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# Lifestyle Dynamics Index: Time Use Methodology and Worldwide Results

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**Abstract**

A novel index which captures lifestyle dynamics is described in this paper. By means of official time use surveys, increasingly spreading worldwide, we develop the so-called Lifestyle Dynamics Index, which is based on the information on activities provided by the Multinational Time Use Study (MTUS). We provide worldwide results of the Lifestyle Dynamics Index for all available countries historically. These results confirm a clear worldwide pattern towards a less dynamic lifestyle. Particularly, we study the case of the United States for the 2003–2012 decade; such results show the potential of this index since it is strongly related to relevant socio-economic information at the individual and household level, namely the per capita total household expenditure, obesity rates, net household savings and consumption of energy related goods. As more data –already collected– were released worldwide, the results of this index will grow exponencially and the potential use for socio-economic policy purposes of the Lifestyle Dynamics Index could be better exploited.

*Keywords: Households, Lifestyle, Time Use, Socio-Economic Behavior*

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# 1 Introduction

Households have traditionally provided relevant socio-economic information later used in a number of ways both in science and policy. Thus, it seems appropriate to approach any kind of study and measurement concerning lifestyle from a household perspective. Among the many dimensions that might be involved when studying lifestyle, lifestyle dynamics have already shown potential economic implications in some fields, e.g. public health [Stearns et al., 2000] and household energy consumption [Sukarno et al., 2017].

This paper provides a novel index which captures lifestyle dynamics by means of official time use surveys which are increasingly spreading out all over the world [United Nations, 2016]. We develop the so-called Lifestyle Dynamics Index based on the information on activities provided by time use diaries available in the Multinational Time Use Study (MTUS), which rigorously unify the classification of human activities displayed in a number of national official statisics worldwide [Fisher and Gershuny, 2016]. Moreover, we chose MTUS data for the harmonization process applied to all official time use surveys under analysis, especially in regard to both the time use variables and the activity variables. Basically, the Lifestyle Dynamics Index is an aggregate index based on each surveyed day for each surveyed member within each surveyed household; more in detail, this index tells us the position of an average day within a country in an ordering from a complete routinary day –just one activity is performed during the whole day– to the craziest possible day –that is, a day with the highest dynamics. Thus, the index summarizes this information for all (adult) individuals within the households that are surveyed; it also summarizes such information for all days in a week along different months within the year, respecting the statistical criteria originally used in each official national statistics which run every survey. We apply our methodology to all surveys up-to-the-date in the MTUS; this provides a tool which allows us to compare different lifestyle dynamics among countries even in different moments under a historical perspective.

The potential socio-economic interest and usefulness of this index is captured by its application to the United States data concerning per capita health expenditure, obesity rates, household expenditure in energy related goods and net household savings. The election of these applications is grounded by some facts noted in relevant literature –see [Hall and Jones, 2007], [Wiklund, 2016], [Sukarno et al., 2017], respectively. Together with the descriptive perspective offered by the results of the Lifestyle Dynamics Index and the diversity of different interpretations of such results, this paper poses an existing relationship of this index with several magnitudes of household and socio-economic interest. This enhances the validity of this index as a tool which summarizes considerable information for further empirical analysis.

In the paper, we firstly describe in full detail the elaboration and mathematical development of the index in section 2. Subsequently, we expose in Section 3 the methods

used to apply the index to the available data. Section 4 is devoted to show the main results and developing some discussion, particularly in the case of the United States in Section 4.1. We conclude with some final remarks.

## 2 Lifestyle Dynamics Index

Assume that an individual may perform every day $N$ different activities, so we denote by $A := \{1, 2, \dots, N\}$ the set of all different activities that can be carried out. Given a fixed period time (e.g. a minute), the total time spent across all the activities sums to $T$ time periods every day (e.g. $T = 1440$ if the time period is a minute).

For a given surveyed individual $i$ in a given day, we shall consider the following three quantities:

- $x_i$ denotes the number of different activities carried out.
- $y_i$ stands for the number of different (non repeated) changes between two different activities.
- $z_i$ stands for the number of total changes (repetitions included) between different activities.

Thus, for each individual $i$ one has $(x_i, y_i, z_i) \in \mathcal{F} \subset \mathbb{N}^3$ (we assume that $0 \in \mathbb{N}$ for simplicity) where $\mathcal{F}$ is some set which implicitly depends on $N$ and $T$.

