

**Money talks: developing activity generation models based on time
and money allocation**

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Abstract

Activity-based travel demand models have become state-of-the-art over the last decade. A crucial assumption of these models is that travel is to be understood in the context of participation in activities. As a consequence, activity participation and time use have become important issues, resulting in the development of models in these respective domains. An issue that has received limited attention is how and to what extent monetary budgets impact on the decision to engage in activities and the time spent in them.

Activity generation models include household income in the explanatory variables, but do not describe how trade-offs in the allocation of monetary household budgets lead to prioritizing one activity over another. Micro-economic models of time allocation account for monetary budget constraints, but make limiting assumptions about the monetary input per unit time allocation. Typically, it is assumed that one time unit of activity participation requires a constant (across individuals) amount of money to be input.

There are several reasons for trying to describe the impact of monetary budgets on activity participation and time use in a more comprehensive way. First, changes in household income are probably the key factor underlying the structural changes in travel behaviour we have witnessed over the past decades. Hence, insights in how additional income is spent on various purposes, and how expenditures for travel are traded off against consumption or housing, can help us to predict structural changes in travel behaviour due to expected changes in income per capita. Second, increasing diversification in lifestyles implies that assuming fixed expenditure rates associated with activities is a too limiting approach, and that instead the expenditure rate is a deliberate household decision taken such as to fulfill particular household needs.

To deal with the above issues, this paper proposes a random utility maximisation model of the allocation of time and money (household income) on the household level. It assumes that households aim at allocating time to activities such that the overall utility is maximised. The utility derived from activity participation is, however, affected by the allocation of money. In this respect, it is assumed that the allocation of money not only depends on the available income, but also on specific preferences associated with a household's lifestyle and attitudes.

The paper proposes a model specification and demonstrates the impact of changes in monetary budgets in numerical examples. In addition, a simplified version of the model is tested on a 1998 Dutch database containing data about households' time use and expenditure patterns.

1. Introduction

Over the past decades much work has been done on developing models of how activity and travel patterns emerge, how much time is spent in activities and travel and how activities are organised in space and time (Arentze and Timmermans, 2004; Bhat et al., 2004; Roorda et al., 2007). An important notion in most of these studies is that time constraints, combined with travel times implied by the geographical location of activity sites, play a major role in decisions about activity engagement, activity duration and location choice (Kitamura, 1984; Ettema, 2005). On the constraints side, time geography (Hagerstrand, 1970) provides a formal framework to describe the options for activity engagement given the locations of activity sites and the travel options provided by the transportation system (Burns, 1979; Kwan, 1999; Miller, 1999, Weber and Kwan, 2003). However, even within these available options, individuals will make decisions as to whether to engage and how much time to spend on various activities, which will impact on the timing of trips. Moreover, constraints-based approaches in geography tend to be based on the realistic assumption that activity-agenda are fixed and do not allow for adaptation.

To address this issue, time allocation and participation models have been proposed, that are based on the assumption that spending time in activities yields utility (but with decreasing marginal returns) and that durations are chosen such that utility is maximised, subject to constraints. (Bhat and Misra, 1999; Ettema, 2005; Kitamura, 1984). Hence, both theoretical and operational models are available to predict how changes in the transportation and geographical context lead to changes in activity participation and duration.

Given the attention that has been given to conceptualising and modelling time constraints and time allocation, the relative neglect of monetary constraints on activity participation and duration is remarkable. It could be argued that time has a more direct limiting effect on activities on a given day and that the usual focus of researchers is on daily activities. Yet, availability of monetary resources may allow one to acquire facilities needed for activity participation (car, membership etc.) or to directly spend money on activities (seeing a movie, eating out). Therefore, it has been recognised since the sixties (Becker, 1965; Evans, 1971), that monetary constraints play a major role in decisions regarding activity participation. Obviously, many activities require direct or indirect input of money. The fact that income is limited and money can be spent only once then implies that the way in which money is spent is

related to the participation in activities. Existing activity and travel models recognise the impact of monetary constraints in an indirect way by incorporating income as an explanatory factor in models of activity participation and duration in much the same way as socio-demographic variables. However, this practice does not reflect the fact that the limited availability of money necessitates trade-offs regarding activity participation. In particular, if the monetary budget is limited, not all activities may be engaged in with the desired frequency and duration. To some extent, existing econometric models of time use address this issue since they assume that time is allocated to activities subject to both a time and an income constraint (Becker, 1965; Jara-Diaz, 1998; Munizaga et al., 2006). To operationalise this notion, it is typically assumed that activities have a fixed consumption rate of goods and/or money. Time needs then be allocated such that the total expenditure to activities does not exceed total household income. Although the Becker-Jara-Diaz framework provides a useful framework for describing time allocation under monetary budget constraints, we feel that it has some limitations if we are to predict longer term changes in the allocation of time and money to activities and travel.

