electronic **International Journal of Time Use Research**
2013, Vol. 10, No. 1, 9-37 *dx.doi.org/10.13085/eIJTUR.10.1.9-37*

A measure of concentration of the use of time, with an application to the pattern of daily leisure activities

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Abstract

Drawing an analogy with industry concentration, a well-grounded measure of individual concentration (or specialization) of the use of time is presented. Equipped with this measure, we explain and provide evidence of a "division of leisure" effect on the organization of daily leisure activities. A demand model featuring subsistence daily leisure shows that the concentration of leisure can vary with the quantity of leisure available. Sequential moment conditions and the exogenous possibility of more leisure brought about by the weekend unveil an asymmetrically U-shaped response in a sample of employed German men.

JEL-Codes: J22

Keywords: Time allocation; Herfindahl-Hirschman index; IV estimation

This paper originated from a conversation with Ricard Torres and was written during my stay at the University of Girona, whose hospitality I gratefully appreciate. I am also indebted to the anonymous referee, Gerhard Bosch, Dan Hamermesh, Joachim Merz, Xavier Sala-i-Martin, Sabine Sonnentag, and seminar participants at the Sophia Antipolis campus of the SKEMA Business School for helpful comments, and to Kristina Kott, of the German Federal Statistical Office, for able assistance with the data. Financial support from the Spanish Ministry of Education (ECO2011-29751/ECON) is gratefully acknowledged.

1 Introduction

The objective of this paper is twofold. The first objective is to investigate a measure of concentration of an individual's use of time. For good reasons, the statistical analysis of time-use observations has become widespread in economics and other social sciences. A measure of individual concentration of the use of time seems necessary for any quantitative study attempting to explain the causes or consequences of variation in the degree of concentration (or specialization) of the use of time. The second objective is to examine theoretically and empirically the pattern of daily leisure activities in terms of this measure[1]. While on working days many people relax just watching the TV, on non-working days many people watch the TV but also go out. Can variations in the concentration of leisure activities be explained on the basis of the quantity of leisure available? In other words, is there a "division of leisure" effect on the organization of daily leisure activities? From a theoretical viewpoint, the answer to this question informs about the structure of consumer preferences driven the demand for daily leisure. From a more empirical perspective, it contributes to understanding the determinants of the demand for variety (Gronau and Hamermesh, 2008), which, in turn, may prove useful for organizing the diversity of the supply of recreational activities.

Drawing an analogy with the concentration of firms within an industry, Section 2 derives a measure of individual concentration of the use of time that possesses properties considered desirable for measures of industry concentration. Section 3 develops a simple theoretical model for the concentration of daily leisure activities, whose main purpose is to show that the sign of the reaction of concentration to variations in the quantity of leisure available is theoretically ambiguous. Section 4 examines empirically the pattern of concentration of daily leisure activities in a sample of male workers extracted from the German Time Budget Survey (ZBE) 2001/2002. Although both the quantity of leisure and its degree of concentration are certainly chosen by the individual, we argue that the ZBE panel structure as well as the exogenous reduction in market work brought about by the weekend for many workers, offer an avenue for identifying the causal effect of the former on the latter. Conclusions and some directions for future research are provided in Section 5.

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1 Other aspects of leisure such as quantity, quality, inequality, timing, togetherness, or recovery, have been investigated by a large socio-economic and psychological literature interested on behavioral and welfare comparisons. See, among many others, Owen (1971), Juster and Stafford (1985), Kooreman and Kapteyn (1987), Robinson and Godbey (1999), Bittman and Wajcman (2000), Hamermesh (2002), Mattingly and Bianchi (2003), Bittman (2005), Jenkins and Osberg (2005), Kahneman and Krueger (2006), Aguiar and Hurst (2007), Sonnentag et al. (2009), and Sevilla et al. (2012).

2 A measure of concentration of the use of time

The kind of concentration that we aim to measure is that implicit in a vector with the times spent on a series of activities, i.e. in an activity profile. Existing measures of time-use concentration respond to alternative aims, such as measuring intra-household specialization (Bonke et al., 2008) or assessing variability in a sample of activity profiles (González Chapela, 2006), and require at least two profiles to be computed. Closely connected with the concept of concentration are the notions of diversity, variety, and specialization. A time-use profile heavily concentrated on a few activities would be typically classified as little diversified and varied, or as very specialized. Hufnagel (2008) deals with the evaluation of time-use diversity across consecutive days, what requires at least two activity profiles. Variety, understood as the number of different activities undertaken (Gronau and Hamermesh, 2008; Ray, 1979; Sonnentag, 2001), ignores how time is distributed across activities engaged in. Baumgardner's (1988) measure of physicians' degree of specialization is constructed from quantities of outputs, but there may be cases where the times spent producing the outputs offer a more accurate way of measuring specialization, or are, indeed, the only available information.

In the 1960s several articles began to appear that examined the concentration measures employed in empirical analyses of industrial structure. Perhaps the best summary of those articles is Hall and Tideman (1967), who developed a set of desirable properties for measures of concentration in an industry. By equating activity profiles with industries, activities with manufacturing plants, and time with firm size, advantage of those efforts is taken here for defining a well-grounded measure of concentration of the use of time.

Let P_m denote the relative time share spent on activity m, $m = 1,\ldots,M$. Following Hall and Tideman (1967), a measure of concentration of the use of time ought to be: (1) One dimensional, i.e. unambiguous. (2) Independent of the total time analyzed, but a function of all the P_m's. (3) Affected by a change in any P_m, with concentration increasing (respectively, decreasing) if there is a shift from activity m to n and $P_m < P_n$ ($P_m > P_n$). (4) Reduced by one-*K*th if each activity is divided into K more specific activities of equal duration. (5) A decreasing function of M when time is spent on M activities of equal duration. (6) Between 0 and 1. Although these properties cannot determine the best measure of concentration to use, they serve to discard measures that are undesirable for theoretical reasons.

A well-known measure of industry concentration that possesses all of the properties set forth by Hall and Tideman is the Herfindahl-Hirschman index (*HHI*)[2]. Hence, the measure

$$(1) \qquad HHI = \sum_{m=1}^{M} P_m^2$$

which is the sum of the squares of all M relative time shares, immediately suggests itself as a measure of concentration of the use of time: It is one-dimensional and utilizes all the P_m's. Its maximum value is 1, which corresponds to the case of complete concentration: $P_m = 1$ for some

[2] For an explanation of the origins of this index, see Theil (1967, p. 316).

m, and $P_n = 0 \; \forall n \neq m$. For given M, the minimum value is $1/M$ which is attained when all relative time shares are equal. This minimum approaches zero as M increases. Properties 3 and 4 are also satisfied because a (small) shift from m to n changes expression (1) by $2(P_n - P_m)$, and because $\sum_{m=1}^{M} K(P_m/K)^2 = 1/K \sum_{m=1}^{M} P_m^2$. The denomination *HHI* is kept to refer to expression (1) hereafter.

In spite of the theoretical appeal of the *HHI*, the concentration ratio, i.e. the fraction of an industry size held typically by its 4, 8, or 20 largest firms, has been frequently employed in empirical studies of industrial structure. Besides being highly correlated with the *HHI* (e.g., see Bailey and Boyle, 1971), the concentration ratio is more operational, for its calculation does not require knowing the size of every firm in the industry. But when it comes to measuring concentration of the use of time, and the time-use information has been collected by the time diary methodology, that shortcoming of the *HHI* is less marked: One of the main reasons behind the current popularity of the time diary is that it permits distinguishing a large number of activities. For example, if (as is typical of European time-use surveys) diarists record activities in 10 minute slots and the activity coding list distinguishes more than 144 activities, a researcher could discern up to 144 main activities on the diary day. (As the referee pointed out, in practice this number is much lower, as people cannot survive on 10 minutes of sleep and 10 minutes of eating to then accomplish 142 other activities.) Indeed, this wealth of detail raises a problem since, for analysis purposes, researchers end up classifying the recorded activities into a few time-use aggregates. As properties 4 and 5 suggest, this practice may alter the degree of concentration observed in the data, and since there are many ways one might classify activities, it calls for assessing the robustness of the findings to different activity aggregations.

