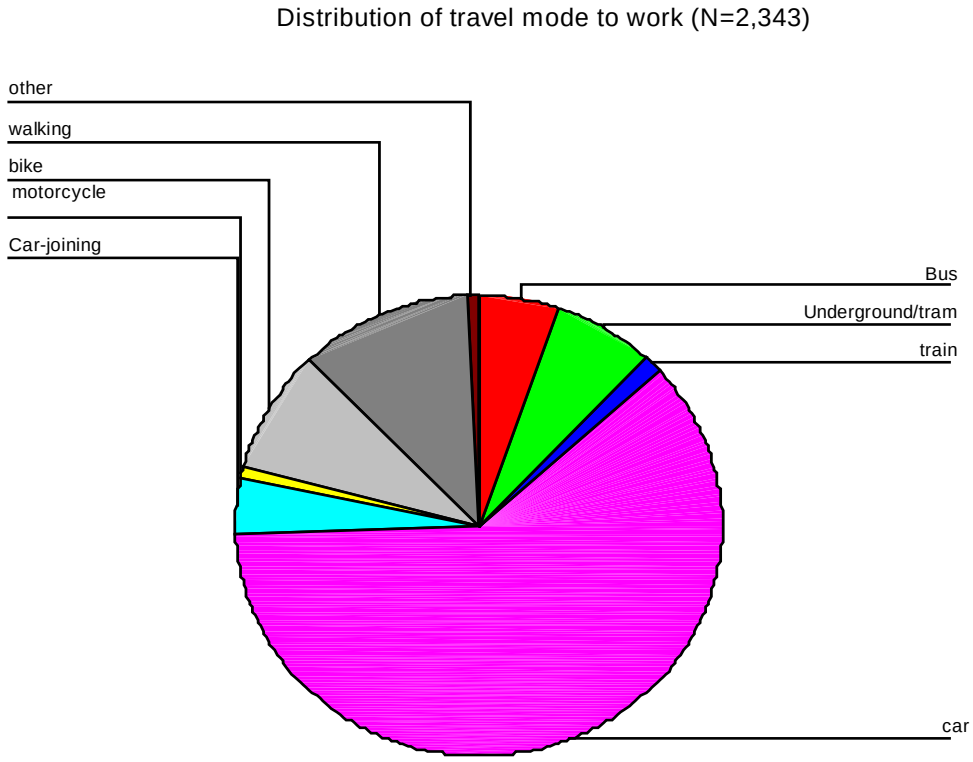

Table 1: Descriptive Overview of Variables in the Analysis (N=1,742)

Variable	Description	Mean	Stand. Dev.	Mean For groups higher education=1 and 0	Mean For groups marital status= 1 and 0	Mean For groups gender =1 and 0	Mean For groups higher education=1 and 0
Income per hour		9.17	6.17				
income 9.5 Euros or more?	1=yes, o=no	0.35	0.48	0.66*, 0.30*	0.41*, 0.24*	0.44*, 0.20*	
Car user	1=yes, 0=no	0.82	0.38				0.88, 0.84
Gender	1=male, 0=female	0.61	0.49				
Marital status	1=yes, o=no	0.61	0.49				
Higher education	1=yes, o=no	0.20	0.40				
Age	Continuous variable	38.5	11.4				
Velocity (for all means of transp.)	In km/hr	40.7	23.2				
Velocity (for car)	In km/hr	43.1	22.6				
Velocity (for public transport)	In km/hr	30.1	22.8				

* Significantly different from one another.

Table 2: Logit Models to Explain Travel Mode Choice (Dependent Variable is "Car User?") (Standard Error in Brackets).

Variable	Model 1	Model 2	Model 3
Velocity	.0305** (.0034)	.0263** (.0035)	.0242** (.0042)
Velocity X income 9.5 or more?		.0127** (.0040)	.0057 (.0048)
Gender			1.0351** (.1610)
Agesq			-.0002* (.00008635)
Family status			.356* (.1657)
Higher education			.1932 (.2152)
Constant	.4194 (.1258)	.3993 (.1276)	.3041 (.2311)
-2 Log Likelihood	1,528.768	1,479.793	1,071.045
Goodness of Fit	2,738.251	2,125.904	1,510.138
Cox & Snell R^2	.053	.058	.083
Nagelkerke R^2	.086	.095	.144
N	1,726	1,656	1,392

* P<0.05, ** P<0.01

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Notes:

[1] For a discussion of production functions see for example Lindenberg 1996.
[2] Unfortunately we do not have enough details about professional status in our data, since the indicators of the type of profession one is occupied with are too general.

[3] The effect of profession on travel mode choice.
It is interesting to note, that another implication of Becker's paper is the influence of professional status on travel mode choice. In this sense, time costs are reflected not only by income. People such as pensioners who get their money not by the hour but as a lump sum have a lower time cost than people who are employed and paid by the hour. Therefore we find, that older people tend to use more public transportation, even when they have an available car. For these people time does not play an important role. The relative costs of using public transportation decrease significantly, and make it their preferred choice. However, as we analyze only working people, we exclude this group from our analysis.

[4] The categories for the variable "distance to working place" in the micro census are 1."below 10 km", 2."between 10 and 25 km",3. "between 25 and 50 km" and 4. "50 km and more". The categories for the variable "duration of travel to working place" in the micro census are 1. "below 10 minutes", 2."between 10 and 30 minutes", 3."30 minutes up to one hour" and 4."one hour and more".
[5] We considered creating more categories for the education variable. However, since we had no data about number of studied years we could not create an interval variable. Additionally, the categories given for education in our data are not ordinal. Therefore, we are satisfied with having only a dummy variable for the categories higher education or not.
[6] The hypotheses are deduced from Becker's theory, but he does not form them explicitly.
[7] We performed a correlation test between the interaction term and each of the other explanatory variables. The correlation was significant but never more than 0.25 with each of the socio demographic characteristics. Therefore we assume, the result implies a true overwhelming effect of sociological characteristics.
[8] We tried to add an income per hour variable in the analysis in model 3, but it turned out to be insignificant.
[9] We asked the German Central Bureau of Statistics to include this variable in future questionnaires.
[10] Modal split is defined as the distribution of travel mode choice in transportation research.
[11] Acknowledgements: The first author would like to thank the DAAD for their financial support. The authors would like to thank Nadia Granato for very helpful comments. We would also like to thank Juergen Hoffmeyer Zlotnik, our participants in the Bounded Rationality seminar conducted in Giessen University in June 2002, the transportation group including Andreas Diekmann, Ben Jann and Axel Franzen in the sociology Institute in Bern and Julia Iser for for helpful comments.