**Definition 2.1.** For any two individuals $i_1$ and $i_2$, we say that $i_1$ *has a lifestyle more dynamic than* $i_2$ if either $x_1 > x_2$ or $x_1 = x_2, y_1 > y_2$ or $x_1 = x_2, y_1 = y_2, z_1 < z_2$ (in short, $(x_1, y_1, z_1) \succ (x_2, y_2, z_2)$).

In other words, $i_1$ has a lifestyle more dynamic than $i_2$ if either $x_1 > x_2$ ($i_1$ carries out more different activities that $i_2$), or $x_1 = x_2$ and $y_1 > y_2$ (both individuals perform the same number of activities, but $i_1$ changes from one activity to another more frequently that $i_2$), or $x_1 = x_2$, $y_1 = y_2$ and $z_1 < z_2$ (both individuals perform the same number of activities and make the same number of different changes between activities, but $i_2$ repeat some of those changes more frequently than $i_1$).

Next we sum all the instances within $\mathcal{F}$. Assume that a given day have been performed $x \in A$ different activities. Let $y(x)$ be the number of different non-repeated changes between two different activities that day. Thus, one has that $y(x)$ takes some value within the set

$$Y(x) := \{y_m(x), \dots, y_M(x)\} \subset \mathbb{N}$$

where $y_m(x) := x - 1$ is the minimum number of different non-repeated changes and $y_M(x) := \min\{x(x-1), T-1\}$ is the maximum number of different non-repeated

changes (where $x(x-1)$ stands for the variations of $x$ activities taken in pairs). Hence, the cardinality of $Y(x)$ is $\ell(x) := y_M(x) - y_m(x) + 1 = y_M(x) - x + 2$, that is,

$$\ell(x) = \begin{cases} x^2 - 2x + 2 & \text{if } y_M(x) = x(x-1), \\ T - x + 1 & \text{if } y_M(x) = T - 1. \end{cases}$$

Assume now that $x$ activities and $y(x) \in Y(x)$ different non-repeated changes have been performed a given day. We shall denote by $z(x, y(x))$ the whole number of changes performed that day. If $y(x) = y_m(x) = x - 1$, then there are no cycles between any two activities (we understand by a cycle between two activities $a$ and $b$ when both changes from $a$ to $b$ and from $b$ to $a$ are undertaken, not necessarily one after the other) and no repeated changes, and so the whole number of changes is just $z(x, y(x)) := y(x) = x-1$ (just one possibility). Otherwise, if $y(x) > y_m(x)$ (i.e., $y(x) \geq x$) then there exists at least one cycle between two activities. In such a case, the minimum number of total changes is $z_m(x, y(x)) := y(x)$ and the maximum number is $z_M(x, y(x)) := T - 1$. Hence, $z(x, y(x))$ take some value within the set

$$Z(x, y(x)) := \{z_m(x, y(x)), \ldots, z_M(x, y(x))\} \subset \mathbb{N}.$$

The cardinality of $Z(x, y(x))$ is $k(x, y(x)) := z_M(x, y(x)) - z_m(x, y(x)) + 1$, that is,

$$k(x, y(x)) = \begin{cases} 1 & \text{if } y(x) = y_m(x), \\ T - y(x) & \text{otherwise.} \end{cases}$$

Thus, if $x$ activities are performed then the number of associated vectors in $\mathcal{F}$ (with first component equal to $x$) is

$$P(x) := \sum_{y(x) \in Y(x)} k(x, y(x)) = \sum_{y(x) = y_m(x)}^{y_M(x)} k(x, y(x)) = 1 + \sum_{y(x)=x}^{y_M(x)} (T - y(x)) =$$

$$= 1 + T(\ell(x) - 1) - \sum_{y(x)=x}^{y_M(x)} y(x) = 1 + T(\ell(x) - 1) - \frac{1}{2}(\ell(x) - 1)(x + y_M(x)) =$$

$$= 1 + \frac{1}{2}(y_M(x) - x + 1)(2T - x - y_M(x)) =$$

$$= \begin{cases} 1 + \frac{1}{2}(x^2 - 2x + 1)(2T - x^2) & \text{if } y_M(x) = x(x-1), \\ 1 + \frac{1}{2}(T - x)(T - x + 1) & \text{if } y_M(x) = T - 1. \end{cases}$$