The entropy measure of information theory has been also used as an index of industrial concentration, e.g. see Theil, 1967, and Horowitz and Horowitz, 1968. In the interpretation of the latter, the entropy quantifies the degree of uncertainty as to which of the firms in the industry will secure the custom of a buyer chosen at random. Analogously, the entropy measure

(2) $$H = -\sum_{m=1}^{M} P_m \ln P_m$$

evaluates the degree of uncertainty implicit in an activity profile: The greater the entropy the greater the uncertainty as to which activity the individual is carrying out on a minute chosen at random. Measure (2), however, fails to satisfy properties 4 (the entropy is reduced by $\ln K$ when each activity is divided into K more specific activities of equal duration) and 6 (as the entropy ranges between 0 and infinity). According to Hall and Tideman (1967), property 6 is not strictly necessary (it simply makes the measure easier to use), but property 4 is very necessary if we are to have confidence in the measure's cardinal properties.

Besides appraising existing measures of industry concentration, Hall and Tideman (1967) proposed a new measure of concentration that satisfied all of their properties. The main difference between the *HHI* and the so-called *TH* index is that while the former weights each firm by its relative share, the latter weights by the firm rank—the mth largest firm receives weight m, whereby the number of firms in the industry becomes emphasized. As the number of activities engaged in may indicate in part the presence of constraints on the use of time (more activities suggest fewer constraints), one could argue that the number of activities should be stressed in a measure of time-use concentration. This goal is accomplished by the *THI* equivalent

(3) $$THI = \frac{1}{\left(2\sum_{m=1}^{M} mP_m\right) - 1}$$

where (abusing somewhat the notation) the mth longest activity receives weight m.

3 The concentration of daily leisure activities – A simple theoretical model

In this section, a simple demand model for daily leisure activities is developed that allows analyzing the effect of the quantity of leisure on its degree of concentration. This model can be viewed as a particular case of Becker's (1965) general theory of choice, where, for analytical convenience, market goods are abstracted. Hence, too, it can be seen as the obverse of classical demand models. Although the definition of leisure is not completely specified until Section 4, our concept of leisure tallies with Ås (1978) notion of free time, i.e. time that is left after satisfying basic physiological needs, working for pay, and doing things we are committed to.

On a certain day, an individual is faced with the choice of dividing a certain amount of leisure (L) into two activities[3]:

(4) $$L = L_1 + L_2$$

where L_m denotes time devoted to activity m, $m = 1, 2$. Preferences over activities are represented by the utility function

(5) $$U(L_1, L_2) = (L_1 - \gamma_1)^{\alpha_1} (L_2 - \gamma_2)^{\alpha_2}$$

(Geary, 1950-51, Stone, 1954; see also Prowse, 2009), which possesses some desirable properties. In expression (5), $\alpha_m > 0$ and (without loss of generality) $\alpha_1 + \alpha_2 = 1$. Although there is no requirement that any γ_m be positive, the sum $\gamma_1 + \gamma_2$ is interpreted here as the minimum daily leisure needed by the individual to live his/her life. In the terminology of Goodin et al. (2005, 2008), $\gamma_1 + \gamma_2$ would be defined as necessary time in leisure, although these authors do not consider that everyone needs to devote some time to leisure on a daily basis. Nevertheless, the existence of a subsistence quantity of daily leisure may not be an unreasonable assumption.[4] Theory and evidence in the field of work and organizational psychology indicate that leisure allows recovering our physical and mental capabilities from effort expended at work (see e.g. the

[3] This decision can be viewed as the second stage of a 2-stage budgeting where leisure is weakly separable from goods and the price of leisure is normalized to 1.

[4] The model in Leuthold (1968) allows for "minimum required" hours of leisure over the year.

volume edited by Sonnentag et al., 2009; this role of leisure was also suggested by Becker, 1965, p. 498, and Stafford and Cohen, 1974, and is explicit in Schwartz and McCarthy, 2007). Also, people may tend to engage frequently in leisure activities in order to gratify psychological needs such as affiliation, self-expression, or status (Tinsley and Eldredge, 1995). In our sample of employed German men, for example, 98.3 percent report some leisure in each of the three diary days, whereas in Spain and in the US the percentage of the population aged 15+ who reports some leisure on a typical day is, respectively, 97.6 and 95.9.[5] The portion of minimum daily leisure spent on activity m is denoted γ_m. Influencing the distribution of that minimum between activities may be factors such as activity set-up costs (created for example by the need to travel and coordinate with others), the price of the goods consumed in the course of the activities, the degree of recovery obtained from each activity, or the particular psychological needs gratified. Intuitively, set-up costs and goods prices should be inversely related to γ_m, whereas recovery and preferences for the needs gratified should be directly related. Some evidence on this issue is provided in Section 4.

Maximizing (5) subject to the adding-up constraint (4) yields the following system of demand functions:

(6) $$L_m = \gamma_m + \alpha_m \left(L - (\gamma_1 + \gamma_2) \right), \quad m = 1, 2$$

which expressed in relative shares form produces

(7) $$P_m \equiv \frac{L_m}{L} = \left(\frac{\gamma_m}{\gamma_1 + \gamma_2} \right) \left(\frac{\gamma_1 + \gamma_2}{L} \right) + \alpha_m \left(1 - \frac{\gamma_1 + \gamma_2}{L} \right), \quad m = 1, 2$$

Analogously to expression (4.7) in Deaton and Muellbauer (1980, p. 145), P_m is a weighted average of demand patterns pertaining to days where L is so small that $P_m = \gamma_m / (\gamma_1 + \gamma_2)$ and days where L is so large that P_m approaches α_m. P_m is increasing and concave in L if and only if $\alpha_m > \gamma_m / (\gamma_1 + \gamma_2)$, and decreasing and convex if the inequality is reversed.[6] Of course, in this two-activity model if P_m is, say, increasing in L, P_n has to be decreasing. The composition of leisure would be independent of L if and only if $\alpha_m = \gamma_m / (\gamma_1 + \gamma_2)$ or $\gamma_m = 0$, $m = 1, 2$, whereby, in the light of this model, the finding of an empirical response of concentration to L would add to the support of the minimum daily leisure assumption.

The direction of the effect of variations in L on the concentration of leisure cannot, in general, be determined *a priori*.[7] Suppose, to be specific, that $\gamma_1 > \gamma_2$, implying that $P_1 > P_2$ on days where

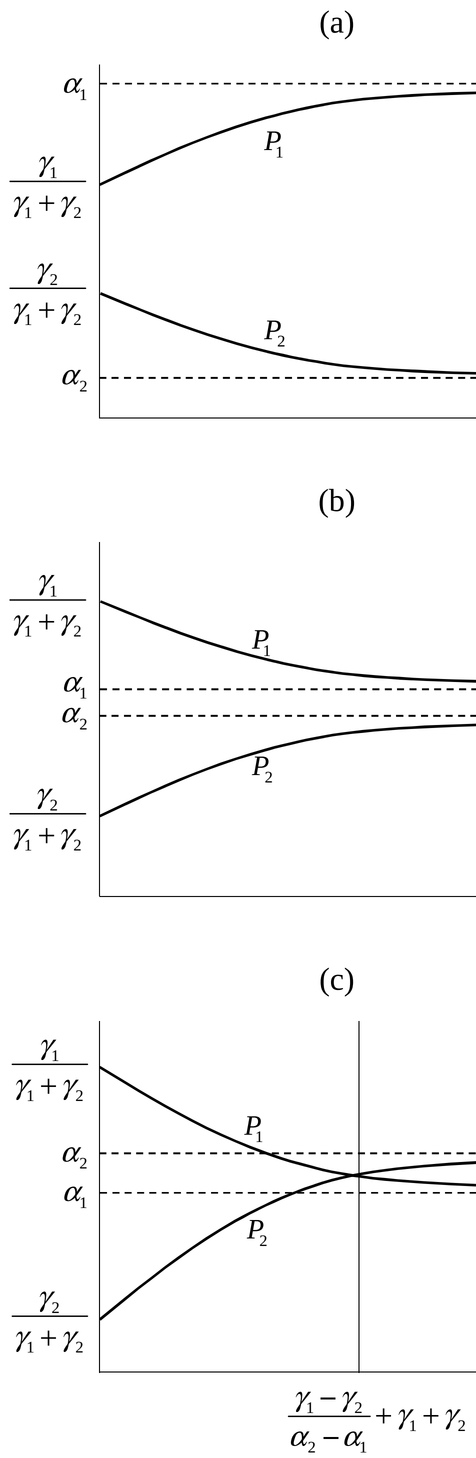
5 Author's calculations with data from the German Time Budget Survey 2001/2002, the Spanish Time Use Survey 2002-2003, and the American Time Use Survey (ATUS) 2003. In the first two surveys the definition of leisure is that of Leisure 1 (see Section 4); in the ATUS, leisure is defined as time devoted to ATUS major categories 12 and 13 plus associated travel.