The most salient limitation is the assumption that activities have fixed consumption rates of money and goods. In this paper, we argue that lifestyles are increasingly important in decisions about time use and expenditures. As a consequence, the input rate of money into activities (or goods) depends on lifestyle, reflecting differences in values and attitudes. For instance, even with the same income, different households may decide to invest different amounts of money into an activity of similar duration, such as eating out. Ettema (2009) provides evidence that expenditures are related to specific household characteristics and preferences, such as size of social network etc. Stated differently, the expenditure rate per activity (in euros/minute) is not given but is a deliberate decision made by the household in accordance with its lifestyle.

Treating the expenditure rate per time unit in a more flexible way is particularly important if we are to predict changes in time use and activities over longer time horizons, during which incomes may structurally increase (or decrease). If incomes increase, this implies that more money can/will be spent on activity participation. This may be done by spending more time in more expensive activities that produce a higher utility. Alternatively, however, more money can be invested in activities, such as to increase the utility gained per time unit of that activity. In this

respect one can think of the eating out example mentioned earlier, but also about investing more in the home location as a place for family and leisure activities, spending more money on hobbies etc. If the attractiveness of an activity increases by investing more money in it, it is likely that more time is spent on it. Thus, the impact of increasing income on time use depends on a household or individual spending more time in more expensive activities, but also investing in the quality of activities. The net effect is then dependent on the extent to which the utility of different activities is sensitive to the input of money. Ettema (2009) indeed finds that with increasing income the additional money is not equally spent on all activities.

In the context of the above discussion, this paper proposes a model to simultaneously describe the allocation of time and money to activities. The model builds on existing time allocation models such as Bhat and Misra (1999) and Ettema (2005), but accounts for the fact that the input of money in activities may structurally increase the utility of activities, which in turn affects time allocation. The paper is organised as follows.

2. Model

2.1. Utility of time and money allocation

Our model departs from existing time allocation models. It is assumed that the utility V_j derived from spending time t on activity j is given by:

$$V_j = \alpha_j \ln(t_j) \quad (1)$$

where α_j reflects the attractiveness of activity j . Next, it is assumed that individuals intend to maximise the utility of their daily activity pattern by allocating time to utilities in an optimal way. In doing so, individuals face the constraint that they are only able to allocate a maximum amount of time T to activities. Given that there are J activities, this leads to the following general optimisation problem:

$$\begin{aligned} \text{Max } V &= \sum_{j=1..J} \alpha_j \ln(t_j) \\ \text{s.t. } \sum_{j=1..J} t_j &= T \end{aligned} \quad (2)$$

It is easily shown (see Kitamura, 1984) that the optimal time allocation to activity j is obtained by:

$$t_j^* = \frac{\alpha_j}{\sum_k \alpha_k} T \quad (3)$$

In existing time allocation models, the attractiveness of activities α_j depends on characteristics of the individual:

$$\alpha_j = f(X_i) \quad (4)$$

where X_i is a vector of characteristics of individual i . However, since the aim of this study is mainly to explore the concept and get first empirical results, we will assume that attractiveness α_j is a constant and do not include socio-demographic characteristics. In addition, however, we assume that the attractiveness of activity j depends on the amount of money spent on various purposes. These purposes may be directly linked to the activity, but may also be more general. For instance, the attractiveness of a hobby (e.g. painting) may be affected by the money invested in the materials necessary for this hobby, but also by the facilities offered by the dwelling (such as an extra room), which have necessitated investment. In the most general case, which we initially adopt here, money spent on each purpose p can influence the attractiveness of each activity j :

$$V_j = (\alpha_j + \sum_{p=1..P} \gamma_{pj} \ln(e_p)) \ln(t_j) \quad (5)$$

where:

e_p is the expenditure to purpose p ;

γ_{pj} is a parameter reflecting the impact of $\ln(e_p)$ on utility V_j .