Now, as we have $N$ different activities, the cardinality of $\mathcal{F}$ is

$$|\mathcal{F}| = \sum_{x=1}^{N} P(x) = \mathcal{P}_1 + \mathcal{P}_2$$

where $\mathcal{P}_1 := \sum_{x=1}^{n} P(x)$, $\mathcal{P}_2 := \sum_{x=n+1}^{N} P(x)$, and for those $x \in \{1, \ldots, n\}$ one has $y_M(x) = x(x-1)$, and for $x \in \{n+1, \ldots, N\}$ one has $y_M(x) = T - 1$. Firstly we compute $\mathcal{P}_1$.

$$\mathcal{P}_1 = \sum_{x=1}^{n} P(x) = n + \frac{1}{2} \sum_{x=1}^{n} (x^2 - 2x + 1)(2T - x^2) =$$

$$= n + \frac{1}{2}\sum_{x=1}^{n}(-x^4 + 2x^3 + (2T-1)x^2 - 4Tx + 2T) =$$

$$= n + \frac{1}{2}(-S_n^4 + 2S_n^3 + (2T-1)S_n^2 - 4TS_n^1 + 2Tn)$$

where

$$S_n^1 := \sum_{i=1}^{n} i = \frac{n(n+1)}{2}, \qquad S_n^2 := \sum_{i=1}^{n} i^2 = \frac{n(n+1)(2n+1)}{6},$$

$$S_n^3 := \sum_{i=1}^{n} i^3 = \frac{n^2(n+1)^2}{4}, \qquad S_n^4 := \sum_{i=1}^{n} i^4 = \frac{n(n+1)(2n+1)(3n^2+3n-1)}{30}.$$

On the other hand, we have

$$\mathcal{P}_2 = \sum_{x=n+1}^{N} P(x) = (N-n) + \frac{1}{2}\sum_{x=n+1}^{N}(T-x)(T-x+1) =$$

$$= (N-n) + \frac{1}{2}\sum_{x=n+1}^{N}(x^2 - (2T+1)x + T^2 + T) =$$

$$= \frac{1}{2}\left((N-n)(2+T^2+T) + \sum_{x=n+1}^{N} x^2 - (2T+1)\sum_{x=n+1}^{N} x\right) =$$

$$= \frac{1}{2}\left((N-n)(2+T^2+T) + \sum_{x=1}^{N-n}(x^2+2nx+n^2) - (2T+1)\sum_{x=1}^{N-n}(x+n)\right) =$$

$$= \frac{1}{2}\left((N-n)(2+T^2+T) + S_{N-n}^2 + 2nS_{N-n}^1 + n^2(N-n) - (2T+1)(S_{N-n}^1 + n(N-n))\right)$$

In our particular case, the number of activities provided within the Multinational Time Use Study is $N = 69$ and the considered time period is $T = 1440$ minutes, which implies that the set $\mathcal{F}$ has cardinality 47.191.856. In other words, we build a rank of 47.191.856 elements by following the criterion introduced in Definition 2.1.

Then, for each individual in the survey, we compute its associate vector $(x, y, z)$ and locate the position of such a vector in the above rank. We then normalize so as to 100 become the highest possible value, and finally we take the average for all the individuals in the survey. The resulting number is what we have called Lifestyle Dynamics Index.

# 3 Data and Methods

Main data source for the construction of the index is the Multinational Time Use Study (MTUS) by the Centre for Time Use Research at the University of Oxford (see [Fisher and Gershuny, 2016] for further details).

Additional data used for some discussion and potential applications of the proposed index can also be found in [World Bank, 2016], [Bureau of Economic Analysis, 2017] and [Ogden et al., 2015][1].

We programmed mathematical routines explained in Section 2 into R code to generate numerical results and graphical representations using `plyr, DT, xtable, plotly` and `ggplot2` packages [R Core Team, 2014]. We used [RStudio Team, 2017] software running in an `Intel(R) Core(TM) i7 CPU 950 @ 3.07GHz x64 8.00GB`.