6 The total leisure elasticity ($e_m = d \log L_m / d \log L$) is determined analogously. If $\alpha_m > \gamma_m / (\gamma_1 + \gamma_2)$, then $e_m > 1$ and activity m would be considered a luxury; if $\alpha_m < \gamma_m / (\gamma_1 + \gamma_2)$, then $e_m < 1$ and activity m would be a necessity. Inferiority cannot occur with $\alpha_m > 0$.

7 In the specific case that $\gamma_1 = \gamma_2$ and $\alpha_1 \neq \alpha_2$, concentration would always increase with L.

$L = \gamma_1 + \gamma_2$. Then, three cases can be distinguished, illustrated respectively in panels (a)-(c) of Figure 1.

Figure 1
The effect of variations in L on the concentration of leisure



Source: Own illustration.

In the first case $\alpha_1 > \gamma_1/(\gamma_1+\gamma_2)$, so that P_1 would increase with L. Then, by the third property established in Section 2, the concentration of leisure would unambiguously increase on days where the individual had more leisure available. The second case assumes $\alpha_1 < \gamma_1/(\gamma_1+\gamma_2)$ and $\alpha_1 > \alpha_2$. Hence, P_1 would decrease with L, but even if L were very large, P_1 would be greater than P_2. Thus, the concentration of leisure would decrease on days where the individual had more leisure available. The third case shares features of the previous two situations. Suppose again that $\alpha_1 < \gamma_1/(\gamma_1+\gamma_2)$, but now $\alpha_1 < \alpha_2$. Then, P_1 would decrease with L as in the second case, but now P_1 would be above P_2 only in the region where $L < (\gamma_1 - \gamma_2/\alpha_2 - \alpha_1) + \gamma_1 + \gamma_2$, being below P_2 when $L > (\gamma_1 - \gamma_2/\alpha_2 - \alpha_1) + \gamma_1 + \gamma_2$. As a result, the relationship between the quantity of leisure and its degree of concentration would be U-shaped, with the peak of the U located asymmetrically if $(\gamma_1 - \gamma_2/\alpha_2 - \alpha_1) + \gamma_1 + \gamma_2$ deviated from the mean of L.

4 The concentration of daily leisure activities – Evidence from time diary data

4.1 Data, Measures, and Correlations

The German Time Budget Survey (ZBE) 2001/2002, a nationally representative quota sample of private households, is particularly unique as a rich source of information on time use and labor force characteristics. In the households interviewed, all individuals of 10 years and older were requested to complete three time diaries based on 10-minute intervals: two weekdays and a Saturday or Sunday, all pertaining to his/her reference week. If the completion of some diary was to be postponed, it was so for a complete week, so that the effective diary day corresponds to the same day of the week that the designated day. Socio-demographic and socio-economic characteristics of household members, including a sequence of questions about working on weekends, were collected by means of additional questionnaires.[8]

Although Ås (1978) notion of free time is a helpful classificatory principle of activities, the classification of some activities may be disputed. Hence, I will compute more than one measure of leisure, as in for example Aguiar and Hurst (2007) and Sevilla et al. (2012). Leisure 1 gathers time spent on social life and entertainment, sports and outdoor activities, hobbies and games, and mass media, which are activities that we cannot pay somebody else to do for us and that are not biological needs. To these, Leisure 2 adds child care (specifically, reading, playing,

[8] The Institute for the Study of Labor offers metadata for this survey at http://idsc.iza.org/metadata/. See also Statistisches Bundesamt (2005). To avoid seasonal distortion in the use of time, the survey was conducted over the course of one year, distributing the whole survey size evenly between April 2001 and March 2002. The tasks reported in the diaries were coded on the basis of an activity list encompassing some 230 activities capable of aggregation into the standardized Eurostat codes (see Eurostat, 2004). The high average number of activity episodes per day (ranging from the first to the third diary day: 25.3, 24.8, and 23.4, respectively), the very low prevalence of diaries with fewer than 7 episodes (0.1, 0.1, and 0.3 percent, respectively), and the very low presence of diaries missing two or more basic activities (0.4, 0.4, and 0.7 percent, respectively) indicate diary data of good quality (Juster, 1985; Robinson, 1985; Fisher et al. 2012).

and talking with child), gardening and pet care (specifically, the latter refers to outdoor activities with pets), and volunteer work and meetings. Finally, Leisure 3 will sum together Leisure 2 and time spent sleeping, an activity pursued largely for restorative purposes (e.g., see Biddle and Hamermesh, 1990).[9] As usual, the travel time associated to each activity is embedded in the total time spent on it.

As to the number of activities distinguished (M), I will work at a rather aggregated level to avoid unbalances in the measured detail of the different leisure domains. Thus, in the case of Leisure 1, the activities distinguished will be those listed in the previous paragraph, so that $M = 4$. The additional activities included in Leisure 2 will serve to assess the impact on the results of the number of activities distinguished: M will be alternatively set at 5 and 7 for Leisure 2, depending on whether child care, gardening and pet care, and volunteer work and meetings are aggregated together. For the same reason, M will be alternatively set at 6 and 8 for Leisure 3. Previewing the results, our main empirical conclusions will be unaffected by those changes in M.

The study sample is restricted to employed men aged 23-59 to exploit the market work reduction brought about by the weekend for many workers as an exogenous source of leisure. The sex and age selection criteria are intended to reduce sample selection issues. I also discarded persons who completed less than three diaries or who, in some diary, provided unspecified uses of time, presented fewer than 7 activity episodes, missed two or more of the four basic activities defined in Fisher et al. (2012), or reported no leisure (as measured with Leisure 1). The last requirement is a consequence of the *HHI* being only calculated when leisure is greater than zero, and excludes 1.7 percent of the observations that satisfy the other criteria for inclusion in the sample. This leaves us with 2,266 men, contributing a total of 6,798 diary days. Table 1 presents some characteristics of these persons. The sample will be further restricted for some specifications to workers who did not postpone the completion of the first diary, which yields a sample size of 1,431 men. Demographic differences between both samples are statistically insignificant, although the subsample presents, on average, 15 minutes more Leisure 1 (and 13 minutes less market work) per day, and concentration is about 3 percent smaller.

Table 2 presents sample descriptive statistics on the quantity, cross-activity distribution, and degree of concentration of leisure, organized by day of the week. The last row of the table lists the number of diaries used in the calculations. Leisure patterns are pretty stable from Monday to Thursday, irrespective of the leisure measure considered. In terms of our narrowest measure, leisure activities take up (on average) almost 4 hours each of those days, with approximately 61 percent of this time being devoted to mass media and 28 percent to social life and entertainment. Fridays bring about an extra hour of leisure and a change in its distribution, which becomes less tilted towards mass media (sleep, in the case of Leisure 3) and more inclined towards social life and entertainment.

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[9] Leisure 1 includes the activities classified into 1-digit codes 5-8 of Eurostat (2004, Annex VI). Leisure 2 includes additionally the 1-digit code 4 and 3-digit codes 341, 344, and 383. To these, Leisure 3 adds the 2-digit code 01.

Table 1
Descriptive statistics

Variable	Mean	Std. dev.	Minimum	Maximum
Age	43.2	8.3	23	59
Leisure 1	5.0	2.9	.2	19.7
Leisure 2	5.7	3.1	.2	21.3
Leisure 3	13.5	3.8	1.2	23.8
HHI Leisure 1	.66	.21	.25	1
HHI Leisure 2[a]	.59	.21	.21	1
HHI Leisure 2[b]	.59	.21	.19	1
HHI Leisure 3[a]	.48	.13	.22	.98
HHI Leisure 3[b]	.48	.13	.22	.98
Variable (%)	Mean	Variable (%)		Mean
Married	79.5	Very good or good health		76.9
College graduate	34.1	Works every Sat[c]		15.0
Non-German	1.2	Works every Sun[d]		7.5

Notes: Data are of 2,266 employed men. Leisure is expressed in daily hours. [a]: Child care, gardening and pet care, and volunteer work and meetings are aggregated together; [b]: Those three activities are kept disaggregated. [c]: Percentage of those completing a diary for a Saturday. [d]: Percentage of those completing a diary for a Sunday.
Source: German Time Budget Survey (ZBE) 2001/2002, own calculations.