Thus, expenditure to purpose p may add to the utility derived from an activity j . It is recognised that theoretically, the set of possible relationships between money and activities is more diverse than described here. For instance, one could also argue that activities require a fixed input of money per time unit (e.g. of more time is spent on eating out on a monthly basis, more money will be spent on this purpose). This would imply that more money is spent on activities that are preferred and are therefore pursued more frequently and for longer durations. Technically, this effect could be incorporated in the model by specifying a direct link between time spent on an activity, consumption of goods and/or services and the cost associated with this, as in existing micro-economic frameworks (Becker, 1965; Jara-Diaz, 1998). In this paper, however, we have emphasized the notion that most monetary expenditures are less directly linked to individual activity episodes and their durations. For instance, investment in the quality of the home or in equipments such as TV sets and DVD-players aim at increasing the utility of spent home in general, and not related to a specific episode. Likewise, subscription to a sports or social club or buying sports equipment are expenditures aiming at improving the quality of leisure time without direct linkage to activity episodes or activity duration. Hence, we assume that money is primarily spent on facilities that improve the conditions for activity participation, resulting in higher utilities derived from a certain time spent on an activity. According to eqn. 5 we assume that investment of money in facilities results in an increased utility of one time unit of activity participation, implying that γ_{jp} is positive. The above also implies that the relationship between money and activities does not hold on a daily level, but over longer periods, since investment in facilities is not tied to one episode of an activity. In addition, we assume that expenditure to p may also yield a utility in itself, which is not associated with activity participation. This utility V_p is a function of the expenditure to purpose p :

$$V_p = \vartheta_p \ln(e_p) \quad (6)$$

This intrinsic utility expresses the benefit from owning certain goods or equipment, or having access to certain services, apart from their impact on activity participation. For instance, owning a painting may have intrinsic utility in itself, irrespective of the time spent home. Likewise, membership of a tennis club, giving access to certain facilities,

may have a utility independent of the time spent playing. We assume that in allocating time and money to activities, individuals/households maximise an overall utility V_j , subject to temporal and monetary budget constraints.

$$\begin{aligned}
 \text{Max } V &= \sum_{j=1..J} (\alpha_j + \sum_{p=1..P} \gamma_{pj} e_p) \ln(t_j) + \sum_{p=1..P} \vartheta_p \ln(e_p) \\
 \text{s.t. } \sum_{j=1..J} t_j &= T, \quad \sum_{p=1..P} e_p = E
 \end{aligned} \tag{7}$$

where E is the total available monetary budget. Given the specification of the model, E represents the budget available for investment in facilities supporting activities and for acquiring goods and services. Note that E should ideally be defined in the context of the activities and purposes included in the model. That is to say, if the model only includes out-of-home activities and spending purposes associated with those activities, the budget available for those purposes should be used. In reality, the exact budget will be difficult to define, since households can transfer their expenditures between purposes inside and outside the model specification. In addition, households may occasionally exceed their budget, for instance by taking money from savings. This would suggest that the model describes time use and monetary expenditure over longer periods.

2.2. Optimisation procedure

For modelling purposes, the above optimisation procedure is implemented as an iterative search procedure. This procedure maximises utility V , by allocating time to activities (t_j) and money to expenditures (e_p), given a set of parameters α , γ and ϑ , which reflect an individual's preferences. This procedure starts from an equal distribution of time over activities and an equal distribution of money over purposes. Then, time and money are re-distributed in an iterative way, until the optimal allocation, resulting in maximum utility, is found. In this case the derivatives of utility function 6 to all time expenditures and to all monetary expenditures should be equal. The re-distribution of money is based on the derivative of utility to expenditure e , which is given by:

$$\frac{\partial V}{\partial e_p} = \frac{\vartheta_p}{e_p} + \sum_{j=1..J} \gamma_{pj} \ln(t_j) / e_p \quad (8)$$

Assuming that the total amount of money to be distributed is \tilde{E} , the amount assigned to purpose p equals:

$$\tilde{E}_p = \tilde{E} \frac{\partial V / \partial e_p}{\sum_{q=1..Q} \partial V / \partial e_q} \quad (9)$$

Since the utility derived from each spending purpose p is characterised by decreasing marginal returns (see eqns, 1 and 6), this results in an increase in total utility. The amount of expenditure to be re-distributed depends on the differences in the derivatives to monetary expenditure as follows:

$$\tilde{E}_p = E \left(1 - \frac{\min_p \partial V / \partial e_p}{\max_p \partial V / \partial e_p} \right) \quad (10)$$

This implies that the larger the difference between the derivatives to money, the larger the amount of money to be redistributed. Once the allocation is closer to being optimal, the derivatives are more similar to each other and a smaller fraction of total expenditure is redistributed. Given the monetary expenditures, the optimal time allocation is simply obtained by computing the shares according to eqn. 3.