# 4 Results and Discussion

The performance of the Lifestyle Dynamics Index is shown numerically in Table 1 and graphically in Figure 1. We got 40 observations for this index in the 1965–2012 period, which dispersely within such time period comprise 10 countries (Australia, Austria, France, Germany, Israel, Italy, The Netherlands, Spain, United Kingdom and United States) of 4 continents (Asia, America, Europe and Oceania). Firstly, we observe an overall decline at a worldwide level of the Lifestyle Dynamics Index in the 1965–2012 period; Figure 1 plots all the data, which can be seen more accurately and in detail in the interactive version of the figure.

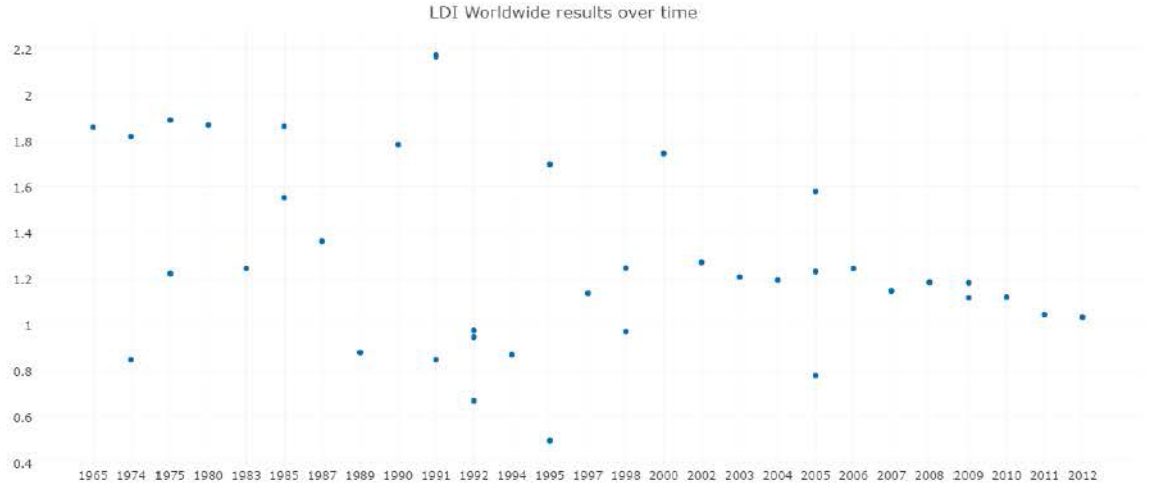



Figure 1: The Lifestyle Dynamics Index over time (all countries). Please click on the figure for an interactive version of the plot.

Secondly, for each of the 4 countries with more than one observation (Spain, The Netherlands, United Kingdom and United States) we also observe an overall decline in the lifestyle dynamics over time; The Netherlands and United States show a more monotonic decline with less volatility, whereas United Kingdom exhibits a more volatile

[1]For US household expenditure, US households net saving and US consumption in energy related goods, and the US obesity rates, respectively.

evolution. Spain must be commented specially, since according to the official national surveys we just have two observations (2002 and 2009) and a decline is observed; the remaining observations are regional results for the Basque region and might not be capturing all statistical power needed for overall national conclusions at the spanish level. A closer and filtered look at all these numerical data for all countries can be carried out through the interactive version of Table 1.