This one-hour increase in leisure has little impact on its concentration (when averaged across individuals) except for Leisure 3, whose concentration decreases by some 8 percent. On Saturdays, leisure increases substantially, social life and entertainment reaches the weekly maximum and mass media the weekly minimum. Coinciding with these changes, the concentration of leisure decreases noticeably with respect to Fridays (from around 4 percent in the case of Leisure 1 to about 9 percent in the case of Leisure 3). Hours of leisure reach the weekly maximum on Sundays and concentration the weekly minimum. With reference to Saturdays, the modest increase in Leisure 1 and Leisure 2 observed on Sundays is accompanied by a substantial reduction in concentration (11 and 9 percent, respectively), due to the larger importance of sports and outdoor activities. The evolution of concentration over the week as measured by the *THI* is essentially the same. The outstanding preponderance of mass media on those days where leisure is smaller suggests that that activity's minimum daily time might be much larger than that of other activities. As shown in Table 3, a reason for this could be mass media's lower related travel and necessity of coordination with others, which reduce set-up costs. Yet, the fact that hobbies and games present similar figures but a much smaller importance on the time budget indicates that alternative reasons are involved.

At the diary level, the Ordinary Least Squares (OLS) estimates presented in the first two rows of Table 4 suggest a U-shaped relationship between daily leisure and its degree of concentration that is robust to some individual characteristics and the day of the week. The estimated coefficient associated to the quantity of leisure is negative, and that associated to the square of this positive, both being statistically different from zero at the 0.01 level.[10]

Table 2
Average leisure (hours per day), leisure distribution and leisure concentration, by day of the week – Employed prime-age men

Variable	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Leisure 1	3.8	3.8	3.9	3.9	4.8	6.7	7.3
Social life and entertainment	.27	.27	.29	.28	.34	.38	.32
Sports and outdoor activities	.06	.07	.08	.07	.07	.08	.12
Hobbies and games	.04	.05	.04	.05	.05	.05	.05
Mass media	.63	.61	.59	.60	.54	.49	.50
HHI Leisure 1	.69	.70	.67	.67	.68	.65	.58
Leisure 2	4.3	4.4	4.3	4.4	5.5	7.7	8.1
Social life and entertainment	.23	.23	.26	.25	.30	.34	.29
Sports and outdoor activities	.06	.07	.07	.06	.06	.07	.11
Hobbies and games	.04	.04	.04	.05	.05	.05	.05
Mass media	.56	.55	.54	.54	.48	.42	.46
Child care	.02	.02	.01	.01	.02	.02	.02
Gardening and pet care	.04	.03	.03	.04	.04	.04	.02
Volunteer work and meetings	.05	.06	.05	.05	.05	.06	.05
HHI Leisure 2[a]	.62	.63	.62	.60	.61	.57	.52
HHI Leisure 2[b]	.62	.63	.61	.60	.61	.56	.52
Leisure 3	11.8	11.8	11.8	11.8	12.5	15.8	17.7
Social life and entertainment	.08	.08	.09	.09	.14	.17	.14
Sports and outdoor activities	.02	.03	.03	.03	.03	.04	.05
Hobbies and games	.01	.02	.01	.02	.02	.02	.02
Mass media	.19	.18	.18	.18	.18	.18	.20
Child care	.01	.01	.01	.00	.01	.01	.01
Gardening and pet care	.02	.01	.01	.01	.02	.02	.01
Volunteer work and meetings	.02	.02	.02	.02	.02	.03	.02
Sleep	.65	.65	.65	.65	.58	.53	.55
HHI Leisure 3[a]	.52	.52	.52	.51	.48	.43	.43
HHI Leisure 3[b]	.52	.52	.52	.51	.47	.43	.42
Diaries	904	926	888	944	870	1,180	1,086

Notes: Relative shares showing the distribution of leisure across activities are in italics. [a]: Child care, gardening and pet care, and volunteer work and meetings are aggregated together; [b]: Those three activities are kept disaggregated. Source: German Time Budget Survey (ZBE) 2001/2002, own calculations.

The U-shape, however, is not symmetrical: Ranging from our narrowest definition of leisure to the broadest, the minimum of the U is reached at 9.2, 9.6, and 20.2 hours, respectively, i.e. close to the 90th percentile of the corresponding sampling distribution of leisure (located,

[10] The standard errors listed in Table 4 are robust to heteroskedasticity and clustered at the individual level.

respectively, at 9.3, 10.2, and 19.3 hours). Hence, the partial effect of the quantity of leisure on its degree of concentration is negative for most of the leisure range. Computed, for example, at average leisure values, an extra hour of leisure reduces concentration by approximately -0.027, -0.025, and -0.023,[11] implying a 4 to 5 percent reduction in each case. These results change very little when concentration is assessed with the *THI*: The minimum of the U is reached at 9.3, 9.6, and 20.1 hours, and the reduction in concentration induced by an extra hour of leisure is -0.026, -0.025, and -0.022 when computed at average leisure values.

Table 3
Percentage of waking leisure spent on related travel and not alone, by leisure activity – Employed prime-age men

Leisure activity	Related travel	Not alone
Social life and entertainment	11.6	79.0
Sports and outdoor activities	9.4	63.8
Hobbies and games	1.7	46.8
Mass media	-	46.8
Child care	0.0	97.6
Gardening and pet care	49.3	57.4
Volunteer work and meetings	17.9	64.7

Notes: Mass media has not related travel in the Eurostat activity coding list. In the ZBE 2001/2002, no respondent reports travel related to child care as main activity. Source: German Time Budget Survey (ZBE) 2001/2002, own calculations.

Regarding the other effects presented in Table 4, having a college degree or being in good health is negatively associated with concentration, particularly when sleeping is not included in leisure. Being married is essentially unrelated to concentration when child care is excluded from leisure, but becomes a strong predictor for concentration otherwise: ceteris paribus, married men's Leisure 2 concentration is, on average, 4 to 5 percent smaller, the larger reduction observed when child care is kept disaggregated from other activities. No statistically significant differences in concentration are observed from Monday to Thursday, but concentration (as measured from Leisure 1 and Leisure 2) is greater on Fridays and Saturdays, and smaller on Sundays. These end-of-the-week differences in concentration might be the result of social norms regulating the type of leisure activities allowed on certain days, and/or of the availability of more leisure companions within and outside the household (Bittman, 2005; Jenkins and Osberg, 2005).

The existence of a significant and generally negative partial correlation between the quantity of leisure and its degree of concentration does not demonstrate a causal relationship. At the very least, we are faced with the prospect of omitted variable bias. It is conceivable, for example, that persons who like practicing some sport present less concentrated leisure profiles and demand more leisure.

[11] This partial effect is computed by subtracting the value of the regression function for concentration evaluated at mean leisure from this function's value evaluated at that mean plus 1, holding other regressors fixed.

Table 4
Leisure concentration regressions – Employed prime-age men

	Dependent variable: HHI, computed from									
	Leisure 1		Leisure 2[a]		Leisure 2[b]		Leisure 3[a]		Leisure 3[b]	
Independent variables	(1)		(2)		(3)		(4)		(5)	
Leisure	-.067	(.003)**	-.072	(.003)**	-.073	(.003)**	-.075	(.004)**	-.075	(.004)**
Leisure squared	.0037	(.0002)**	.0038	(.0002)**	.0038	(.0002)**	.0019	(.0001)**	.0019	(.0001)**
Age	-6×10^{-4}	(.003)	-.002	(.003)	-.0023	(.0031)	-.0026	(.0016)	-.0027	(.0016)
Age squared	1×10^{-5}	(3×10^{-5})	4×10^{-5}	(3×10^{-5})	5×10^{-5}	(4×10^{-5})	3×10^{-5}	(2×10^{-5})	3×10^{-5}	(2×10^{-5})
Married	.007	(.008)	-.023	(.008)**	-.028	(.008)**	-.004	(.004)	-.005	(.004)
College	-.014	(.006)*	-.012	(.006)*	-.013	(.006)*	.001	(.003)	.001	(.003)
Non-German	.017	(.031)	.036	(.032)	.039	(.032)	-.007	(.015)	-.007	(.015)
Very good or good health	-.017	(.007)**	-.014	(.007)*	-.013	(.007)*	-.006	(.004)	-.006	(.004)
Tue	.011	(.009)	.013	(.009)	.012	(.009)	-.001	(.004)	-.001	(.004)
Wed	-.008	(.009)	-3×10^{-6}	(.009)	.001	(.009)	-.002	(.005)	-.002	(.005)
Thu	-.010	(.009)	-.011	(.009)	-.010	(.009)	-.007	(.005)	-.007	(.005)
Fri	.028	(.009)**	.026	(.009)**	.026	(.009)**	-.027	(.005)**	-.027	(.005)**
Sat	.027	(.009)**	.023	(.009)*	.023	(.009)*	.001	(.005)	.001	(.005)
Sun	-.026	(.009)**	-.012	(.009)	-.009	(.009)	.023	(.005)**	.023	(.005)**
Intercept	.885	(.061)**	.878	(.063)**	.882	(.064)**	1.20	(.043)**	1.20	(.044)**
R^2	.136		.148		.149		.410		.409	

Notes: Data are of 6,798 diaries pertaining to 2,266 individuals. The estimation method is OLS in all columns. The independent variable Leisure is measured in hours and its definition is consistent with that of the dependent variable. Heteroskedasticity robust standard errors clustered at the individual level are in parentheses. [a]: Child care, gardening and pet care, and volunteer work and meetings are aggregated together; [b]: Those three activities are kept disaggregated. *: Significant at 5 percent. **: Significant at 1 percent.
Source: German Time Budget Survey (ZBE) 2001/2002, own calculations.