2.3. Illustration of the model

The implications of the model structure and the outcome of the optimisation procedure are illustrated in an example (Table 1). Assume that time is allocated to three activities, and money is allocated to three purposes. In case 1, it is assumed that the impact of money on the utility of activities is zero (all γ_{pj} are zero) and all initial attractivenesses α_j are equal. In this case, the time allocation only depends on attractiveness α_j , resulting in equal amounts of time being allocated to each activity. The allocation of money is only determined by the ϑ -parameters, implying that most money is allocated to purpose 2, which has the largest ϑ .

In case 2, we assume that money spent on each purpose impacts on the utility of one activity, as indicated by the γ_{xx} parameters. This affects the allocation of both time and money. First, since activity 3 benefits most from the monetary input, it becomes more attractive, and more time is spent on it, according to eqn. 3. Second, investing money in activity 3 is the most effective way of producing utility. As a consequence, more money goes into this activity than in the other activities. Note also that whereas purpose 2 has the largest ϑ , it no longer receives the largest share of money, since its impact on activity 2 is less.

In case 3, the monetary expenditure to purpose 3 not only positively influences the utility of activity 3, but also of activity 2. As a consequence, activity 2 gains in attractiveness and relatively more time is spent on it. Also, purpose 3 becomes even more efficient in producing utility (through increasing the attractiveness of both activities 2 and 3) so that more money is spent on it.

Table 1: Illustration of model characteristics

	Case 1	Case 2	Case 3
α_1	1.0	1.0	1.0
α_2	1.0	1.0	1.0
α_3	1.0	1.0	1.0
γ_{11}	0	0.2	0.2
γ_{11}	0	0.3	0.3
γ_{11}	0	0.4	0.4
γ_{32}	0	0	0.1
ϑ_1	0.3	0.3	0.3
ϑ_2	0.7	0.7	0.7
ϑ_3	0.4	0.4	0.4
t_1	100	75	69
t_2	100	100	114
t_3	100	125	118
e_1	646	688	621
e_2	1495	994	932
e_3	859	1317	1447

3. Estimation procedure

3.1. Procedure

One objective of this paper is to empirically verify the proposed model. To this end the following approach is used to link the theoretical model from section 2 to empirical data. First, we assume that individuals are heterogeneous with respect to the utility derived from time spent on activities and money spent on various purposes. To represent this we include error terms into the respective utility functions:

$$V_j = (\alpha_j + \varepsilon_j) \ln(t_j) \tag{11}$$

$$V_p = (\vartheta_p + \eta_p) \ln(e_p) \quad (12)$$

An implication of adding the error terms is that the optimal allocations of time and money, t_j^* and e_p^* will follow a probability distribution function. The shape of this distribution depends on the distribution assumed for the ε_j and η_p terms. At this stage of development of the modelling approach, we did not derive a formal relationship between the distributions of t_j^* and e_p^* and the error terms, but used a more ad hoc approach. First, we have assumed that the error terms ε_j and η_p are independently and identically distributed, and that they follow a normal distribution with mean 0 and s.d. σ . In addition, we assume that the distributions of t_j^* and e_p^* are also i.i.d. normal distributed, with mean μ_j or μ_p and s.d. ζ_j or ζ_p . Without providing formal proof of this, we ran many optimisations under randomly drawn parameter settings (for α_i and ϑ_p) which suggested that this is a plausible assumption. The means μ_j and μ_p of the resulting distributions depend on the parameters α_i and ϑ_p , whereas the s.d. ζ_j and ζ_p depend on the s.d. σ of the error terms. For estimating parameters α_i and ϑ_p , we have applied a simulation procedure involving repeated optimisations of t_j^* and e_p^* under various sets of randomly drawn error terms ε_j and η_p , resulting in normal distributions t_j^* and e_p^* with mean μ_j and μ_p and s.d. ζ_j and ζ_p . Then, the following goodness-of-fit function is defined:

$$GOF = \sum_i \left(\prod_j P(t_j^{oi} | \mu_j, \zeta_j) \right) \prod_p P(e_p^{oi} | \mu_p, \zeta_p) \quad (13)$$

where:

- t_j^{oi} is the observed time spent on activity j by individual i ;
- e_p^{oi} is the observed money spent on purpose p by individual i ;
- $P(x | \mu, \sigma)$ is the probability of x according to a normal probability function with mean μ and s.d. σ .

Thus, the GOF expresses the extent to which observed time and money expenditures differ from the ones predicted by the optimisation procedure described in section 2.2. based on a set of parameters and distributions of error terms. To find the optimal set of parameters a Golden Section search procedure is followed to minimise the GOF.

3.2. Test of estimation procedure

The estimation procedure was first tested on simulated data. Based on a given set of parameters, and assuming given time and money budgets, the optimisation procedure in section 2.2 was used to generate predictions of time and money expenditures. Next, 100 cases were simulated by adjusting each expenditure (both time and money) by a random term with mean zero and uniformly distributed with range +/- 10%. Then, the Golden Section search procedure was applied to estimate the parameters, using the estimation procedure outlined in section 3.1. Table 2 summarises the estimated parameters. The estimation results suggest that the estimation procedure is well capable of disentangling the ‘fixed’ attractiveness α and the money dependent effect represented by γ .

Table 2: Outcome of parameter estimation on simulated data

	Original	Estimated
α_1	1.000	1.000
α_2	0.800	0.813
α_3	0.600	0.624
γ_{11}	0.200	0.205
γ_{11}	0.300	0.304
γ_{11}	0.400	0.407

4. Data

The data to empirically test the model of time and money allocation was taken from a 1998 Dutch study, in which a wide variety of issues were investigated, such as political convictions, opinions about labour market and immigration etc. In addition, the survey included detailed questions about time allocation and monetary

expenditures for a variety of activities and purposes. The original data set consists of 15,082 individuals. Table 3 gives some descriptions of the time and money expenditures to various activities and purposes. Although time expenditures were measured in hours per week or month (depending on activity type), and monetary expenditures were measured in guilders per month, all expenditures have been recomputed to hours or guilders per day, to facilitate comparison. These figures suggest a high variation in temporal and monetary expenditures. Whereas the mean time expenditures are intuitively plausible, with most time spent on personal care (including sleep), family and work, the standard deviations are very high, suggesting high variations between individuals. The high skewness scores suggest for each activity a limited number of outliers with large amounts of time spent on these activities. The highest average daily expenditures are on the dwelling (including rent/mortgage), eating, travel, holidays and consumer goods. Again we see a large variation, with in most cases (except eating) outliers with high expenditures on one purpose. In addition, for various activities, time and monetary expenditures are available (i.e. time use and monetary expenditure can be directly matched), implying that expenditure rates (in guilders/day) can be derived. Table 3 suggests that considerable variation exists also with respect to these expenditure rates, providing support for our claim that the amount of money invested in one time unit of an activity is not constant, but the outcome of a deliberate decision.