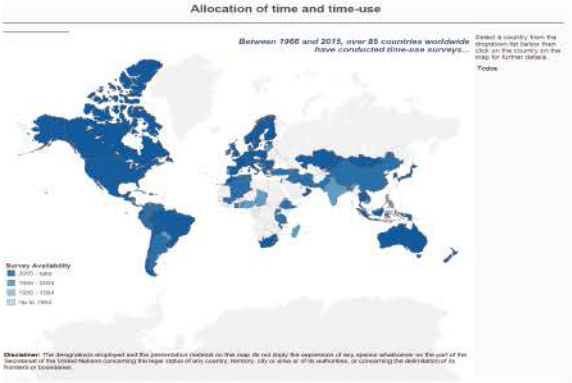
| # | Survey ID | Lifestyle Dynamics Index | Country | Year |
|---|---|---|---|---|
| 1 | australia1974 | 1.82 | australia | 1974 |
| 2 | austria1992 | 0.94 | austria | 1992 |
| 3 | france1998 | 0.97 | france | 1998 |
| 4 | germany1991 | 2.17 | germany | 1991 |
| 5 | israel1991 | 0.85 | israel | 1991 |
| 6 | italy1989 | 0.88 | italy | 1989 |
| 7 | netherlands1975 | 1.89 | netherlands | 1975 |
| 8 | netherlands1985 | 1.86 | netherlands | 1985 |
| 9 | netherlands1990 | 1.78 | netherlands | 1990 |
| 10 | netherlands2000 | 1.74 | netherlands | 2000 |
| 11 | netherlands2005 | 1.58 | netherlands | 2005 |
| 12 | netherlands1980corrected | 1.87 | netherlands1980corre | 1980 |
| 13 | netherlands1995corrected | 1.70 | netherlands1995corre | 1995 |
| 14 | spain1992 | 0.97 | spain | 1992 |
| 15 | spain1997 | 1.13 | spain | 1997 |
| 16 | spain2002 | 1.27 | spain | 2002 |
| 17 | spain2008 | 1.18 | spain | 2008 |
| 18 | spain2009 | 1.12 | spain | 2009 |
| 19 | uk1974 | 0.84 | uk | 1974 |
| 20 | uk1983 | 1.24 | uk | 1983 |
| 21 | uk1987 | 1.36 | uk | 1987 |
| 22 | uk1995 | 0.49 | uk | 1995 |
| 23 | uk2000 | 1.75 | uk | 2000 |
| 24 | uk2005 | 0.78 | uk | 2005 |
| 25 | usa1965 | 1.86 | usa | 1965 |
| 26 | usa1975 | 1.22 | usa | 1975 |
| 27 | usa1985 | 1.55 | usa | 1985 |
| 28 | usa1992 | 0.67 | usa | 1992 |
| 29 | usa1994 | 0.87 | usa | 1994 |
| 30 | usa1998 | 1.24 | usa | 1998 |
| 31 | usa2003 | 1.21 | usa | 2003 |
| 32 | usa2004 | 1.19 | usa | 2004 |
| 33 | usa2005 | 1.23 | usa | 2005 |
| 34 | usa2006 | 1.24 | usa | 2006 |
| 35 | usa2007 | 1.14 | usa | 2007 |
| 36 | usa2008 | 1.18 | usa | 2008 |
| 37 | usa2009 | 1.18 | usa | 2009 |
| 38 | usa2010 | 1.12 | usa | 2010 |
| 39 | usa2011 | 1.04 | usa | 2011 |
| 40 | usa2012 | 1.03 | usa | 2012 |

Table 1: The Lifestyle Dynamics Index, overall results. Please click on this caption for an interactive table of these results.

An alternative look at the results may consists of mapping the latest available data generated with the Lifestyle Dynamics Index –see Figure 2(a), where a darker color means a higher lifestyle dynamics. However neither the number of countries nor the timing of the latest available data are fully satisfactory, this map points towards some differences within European countries and some potential similarities with the

United States. Most importantly, mapping these results show the potential information that can be captured with the Lifestyle Dynamics Index as more surveys –whose data are already collected– are released in the Multinational Time Use Study (MTUS); actually, MTUS has over 60 time use surveys from about 25 countries, and according to [United Nations, 2016] there are over 85 countries which conducted time use surveys worldwide since 1966 –see Figure 2(b). Thus, it is apparent in Figure 2 the further application and extension of this index in the future worldwide.

(a) The Lifestyle Dynamics Index: Latest Results Worldwide




(b) All Time Use Surveys Conducted Worldwide

*Retrieved from the United Nations Statistics Division Time use data portal (click on the figure for the official link)*

Figure 2: Up-to-date latest results of the Lifestyle Dynamics Index and its potential application to other time use surveys worldwide. Please click on each figure for an interactive version of every plot.

A clear fact is that our basic input for the construction of this index –time use surveys– is not yet part of yearly official national statistics in most of the countries –or even just with some other fixed and clear frequency as bi-annual, quinquennal, etc. This limits partially or even completely our current explotation and further discussion based on the data generated with the Lifestyle Dynamics Index in most of the countries. However, we have an interesting exception in the United States of America, where yearly since 2003 official time use surveys have been running, so that we finally have at least a complete decade of results which we discuss separately below; although just a decade of yearly data may be insufficient for more accurate econometric analysis, it showed potential for further and future uses of this index for multidisciplinary public

decision making.