Or that good weather conditions during the survey reference week encouraged both the range of leisure activities undertaken and the demand for leisure. Therefore, the estimated partial correlation might be influenced by unobserved individual and/or week effects. It is also possible that unobserved diary day effects are biasing the estimates. This would be the case if, for example, a friend's visit on the diary day promoted both the demand for leisure and the range of leisure activities undertaken. For all these reasons, the main estimates presented in Table 4 are to be reexamined.

4.2 Estimation Method

Assume that individual i's leisure concentration and leisure quantity on day d (denoted, respectively, HHI_{id}^L and L_{id}) are related according to

$$(8) \qquad HHI_{id}^L = \beta_0 + \beta_1 L_{id} + \beta_2 L_{id}^2 + \beta_3 I_{id}^{Fri} + \beta_4 I_{id}^{Sat} + \beta_5 I_{id}^{Sun} + \mu_i + u_{id}, \quad d = 1,2,3$$

where the β's are unknown parameters to be estimated. The three diary days available in the ZBE 2001/2002 are sorted out from Monday to Sunday, so that $d=1$ and $d=2$ indicate weekdays and $d=3$ indicates the Saturday/Sunday. Thus, diaries are arranged chronologically except for individuals who postponed the completion of a weekday diary. The possible convexity of the concentration profile is captured by the terms L_{id} and L_{id}^2, whose associated coefficients, β_1 and β_2, would be respectively negative and positive. I_{id}^{Fri}, I_{id}^{Sat} and I_{id}^{Sun} are indicator variables taking on value one if the diary pertains to the day indicated in the superscript and value zero otherwise. The mean-zero unobserved variable μ_i, which represents individual-level features and circumstances influencing the concentration of leisure that were invariant during the survey week, is allowed to be arbitrarily correlated with the observed explanatory variables. Included in μ_i would be, for example, the total weekly hours of work and the prices of goods consumed in the course of leisure activities if those prices were invariant during the survey week. The mean-zero variable u_{id} stands for unobserved factors altering the concentration of leisure on day d. It is assumed to be weakly exogenous:

$$(9) \qquad E\left(u_{id} \middle| \mathbf{x}_{id-1}, \mathbf{x}_{id-2}, \mu_i\right) = 0, \quad d = 1,2,3$$

where $\mathbf{x}_{id} \equiv (1, L_{id}, L_{id}^2, I_{id}^{Fri}, I_{id}^{Sat}, I_{id}^{Sun})$ and d assumes a chronological ordering (i.e., (9) does not hold if i postponed the completion of a weekday diary). Moment conditions similar to (9) are typical of intertemporal decision making models under uncertainty (e.g., see Hall, 1978, and Altonji, 1986), where a rational expectations assumption makes u_{id} to be uncorrelated with explanatory variables dated at $d-1$ or earlier. In this study, u_{id} is allowed to be correlated with L_{id} and L_{id}^2 because the quantity of leisure is under the individual's control. In this context, it is well-known that the pooled OLS estimator of (8) is biased and inconsistent[12]. To get rid of μ_i ,define $\Delta HHI_{i3}^L = HHI_{i3}^L - HHI_{i2}^L$, $\Delta L_{i3} = L_{i3} - L_{i2}$, $\Delta L_{i3}^2 = L_{i3}^2 - L_{i2}^2$ and $\Delta u_{i3} = u_{i3} - u_{i2}$. Then,

12 See for example Wooldridge (2002, Ch. 10). The asymptotic analysis is as the number of sample individuals tends to infinity.

(10) $$\Delta HHI_{i3}^{L} = \beta_4 + \beta_1 \Delta L_{i3} + \beta_2 \Delta L_{i3}^2 + \gamma_1 I_{i3}^{Sat-Fri} + \gamma_2 I_{i3}^{Sun-MTW} + \gamma_3 I_{i3}^{Sun-Fri} + \Delta u_{i3}$$

In this expression, each I is an indicator variable taking on value one if the difference was taken as indicated in the superscript and value zero otherwise. For example, $I^{Sun-MTW}$ equals one if the second diary day is Monday, Tuesday, Wednesday, or Thursday, and the third diary pertains to a Sunday. The unknown parameters γ are such that $\beta_3 = -\gamma_1$ and $\beta_5 = \beta_4 + \gamma_2$. It can also be shown that

(11) $$\gamma_3 = \gamma_1 + \gamma_2$$

a result that will be tested in the data.

While expression (10) is a standard cross section equation that can be estimated by OLS, the key conditions for OLS to consistently estimate β_1 and β_2,

(12a) $$E\left(\left(L_{i3} - L_{i2}\right)\left(u_{i3} - u_{i2}\right)\right) = 0$$

(12b) $$E\left(\left(L_{i3}^2 - L_{i2}^2\right)\left(u_{i3} - u_{i2}\right)\right) = 0$$

will not hold if L_{id} or L_{id}^2 are correlated with u_{id}. I use responses to the questions "Does it happen that you work on weekends? If Yes, how often?", which are asked of all workers by the ZBE 2001/2002, as well as L_{i1} and L_{i1}^2, to instrument ΔL_{i3} and ΔL_{i3}^2. Working on weekends is likely to have a substantial negative impact on the quantity of leisure (e.g., Bittman, 2005, has found a big fall in leisure activities associated to Sunday employment in Australia), and is therefore expected to be negatively correlated with ΔL_{i3} and ΔL_{i3}^2. The validity of this information as an instrument relies upon being uncorrelated with preferences for the concentration of leisure on the Saturday/Sunday of the reference week. This assumption would be questioned if, for example, those who work on weekends got more tired and the degree of tiredness influenced the organization of leisure activities. To check for that possibility, I estimated (10) by OLS with the working on weekends instrument (as specified in the following paragraph) included among the explanatory variables. When sleep is not counted as leisure, the coefficient on the instrument is positive but statistically not different from zero (the *p*-values range from 0.10 to 0.28). When sleep is counted as leisure, the coefficient on the instrument is negative and statistically different from zero (*p*-value 0.01; in the subsample, *p*-values are at or around 0.10). These results cast some doubts on the validity of this instrument when sleep is considered leisure. The validity of L_{i1} and L_{i1}^2 rests on a different rationale: Under the weak exogeneity assumption stated in (9), L_{i1} and L_{i1}^2 are uncorrelated with Δu_{i3}.[13] Since this assumption will not hold in the case of individuals who postponed the completion of the first diary, these persons will be excluded

[13] The validity of L_{i1} (respectively, L_{i1}^2) as an instrument for ΔL_{i3} (ΔL_{i3}^2) does not rule out serial correlation in u_{id}: Correlation between L_{id} (or L_{id}^2) and u_{id} can be prompted by a white noise term, whereas correlation in u_{id} can be induced by a serially correlated preference shifter (Arellano and Honoré, 2001, p. 3238). The validity of L_{i1} and L_{i1}^2 does require, however, that L_{id} and L_{id}^2 exert only a contemporaneous effect on HHI_{id}^{L}.

from some estimations. Correlation between L_{i1} (respectively, L_{i1}^2) and ΔL_{i3} (ΔL_{i3}^2) can be induced by a time-varying serially correlated preference for leisure.

Five mutually exclusive answers are possible to the above-mentioned questions on working on weekends: “Never”, “Every week”, “Every two weeks”, “Every three-four weeks”, and “More rarely”, which are provided separately for Saturdays and Sundays. From this information I constructed a series of indicator variables corresponding to the five possible responses. The indicator for “Every week”, for example, takes on value 1 if the worker completed a diary for a Saturday (respectively, a Sunday) and reports working every Saturday (Sunday), and value 0 otherwise. As shown in Table 1, 15.0 percent of those whose third diary day is a Saturday work every Saturday, whereas the corresponding figure for Sundays is 7.5 percent.[14] Reduced form regressions for ΔL_{i3} and ΔL_{i3}^2 on all exogenous variables, including L_{i1}, L_{i1}^2 and the indicators for “Every week”, “Every two weeks”, “Every three-four weeks”, and “More rarely”, revealed that the last three indicators are individually insignificant in each regression. As weak instruments can harm the finite-sample properties of instrumental variables (IV) estimators even in large samples (see e.g. the survey article by Murray, 2006), only the indicator for working every weekend will be included in the instrument set.