Table 3: Descriptives of Time and Monetary Expenditures

AVERAGE TIME EXPENDITURES (hours/day)							
	<i>Personal</i>	<i>Eat</i>	<i>Family</i>	<i>Reading</i>	<i>Household</i>	<i>ICT</i>	<i>Home improvement</i>
Mean	7.88	1.32	6.76	1.62	1.71	0.54	0.22
s.d.	1.64	0.97	6.78	1.96	1.69	1.32	0.39
Skewness	3.04	7.90	3.28	4.59	3.77	5.63	6.83
	<i>Hobbies</i>	<i>Voluntary work</i>	<i>Social</i>	<i>Study</i>	<i>Work</i>	<i>Travel</i>	
Mean	0.80	0.19	0.49	0.14	2.79	0.33	
s.d.	0.83	0.46	0.48	0.46	2.47	0.51	
Skewness	2.78	5.92	4.03	8.41	0.28	5.90	
AVERAGE MONETARY EXPENDITURES (guilders/day)							
	<i>Dwelling</i>	<i>Medical</i>	<i>Reading</i>	<i>Hobbies</i>	<i>Travel</i>	<i>ICT</i>	<i>Consumer goods</i>
Mean	16.86	6.48	2.56	3.75	11.70	0.72	7.34
s.d.	30.99	10.36	5.93	6.63	13.94	2.48	20.49
Skewness	39.08	15.74	29.65	15.90	9.90	45.90	61.40
	<i>Eat</i>	<i>Home improvement</i>	<i>Study</i>	<i>Telephone</i>	<i>Holidays</i>	<i>cleaning</i>	<i>Alimony</i>
Mean	23.34	1.59	2.05	2.81	9.24	1.48	0.89
s.d.	12.77	13.97	7.03	24.85	22.30	10.79	8.82
Skewness	0.27	108.68	15.19	116.05	40.37	46.10	33.98
AVERAGE EXPENDITURE RATES (guilders/day)							
	<i>Eat</i>	<i>Dwelling</i>	<i>Reading</i>	<i>ICT</i>	<i>Hobbies</i>	<i>Home improvement</i>	<i>Travel</i>
Mean	21.45	4.42	2.14	1.57	8.49	10.22	46.41
s.d.	15.04	7.43	6.03	3.49	23.21	32.01	80.78
Skewness	1.33	13.49	27.67	18.83	31.63	32.82	11.27

To limit the calculation times in this exploratory stage, we took a random subsample of 335 individuals. To estimate the model, broader categories of activities were created consisting of multiple original categories. On the activity side, these broader categories concern in-home task, in-home family, in-home leisure and out-of-home leisure activities. The expenditures concern in-home maintenance, housing and consumption, in-home leisure and out-of-home leisure. The categorisation of activities as well as the aggregate time and money expenditures in the subsample are summarised in Table 4.

Table 4: Definition of activity categories and spending purposes, with time and money expenditures per category

		Time expenditure (minutes/day)		
Activity	Original Category	Mean	s.d.	Skewness
In-home task	Personal care	1003	222	2.39
	Housekeeping			
	Home improvement			
In-home family	Eating	890	767	2.49
	Family time			
In-home leisure	Reading	237	281	3.91
	ICT			
Out-of-home leisure	Hobbies	164	122	2.01
	Social visits			
	Travel			
		Monetary expenditure (guilders/day)		
Purpose	Original Category	Mean	s.d.	Skewness
In-home task	Cleaning	2.80	3.80	2.75
	Home improvement			
Dwelling and consumption	Dwelling	49.78	27.01	4.21
	Consumer goods			
	Eating			
	Telephone			
In-home leisure	Reading	3.41	5.15	10.26
	ICT			
Out-of-home leisure	Hobbies	14.89	11.16	1.25
	Travel			

Hence, our study excludes work, of which the duration is assumed to be given, and focuses on activities about which time use decisions can be made on a daily basis. Also, expenditures are selected that are related to performance of activities. The underlying assumption of these categories is that certain monetary expenditures impact on the attractiveness of certain activities. In this respect it is assumed that expenditure on dwelling and consumption may impact on both INJ and IHL activities.

5. Estimation results

To test the theoretical model, three models were estimated. The first model includes α_j and γ_{jj} parameters for all activities. It is assumed that monetary expenditures only

impact on one activity type, to which they are directly coupled. That is to say, we assume that the utility derived from one time unit of activity participation is determined by the money invested in only one type of facility. In this respect, the following linkage is assumed:

Facility	Impacts on activity:
In-home task	In-home task
Dwelling	In-home family
In-home leisure	In-home leisure
Out-of-home leisure	Out-of-home leisure

In addition ϑ parameters (representing the utility of spending money on a purpose per se) were estimated for the purposes ‘dwelling’ and ‘out-of-home leisure’. These were included because the high monetary expenditures to these purposes could not be well explained only by the time spent in the corresponding activities.

The second model allows monetary expenditure to impact on multiple activities. In the second model, money spent on ‘in-home leisure’ impacts on in-home family and in-home leisure activities.