## 4.1 The case of the United States of America

The American Time Use Survey [Bureau of Labor Statistics, 2016] lets us analyse better than anywhere else lifestyle dynamics on a yearly basis, with the help for our purpose of the Multinational Time Use Study [Fisher and Gershuny, 2016]. We focus our discussion actually in the 2003–2012 period since the Multinational Time Use Study has updated its database –our main input data– up to 2012, however the American Time Use Survey has released data until 2015. We stick to the American Time Use Study (ATUS) –since 2003– and disregard previous historical data to avoid potential and critical methodological changes, which now can perfectly be identified and tracked in the ATUS.

Over the 2003–2012 period we found out at least four relationships of the Lifestyle Dynamics Index with hot topics in the US socio-economic arena: (i) public health expenditure, (ii) obesity rates, (iii) household savings and (iv) household expenditure in energy related products. We posit the correlations that were found out below to highlight the validity and potential of the proposed index.

[Hall and Jones, 2007] noted the fact of an increase in health spending for over the past half century, which often opens the debate on whether limiting its growth. A clear-cut result for the Lifestyle Dynamics Index in the United States case suggests a lower lifestyle dynamics –namely, a more routinary lifestyle, according to reported activities performed by US households. By comparing data on per capita heatlh expenditure [World Bank, 2016] to the results obtained with the Lifestyle Dynamics Index, we discovered a revealing correlation. Figure 3 shows that current values of the Lifestyle Dynamics Index exhibit a correlation of $-0.8$ with the per capita total health expenditure of two years later; this fact suggest that our proposed index may serve as a predictor of per capita total health expenditure in two years and therefore could be used for public decision making.

Figure 3: Lifestyle Dynamics Index vs US per capita Health Expenditure. Please click on the figure for an interactive version of the plot.

[Ogden et al., 2015] examined the obesity rates in the US over the 1999–2013 period, with data every two years. In order to compare the data with our index, we use obesity rates in the 2005–2013 period every two years, and lagged so that we can correlate our index in the 2003–2011 period with obesity rates two years later. Figure 4 shows a correlation of $-0.998$ between US obesity rates and its associated Lifestyle Dynamics Index. In addition, according to [Wiklund, 2016] the following is suggested:

*"The idea that obesity is caused by consistent decline in daily energy expenditure is not supported either by objective measures of energy expenditure or physiological theory of weight gain alone"* [Wiklund, 2016].

Our results may help to show that lifestyle dynamics might be a powerful magnitude with explanatory power on the obesity issue, as it is not limited to physical activity.

Figure 4: Lifestyle Dynamics Index vs US obesity rate. Please click on the figure for an interactive version of the plot.

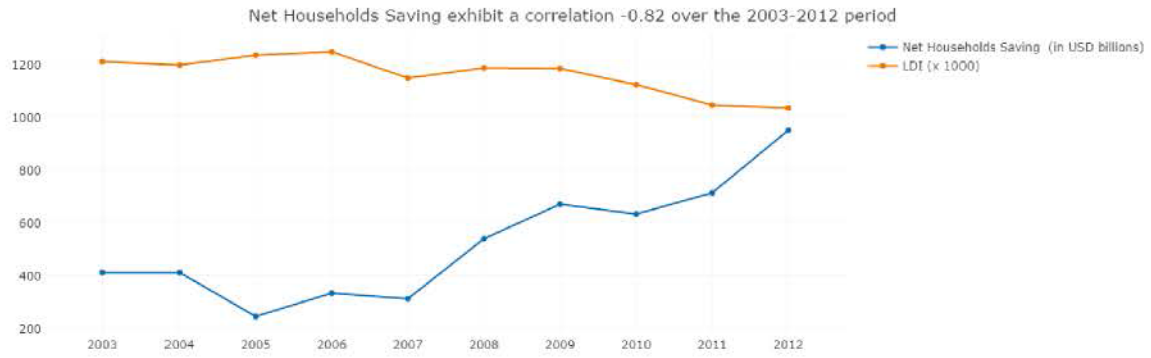



Figure 5: Lifestyle Dynamics Index vs US Net Households Savings. Please click on the figure for an interactive version of the plot.