4.3 Results

Tables 5 and 6 present the estimates of the differenced equation (10). In Table 5, OLS coefficients, which do not control for the endogeneity of ΔL_{i3} and ΔL_{i3}^2 are presented. In Table 6, Generalized Method of Moments (GMM) estimates calculated with optimal weighting matrix are shown. (Auxiliary IV output, including the first-stage regressions for the endogenous variables, is presented in the Appendix.) In both tables, the upper panel lists results for the full sample, whereas results for the subsample of workers who did not postpone the completion of the first diary are shown in the lower panel. Heteroskedasticity robust standard errors appear in parentheses, and probability values in brackets.

When ΔL_{i3} and ΔL_{i3}^2 are treated as exogenous, a U-shaped relationship between daily leisure and its degree of concentration similar to that presented in Table 4 is estimated. Although differencing has reduced the number of observations to 2,266, the relationship is still precisely measured and attains statistical significance at the 0.01 level. According to the estimates for the full sample, and ranging from our narrowest definition of leisure to the broadest, the U function minimum is located at 9.9, 10.5, and 20.8 hours, respectively, whereas an extra hour of leisure is estimated to reduce concentration by approximately -0.028, -0.027, and -0.022 when the effect is computed at average leisure values. Aggregating child care, gardening and pet care, and volunteer work and meetings into one activity leaves the results essentially unaffected, as well as estimating (10) on the subsample.

14 Although Saturdays are considered working days in the German working time law, most people do not work on Saturdays, and, for those who work, special bonuses are agreed upon in most collective agreements. Working on Sundays is prohibited, but exceptions can be approved by the authorities. See Bosch (2009) for more information on working time regulations in Germany.

Table 5
Linear models for the concentration of leisure – OLS differences estimates

	Full sample: 2,266 employed prime-age men									
	Dependent variable: ΔHHI^{L}_{i3}, computed from:									
	Leisure 1		Leisure 2[a]		Leisure 2[b]		Leisure 3[a]		Leisure 3[b]	
Independent variables	(1)		(2)		(3)		(4)		(5)	
ΔL_{i3}	-.064	(.005)**	-.065	(.005)**	-.066	(.005)**	-.068	(.004)**	-.068	(.004)**
ΔL^2_{i3}	.0032	(.0004)**	.0031	(.0003)**	.0032	(.0003)**	.0016	(.0001)**	.0016	(.0001)**
$I^{Sat-Fri}$	-.010	(.016)	-.009	(.015)	-.012	(.015)	.027	(.007)**	.027	(.007)**
$I^{Sun-MTW}$	-.048	(.014)**	-.040	(.014)**	-.037	(.014)**	.029	(.007)**	.030	(.007)**
$I^{Sun-Fri}$	-.082	(.018)**	-.063	(.017)**	-.061	(.017)**	.057	(.008)**	.058	(.008)**
Intercept	.027	(.012)*	.026	(.012)*	.027	(.012)*	-.006	(.006)	-.006	(.006)
R^2	.110		.122		.125		.319		.321	
Test for endogeneity of ΔL_{i3} and ΔL^2_{i3} (robust Wald statistic)	1.22	[.54]	1.16	[.56]	1.62	[.44]				
Wald test: $\gamma_3 = \gamma_1 + \gamma_2$	1.06	[.30]	.44	[.51]	.25	[.62]	.01	[.92]	.03	[.87]
Ramsey's (1969) RESET	2.79	[.43]	1.43	[.70]	1.57	[.67]	15.81	[.00]	15.69	[.00]

Table 5 (Cont.)

	Sub-sample: 1,431 individuals who did not postpone the completion of the first diary									
	Dependent variable: ΔHHI_{i3}^{L}, computed from:									
	Leisure 1		Leisure 2[a]		Leisure 2[b]		Leisure 3[a]		Leisure 3[b]	
Independent variables	(6)		(7)		(8)		(9)		(10)	
ΔL_{i3}	-.058	(.006)**	-.060	(.006)**	-.063	(.006)**	-.061	(.006)**	-.062	(.006)**
ΔL_{i3}^{2}	.0028	(.0004)**	.0028	(.0004)**	.0030	(.0004)**	.0014	(.0002)**	.0014	(.0002)**
$I^{Sat-Fri}$	-.027	(.019)	-.024	(.017)	-.028	(.017)	.036	(.008)**	.035	(.008)**
$I^{Sun-MTW}$	-.055	(.019)**	-.052	(.018)**	-.047	(.018)**	.022	(.009)*	.023	(.009)*
$I^{Sun-Fri}$	-.083	(.021)**	-.071	(.020)**	-.068	(.020)**	.053	(.010)**	.054	(.010)**
Intercept	.029	(.014)*	.027	(.014)*	.029	(.014)*	-.013	(.007)	-.012	(.007)
R^2	.101		.113		.117		.308		.311	
Test for endogeneity of ΔL_{i3} and ΔL_{i3}^{2} (robust Wald statistic)	7.77	[.02]	5.48	[.06]	5.58	[.06]	9.43	[.01]	9.12	[.01]
Wald test: $\gamma_3 = \gamma_1 + \gamma_2$	.00	[.98]	.02	[.88]	.08	[.78]	.15	[.70]	.11	[.74]
Ramsey's (1969) RE-SET	5.36	[.15]	.29	[.96]	.18	[.98]	15.56	[.00]	15.35	[.00]

Notes: Heteroskedasticity robust standard errors are in parentheses and probability values appear in brackets. The activities included in ΔL_{i3} are consistent with those in the dependent variable. [a]: Child care, gardening and pet care, and volunteer work and meetings are aggregated together; [b]: Those three activities are kept disaggregated. *: Significant at 5 percent. **: Significant at 1 percent.
Source: German Time Budget Survey (ZBE) 2001/2002, own calculations.

Table 6
Linear models for the concentration of leisure – GMM differences estimates

	Full sample: 2,266 employed prime-age men				
	Dependent variable: ΔHHI_{i3}^{L}, computed from:				
	Leisure 1	Leisure 2[a]	Leisure 2[b]	Leisure 3[a]	Leisure 3[b]
Independent variables	(1)	(2)	(3)	(4)	(5)
ΔL_{i3}	-.138 (.069)*	-.090 (.033)**	-.096 (.034)**	-.077 (.018)**	-.079 (.018)**
ΔL_{i3}^{2}	.0067 (.0033)*	.0039 (.0016)*	.0040 (.0017)*	.002 (.0005)**	.0021 (.0006)**
$I^{Sat-Fri}$	-.040 (.031)	-.025 (.021)	-.030 (.021)	.028 (.008)**	.027 (.008)**
$I^{Sun-MTW}$	-.025 (.028)	-.032 (.017)	-.028 (.017)	.025 (.010)*	.026 (.011)*
$I^{Sun-Fri}$	-.104 (.028)**	-.078 (.022)**	-.078 (.023)**	.055 (.009)**	.056 (.009)**
Intercept	.116 (.086)	.075 (.047)	.084 (.048)	-.012 (.017)	-.010 (.017)
Hansen J test of over-identifying restrictions (No. OR: 1)	1.83 [.18]	.29 [.59]	.37 [.54]	9.79 [.00]	9.43 [.00]

Table 6 (Cont.)

	Sub-sample: 1,431 individuals who did not postpone the completion of the first diary				
	Dependent variable: ΔHHI_{i3}^{L}, computed from:				
	Leisure 1	Leisure 2[a]	Leisure 2[b]	Leisure 3[a]	Leisure 3[b]
Independent variables	(6)	(7)	(8)	(9)	(10)
ΔL_{i3}	-.072 (.025)**	-.071 (.021)**	-.074 (.021)**	-.115 (.020)**	-.115 (.020)**
ΔL_{i3}^{2}	.0010 (.0019)	.0023 (.0016)	.0024 (.0017)	.0034 (.001)**	.0034 (.001)**
$I^{Sat-Fri}$	-.052 (.023)*	-.043 (.020)*	-.048 (.020)*	.032 (.009)**	.031 (.009)**
$I^{Sun-MTW}$	-.023 (.025)	-.042 (.019)*	-.037 (.019)	-.001 (.015)	.001 (.015)
$I^{Sun-Fri}$	-.090 (.025)**	-.089 (.022)**	-.086 (.023)**	.036 (.013)**	.037 (.013)**
Intercept	.129 (.043)**	.089 (.031)**	.092 (.031)**	-.023 (.012)	-.021 (.012)
Hansen J test of over-identifying restrictions (No. OR: 1)	.53 [.47]	.27 [.61]	.56 [.45]	.08 [.78]	.05 [.82]

Notes: Heteroskedasticity robust standard errors are in parentheses and probability values appear in brackets. The activities included in ΔL_{i3} are consistent with those in the dependent variable. In all columns, ΔL_{i3} and ΔL_{i3}^{2} are instrumented with L_{i1}, L_{i1}^{2} and the indicator for working every weekend. [a]: Child care, gardening and pet care, and volunteer work and meetings are aggregated together; [b]: Those three activities are kept disaggregated. *: Significant at 5 percent. **: Significant at 1 percent.
Source: German Time Budget Survey (ZBE) 2001/2002, own calculations.