The first model shows non-zero α ’s for all activities, suggesting that even without spending money on activities, increasing allocation of time leads to higher utilities. This effect is largest for out-of-home leisure. In itself, no strong conclusions can be drawn from this outcome, since the overall time allocation also depends on the amount of money spent on facilities related to the activity. The estimated γ -parameters give an indication to what extent the utility of time allocation depends on money spent on facilities. The estimation results then suggest that time spent on out-of-home leisure is least dependent on money spent on hobbies and holidays. That is to say, utility generated by spending money on this purpose does not accrue from an increase in the utility from spending time on out-of-home leisure, but rather from enjoyment of the facilities in themselves, as indicated by the estimated ϑ parameter for out-of-home activities. Stronger effects of spending money are found for spendings on in-home tasks and on dwelling/consumption, which increase the time dependent utility of in-home task activities and in-home family time respectively. For in-home family time this seems plausible, since having a nicer dwelling and and having better food and luxury goods makes spending time with the family at home

more enjoyable, possibly leading to more time being spent at home. For in-home task activities the interpretation is less straightforward. Intuitively, one would not expect these task activities to become more attractive resulting in more time being spent on it. In general, it is noted that one should be careful to interpret the model in a causal way (higher spending increase the attractiveness of the activity), since the causality may also work in the other direction: if in-home task activities are deemed more important, more time and more money will be spent on them, leading to the results found here. A limited effect of spendings on the time-dependent utility is found for in-home leisure (reading and ICT (i.e. person computers and games)). Finally, spendings on the dwelling and consumer goods also have an effect on utility independent from time allocation, as suggested by the estimated ϑ . This can be interpreted as the intrinsic utility of owning a certain dwelling or consumer goods.

The second model shows a fairly similar pattern as the first model. However, allowing spendings on in-home-leisure to impact on time spent with the family changes some of the other effects. As in the first model, the effect of spending on in-home tasks and dwelling/consumption positively affects the time related utility of in-home tasks and family time. However, family time also benefits from spending on in-home leisure. The intrinsic utility of spendings on the dwelling has decreased. Also, the constant effects of time spent on in-home family and in-home leisure have decreased (α), since the utility of time has become more dependent on monetary spendings (γ). Interestingly, the second model results in a large improvement in goodness-of-fit, suggesting that finding the rights balance between the utility solely depending on time and money dependent utility is crucial.

Table 5: Estimation results

		Model 1	Model 3
α	In-home task	0.573	0.545
	In-home family	0.281	0.045
	In-home leisure	0.698	0.274
	Out-of-home leisure	0.865	0.431
γ	IHT-IHT	0.622	0.802
	Dwelling-IHfamily	0.489	0.669
	IHL-IHL	0.142	0.129
	OHL-OHL	0.007	0.073
	IHL-IHfamily		0.0563
ϑ	Dwelling	9.102	4.608
	OHL	7.297	9.119
GOF		0.0073	0.0142

6. Conclusions

In this paper we have proposed a model of the simultaneous allocation of time and money to various purposes and activities. This model recognises the fact that investment of money in activities does not take place at a fixed rate, but is a conscious decision of households in order to maximise their utility. Incorporating this decision into time allocation models is necessary in order to accurately predict future time use and activity participation patterns in the context of structural income changes, such as we have witnessed over the past decades. Also the change to a service oriented society in which lifestyles become more important in understanding how time use decisions are made, necessitates the incorporation of monetary budget decision into time use models.

The model proposed in this paper assumes that the utility derived per time unit of activity participation is affected by the amount of money spent on various purposes that are related to the activity. The decision about time and money allocation is thus depicted as an optimisation process in which time and money budgets are adjusted to achieve an optimum yielding an optimal utility. A Golden Section estimation procedure appeared to be capable of disentangling the intrinsic and the money

dependent utility of activities. A first application of the model on combined time use and monetary expenditure data suggests that the model is capable of describing simultaneous temporal and monetary allocation decisions.

The model described in this paper constitutes a first step towards a more comprehensive model of time and money allocation. First, the model presented only includes activity and purpose specific parameters, but does not include the impact of socio-demographic variables on these parameters. Although these variables can be incorporated in the model structure in a straightforward way, empirical tests are needed to reveal which socio-demographics impact on which parameters. A second point for further investigation is to more systematically explore the more flexible impact of monetary expenditures on activities. Although each spending category can theoretically impact on each activity, a model including all these interactions would certainly not be identifiable. Developing a way to systematically find the most salient impacts of monetary expenditure on time use is seen as an important challenge for further research.

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