Back into economic implications and relations of this index, we use household economic information provided by the [Bureau of Economic Analysis, 2017] to check possible correlations with household economic behavior and performance. Figure 5 expose a correlation of $-0.82$ between net household savings and lifestyle dynamics.

Last, recent research by [Sukarno et al., 2017] suggests a relationship between household lifestyle effect and energy consumption. We explored a similar relation for the US case, by correlating personal consumption in energy related goods provided by [Bureau of Economic Analysis, 2017] and the Lifestyle Dyamics Index for the US. Figure 6 provides also evidence in favor or such relation recently revealed by means of a correlation of $-0.74$ between current values of the index and personal consumption in energy related goods one year later.

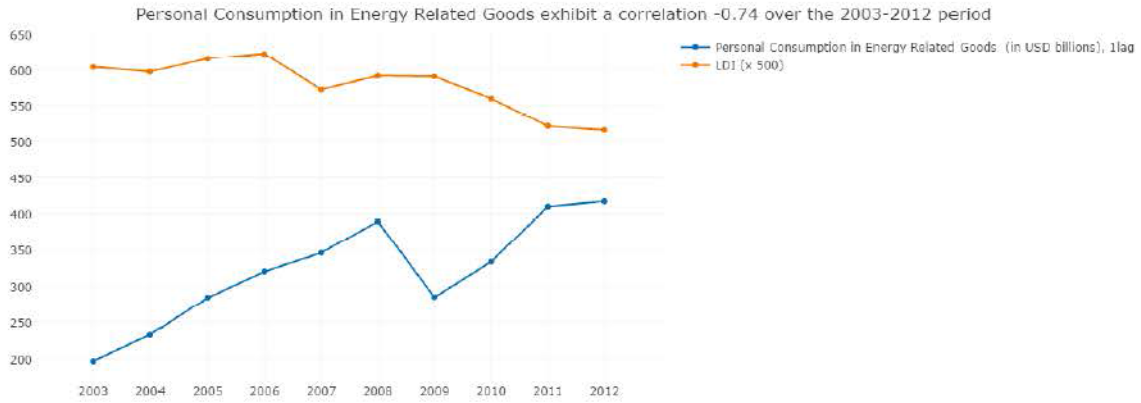



Figure 6: Lifestyle Dynamics Index vs US Personal Consumption in Energy Related Goods. Please click on the figure for an interactive version of the plot.

All these links between the Lifestyle Dynamics Index and relevant socio-economic information in the United States –where both the quantity and the quality of input data used for generating the index is very high– support the validity, the interest and the potential multidisciplinary usefulness of the index in the future both for the US and worldwide.

# 5 Conclusion

Increasing information on time use surveys provided by households from all over the world is likely to be used for analysing lifestyle. We provide in this paper a new methodology resulting in the Lifestyle Dynamics Index, which is able to rank and compare different (adult) lifestyle dynamics for different countries and different years. This measure is comparable for different years within the same country and accross countries even in different years.

We conclude from the results obtained that there is evidence in favour of a decreasing lifestyle dynamics worldwide –that is, since 1960s an average day in an average country seems to be performing less number of activities and fewer original and more repeated routines in daily activities. This overall trend is also observed in the four

countries with more than one point value of the index along time –namely Spain, The Netherlands, United States and United Kingdom.

Current lack of data in most of countries precludes a rigorous econometric analysis, however the case of United States allows us to capture some interesting potential of the Lifestyle Dynamics Index connected to household and socioeconomic implications. Yearly US data avaliable in the 2003–2012 decade suggest that the Lifestyle Dynamics Index is able to capture an inverse relationship with per capita total health expenditure, obesity rates, net household savings and expenditure in energy related goods. Thus, both the validity and potential usefulness and interest of the Lifestyle Dynamics Index as an instrument is confirmed.

Future growth of the results are considerable, since there are many more countries and considerable surveys yet to be included in the Multinational Time Use Study. Moreover, the same methodology is likely to be applied to different groups of population as childred, disaggregate the results by gender, age or even some other demographic variables provided by the surveys. A more detailed study of worldwide results, overall whenever more data become available, could confirm the goodness of the Lifestyle Dynamics Index as a potential instrument for relevant public decision making multidisciplinarily.

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