Instrumenting for ΔL_{i3} and ΔL_{i3}^2 tends to increase (in absolute value) the estimated β_1 and β_2, although the implied relationship between daily leisure and its degree of concentration continues being U-shaped. Estimates are more imprecise, but attain statistical significance at the 0.05 level. According to the estimates for the full sample, and presenting again the results from our narrowest notion of leisure to the broadest, the U function minimum is located at 10.3, 11.7, and 19.2 hours, and an extra hour of leisure reduces concentration by approximately -0.064, -0.044, and -0.021 at average leisure values. In the subsample, β_1 is negative and β_2 is zero (at standard significance levels) in the case of Leisure 1 and Leisure 2, thereby implying an inverse linear relationship between leisure and its concentration. When sleep is counted at leisure, however, the implied relationship is again U-shaped, the peak is reached at 17.0 hours, and an extra hour of leisure reduces concentration by approximately -0.020 at average leisure values.

Since the number of excluded instruments (three) exceeds the number of endogenous variables (two), it is possible to test the overidentifying restrictions on the excluded instruments. The test statistic (Hansen, 1982, J-statistic) is the minimized value of the GMM objective function, and is asymptotically distributed as χ^2 with degrees of freedom equal to the number of overidentifying restrictions (one in this case). The main output of the overidentifying restrictions test is presented separately for each leisure definition at the bottom of each panel in Table 6. When sleep is excluded from leisure, the p-value for this test is above standard significance levels, so that the validity of the instruments is not questioned. Yet, when time spent sleeping is counted as leisure, the validity of the instruments is clearly rejected in the full sample (p-value 0.00). In the subsample, the validity of the instruments is well within confidence bounds irrespective of the leisure definition.

The fact that IV estimates do not expose substantial biases in OLS results suggests that ΔL_{i3} and ΔL_{i3}^2 could not be endogenous. To test for endogeneity, the residuals from regressing ΔL_{i3} and ΔL_{i3}^2 on all the exogenous variables were added to each of the regressions presented in Table 5 (except those in columns (4) and (5), where the instruments revealed as invalid). Then, the joint statistical significance of the residual terms in each regression was tested using a robust Wald test (Wooldridge, 2002, p. 121). Listed in the third from last row of each panel in Table 5 are the results of this test. In the full sample, the claim of exogeneity is well within confidence bounds. In the subsample, the test results suggest that ΔL_{i3} and ΔL_{i3}^2 are endogenous, particularly in the cases of Leisure 1 and Leisure 3.

Additional specification checks can be carried out by testing the restriction on the coefficients in (11) and by testing the statistical significance of powers of the fitted values in the regression for ΔHHI_{i3}^{L}. Under the assumption that model (8) is correct, (11) is obviously true in the population, but estimation biases could impede its verification in the data. Under the same assumption, powers of the fitted values added to (10) must be jointly insignificant (Ramsey, 1969). Results of robust Wald tests for the hypothesis in (11) and for testing the joint significance of $\widehat{\Delta HHI_{i3}^{L}}^2$,$\widehat{\Delta HHI_{i3}^{L}}^3$ and $\widehat{\Delta HHI_{i3}^{L}}^4$ in (10) are presented at the bottom of each panel in Table 5 separately for each regression. The null in (11) is safely within confidence bounds in all cases. When sleep is not counted as leisure, the claim of no functional form mis-specification is not rejected. Therefore, and in agreement with panel (c) of Figure 1, a quadratic function seems sufficient to represent the leisure concentration profile in that case. Yet, when sleep is counted as leisure the claim of no functional form mis-specification is clearly rejected.

Overall, the preceding specification checks tend to favor the estimates in columns (1)-(3) of Table 5 and (9)-(10) of Table 6, which tell a rather consistent story: The concentration of daily leisure activities decreases with the hours of leisure available until hours are so large (around the 90th percentile of its empirical distribution in the case of Leisure 1 and Leisure 2; around the 75th percentile in the case of Leisure 3) that concentration reverses its trend. Thus, when the quantity of leisure is small individuals concentrate on a few leisure activities, whose relative importance in the time budget diminishes as more leisure becomes available. Interpreted in terms of our theoretical model, this empirical pattern is in agreement with the case shown in panel (c) of Figure 1, if the equivalent of $(\gamma_1-\gamma_2)/(\alpha_2-\alpha_1)+\gamma_1+\gamma_2$ were located well above the mean of L. It likewise rejects the claim that daily leisure is not required for subsistence, i.e. that $\gamma_1=\gamma_2=0$. Regarding the size of the effect, at average leisure values the concentration of Leisure 1, Leisure 2, and Leisure 3 would decrease around 4 percent with an extra hour of leisure, but the reduction would be much stronger at for example the 25th percentile of the leisure empirical distribution: 8, 10, and 10 percent, respectively.

The estimation results also suggest the existence of day-of-the-week effects on leisure concentration. There is some evidence of a Friday effect (given by minus the coefficient associated to $I^{Sat-Fri}$) when sleeping in included in leisure: Keeping constant the quantity of leisure, leisure activities become, on average, less concentrated on Fridays than in the period Monday-Thursday. The Saturday effect (estimated by the intercept) is positive in the case of Leisure 1 and Leisure 2, and suggests that, at average leisure concentration values, the concentration of leisure is about 4 percent larger on Saturdays than in the period Monday-Thursday. Concentration on Sundays (obtained by adding the coefficients associated to the intercept and to $I^{Sun-MTW}$) is smaller to that observed in the period Monday-Thursday in the case of Leisure 1.

I re-estimated the model in (10) by the methods explained above but replacing ΔHHI_{i3}^{L} with ΔTHI_{i3}^{L}. The different weighting pattern implicit in the *THI* revealed empirically insignificant. The most reliable estimates suggest, again, a U-shaped relationship between the quantity of leisure and its degree of concentration. The peak of the U is located at 10.0, 10.5, and 17.5 hours (ranging from our narrowest definition of leisure to the broadest), and an extra hour of leisure is estimated to reduce concentration by approximately 4 percent when the effect is computed at average leisure values. I also re-estimated the model excluding the travel time associated to each activity, finding that the main findings reported here were preserved.

5 Conclusions and directions for future research

We have presented the Herfindahl-Hirschman index (*HHI*) as a well-grounded measure of concentration of an individual's activity profile. The operationality of the *HHI* as a measure of time-use concentration is highest when information on the allocation of time is collected by the time diary, as this methodology achieves the highest validity and reliability in the measurement of the use of time. The set of weights with which relative time shares are combined in the *HHI* revealed empirically insignificant in the application contained in this study. Similarly, the main empirical conclusions remained unaltered when the number of activities distinguished in the activity profile was expanded.

A daily leisure demand model predicted a linear or convex profile for the concentration of leisure activities in response to variations in the quantity of leisure available. The observed response in a sample of prime-age German men was indeed convex, with the peak of the function located well to the right of average leisure. To identify this behavior we relied on sequential moment conditions for the concentration of leisure and on weekend working arrangements, which revealed as valid and relevant instrumental variables in many of the specifications considered.

The observed leisure concentration profile is consistent with the existence of a minimum quantity of daily leisure postulated in the theory. It likewise suggests that individuals having less leisure opt for a more concentrated (and perhaps less varied in the sense of Gronau and Hamermesh, 2008) pattern of daily leisure activities, whereby recreation sector firms should probably differentiate their products the most on non-working days. The behavior of women as well as of younger and older men will permit judging the generality of this pattern. Controlling additionally for possible self-selection into the labor force, the estimation of our empirical model could be extended to working women. For students, the exogenous reduction in classes and lectures brought about by the weekend could play the role of the weekend working arrangements in the instrument set.

As market work crowds out leisure (e.g., see Hamermesh, 2006, and Donald and Hamermesh, 2009), another implication of our findings is that market work is constraining the pattern of daily leisure activities. Evaluating the effect that this constraint exerts on individual well-being should be also the goal of future research (the evidence on the effect of the breadth of leisure activities undertaken on individual well-being is rather limited and mixed; see e.g. Ray, 1979, and Sonnentag, 2001), as well as estimating the amount of money required to offset that constraint, which seems relevant for designing effective hourly rate and overtime compensations.

Appendix

Table 7 presents OLS regressions for the potentially endogenous ΔL_{i3} and ΔL_{i3}^2 separately for each leisure definition. The upper panel of the table presents results for the full sample, whereas results for the subsample of workers who did not postpone the completion of the first diary are shown in the lower panel. Standard errors (shown in parentheses) are robust to heteroskedasticity.

Table 7
First-stage regression for ΔL_{i3} and ΔL_{i3}^2 – OLS estimates

	Full sample: 2,266 employed prime-age men					
	Dependent variables (the definition of leisure is indicated by the number after the comma):					
	ΔL_{i3},1	ΔL_{i3}^2,1	ΔL_{i3},2	ΔL_{i3}^2,2	ΔL_{i3},3	ΔL_{i3}^2,3
Independent variables	(1)		(2)		(3)	
Works every Sat/Sun	-.747 (.210)**	-12.34 (2.77)**	-.975 (.233)**	-16.05 (3.34)**	-1.66 (.27)**	-52.88 (7.97)**
L_{i1}	-.269 (.104)**	-4.31 (1.71)**	-.460 (.107)**	-7.27 (1.86)**	-1.02 (.19)**	-30.08 (5.68)**
L_{i1}^2	.030 (.009)**	.553 (.159)**	.038 (.009)**	.694 (.157)**	.035 (.006)**	1.06 (.20)**
$I^{Sat-Fri}$	-.648 (.194)**	-4.91 (2.73)	-.897 (.211)**	-9.23 (3.30)**	-.523 (.222)*	-10.94 (6.68)
$I^{Sun-MTW}$	.530 (.174)**	4.52 (2.44)	.333 (.189)	1.03 (2.90)	1.98 (.22)**	62.06 (6.50)**
$I^{Sun-Fri}$	-.460 (.229)*	-3.19 (3.40)	-1.03 (.24)**	-13.51 (3.91)**	.826 (.263)**	31.81 (8.18)**
Intercept	3.28 (.29)**	39.00 (4.18)**	4.52 (.33)**	60.57 (5.16)**	11.22 (1.31)**	318.9 (39.0)**
R^2	.045	.054	.051	.053	.107	.113
Kleibergen-Paap rank test	6.61 [.037]		22.11 [.000]		57.52 [.000]	
Cragg-Donald statistic	2.70		9.47		26.23	
Kleibergen-Paap *F*-statistic	2.20		7.35		19.11	

Table 7 (Cont.)

	Sub-sample: 1,431 individuals who did not postpone the completion of the first diary					
	Dependent variables (the definition of leisure is indicated by the number after the comma):					
	ΔL_{i3},1	ΔL_{i3}^2,1	ΔL_{i3},2	ΔL_{i3}^2,2	ΔL_{i3},3	ΔL_{i3}^2,3
	(4)		(5)		(6)	
Works every Sat/Sun	-.768 (.243)**	-12.56 (3.35)**	-.932 (.278)**	-15.32 (4.18)**	-1.57 (.34)**	-49.75 (10.02)**
L_{i1}	.021 (.108)	4.66 (1.65)**	-.048 (.121)	4.53 (2.01)*	.395 (.212)	21.91 (6.66)**
L_{i1}^2	-.019 (.009)*	-.525 (.155)**	-.023 (.010)*	-.656 (.180)**	-.028 (.008)**	-1.15 (.25)**
$I^{Sat-Fri}$	-.820 (.224)**	-7.19 (3.22)*	-1.11 (.25)**	-12.63 (3.88)**	-.465 (.254)	-10.48 (7.68)
$I^{Sun-MTW}$	.880 (.224)**	10.27 (3.33)**	.546 (.241)*	5.22 (3.93)	2.21 (.26)**	72.25 (8.00)**
$I^{Sun-Fri}$	-.334 (.289)	-1.83 (4.38)	-.953 (.304)**	-13.58 (4.98)**	.937 (.324)**	34.20 (10.11)**
Intercept	3.21 (.30)**	27.93 (4.27)**	4.31 (.37)**	44.92 (5.74)**	3.67 (1.40)**	30.63 (43.2)
R^2	.061	.038	.088	.055	.159	.149
Kleibergen-Paap rank test	26.11 [.000]		34.79 [.000]		55.94 [.000]	
Cragg-Donald statistic	9.68		14.45		26.47	
Kleibergen-Paap *F*-statistic	8.66		11.54		18.56	

Notes: Heteroskedasticity robust standard errors are in parentheses and probability values in brackets. L_{i1} is measured in hours and its definition is consistent with that of the dependent variable. The Cragg-Donald statistic is the minimum eigenvalue of the *F*-statistic matrix analog for testing the joint significance of the excluded instruments on the first-stage regressions. The Kleibergen-Paap *F* statistic equals to a quadratic form of an orthogonal transformation of the smallest singular value of the F-statistic matrix analog. The Kleibergen-Paap *F* statistic reduces to the Cragg-Donald statistic when the reduced-form errors are i.i.d. *: Significant at 5 percent. **: Significant at 1 percent.,
Source: German Time Budget Survey (ZBE) 2001/2002, own calculations.

Given the definition of ΔL_{i3}, by which leisure hours on a weekday are subtracted from leisure hours on a Saturday or Sunday, it is not surprising to estimate a positive and large coefficient associated to the intercept: Ranging from our narrowest definition of leisure to the broadest, the estimates are 3.3, 4.5, and 11.2 hours, respectively. The leisure gain brought about by the weekend is smaller for individuals working every weekend, whose weekend leisure forgone increases as the definition of leisure broadens: 0.7, 1.0, and 1.7 hours less, respectively. This effect is precisely measured and attains statistical significance at the 0.01 level. Irrespective of the leisure definition, the partial effect of L_{i1} on ΔL_{i3} or ΔL_{i3}^2 is negative for most of the leisure range, a result that seems partly driven by the positive correlation between L_{i1} and L_{i2}. (In the case of Leisure 1, for instance, this correlation is 0.26, whereas that between L_{i1} and L_{i3} is -0.01.) Although all excluded instruments are statistically significant at the 0.01 level in the full sample, and most of them achieve standard significance levels in the subsample, with two endogenous regressors the statistical significance of the excluded instruments is not sufficient in general to identify the β's, as identification requires that the matrix with the reduced-form coefficients associated to the excluded instruments have full rank (Wooldridge, 2002, p. 214). We have tested the null hypothesis that this matrix does not have full rank using the Kleibergen and Paap (2006) rank test. The p-values of this test, listed in Table 7, indicate that our instruments are adequate to identify the β's.

As is well-known, when the vector of instruments is weakly correlated with the endogenous regressors, standard IV coefficient estimates tend to be biased toward $plim(\hat{\beta}^{OLS})$ even in very large samples (e.g., see Staiger and Stock, 1997, and Stock and Yogo, 2005). Since weak instruments can also distort the significance levels for tests based upon standard IV, we shall test for weak instruments using the Stock and Yogo (2005) size-based test.[15] Its null hypothesis is that conventional 5%-level Wald tests for the β's based on IV statistics have an actual size that exceeds a certain threshold, for example 10%. The test statistic with two endogenous regressors is the Cragg and Donald (1993) statistic, whose value and definition are provided in Table 7. Table 7 also presents the value and definition of the *F*-statistic form of the Kleibergen and Paap (2006) statistic, which can be interpreted as a generalization of the Cragg-Donald statistic to the case with non-i.i.d. errors in the reduced-forms for the endogenous regressors. Critical values are taken from Stock and Yogo (2005, Table 5.2). To assure, for example, that the actual size of 5%-level tests for the β's is no greater than 10% (respectively, 15% and 25%), the test statistic must be greater than 13.43 (8.18 and 5.45) with three excluded instruments. In this study, the value of both statistics is generally above the 15% threshold critical value, the main exception being the regressions for Leisure 1 on the full sample. Hence, the estimates presented in column (1) of Table 6 may be biased toward $plim(\hat{\beta}^{OLS})$ because the instruments appear as weak.

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15 The alternative Stock and Yogo (2005) bias-based test requires at least four excluded instruments when there are two endogenous regressors.

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