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New Understanding and Insights from Time-Series Data Based on Two Generic Measures: S-Time-Distance and S-Time-Step

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ABSTRACT

Time distance is an innovative approach for looking at time-series data. Expressed in time units, the approach is easy to understand and provides a useful complement to existing methods. The time distance approach compares time series in the *horizontal* dimension, i.e. for a given level of the variable, based on two generic statistical measures: S-time-distance and S-time-step. These measures are based on a time matrix that summarises information over many units and years and that provides a first-level visualization tool. The paper also introduces the concept of the 'overall degree of disparity', defined as proximity in the indicator space as well as in time, arguing that this concept has the potential to bring new understanding in economics, management, research and statistics.

RÉSUMÉ

La distance temporelle est une approche novatrice pour analyser des séries temporelles. Exprimé en unités de temps, l'approche est facile à comprendre et fournit un complément utile aux méthodes existantes. Cette approche compare les séries chronologiques dans la dimension horizontale, c'est-à-dire pour un niveau donné de la variable, basé sur deux mesures statistiques génériques: *S-time distance* et *S-time step*. Ces mesures sont basées sur une matrice de temps qui résume l'information sur de nombreuses unités et années, et qui fournit un outil de visualisation de première lecture. Le document introduit aussi le concept de «degré total de disparité», défini comme la proximité dans l'espace ainsi que dans le temps, arguant que ce concept a le potentiel pour apporter une nouvelle compréhension en économie, gestion, et statistiques.

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NEW UNDERSTANDING AND INSIGHTS FROM TIME-SERIES DATA BASED ON TWO GENERIC MEASURES: S-TIME-DISTANCE AND S-TIME-STEP

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1. Introduction[1]

1. The way time-series data are analysed and understood is crucial for empirical research and decision-making. This paper argues that the present state-of-the-art methodology does not realise this goal fully. This is because, in addition to the static comparisons embodied in existing approaches, it is equally important to look at the difference (or distance) in time between the two time-series being compared with respect to a reference level of the variable of interest. In graphical terms, the usual approach compares time-series in the *vertical* dimension, i.e. looking at the differences in the levels of two time-series at a given point in time. Conversely, the time-distance approach compares time-series in the *horizontal* dimension, i.e. for a given level of the variable (Sicherl 1973, 1994, 2004a, 2007a, 2011b).

2. Time distance implies looking at the difference in time when two events occurred. In spatial analysis, time distance refers to the time needed to move from one point in space to another. In this paper, we define the concept of time distance as related to the level of the indicator analysed. To that end, Section 2 defines two generic statistical measures (S-time-distance and S-time-step) to complement existing static measures: expressed in standardized time units, these measures can be compared across variables, fields of concern and units of comparison. Section 3 provides several examples of time distance analysis, comparing the descriptive characteristics of conventional time-series and of time-distance tables. Section 4 introduces the concept of 'overall degree of disparity', arguing that disparities in society depend not only on static measures of inequality but also on time-distances in the relevant dimension. Section 5 provides an overview of the range of application of time-distance methodology at both the macro and micro levels, as well as of possible developments of the method, while Section 6 concludes.

2. The time distance concept and the definitions of S-time-distance and S-time-step

3. Time distance is a generic concept that can be applied to all time-series data. Traditionally, time has been used mainly as locational information, i.e. as a descriptor, subscript or identifier in the parameter frame used to organise (or index) a set of variables. The time-distance approach offers new avenues for detecting additional information content in time-series data, complementing existing approaches. By 'swapping' the roles played by the level of the variable and by the time identifier, a given level of the variable can become the descriptor or identifier while time becomes the numeraire; this allows expressing the distances between the compared units of a time-series in terms of time (e.g. years, months, days, etc.).

4. Comparing two points in a time-series entails looking at three types of information: i) the respective levels of the variable; ii) the units (e.g. countries) being compared; and iii) the time (e.g. years) in which different units achieve a given level of the variable. When a given level of the variable is used as

[1] "The real voyage of discovery consists not in seeking new lands but in seeing with new eyes", Marcel Proust.

the descriptor or identifier, and time as the numeraire, one can use the information contained in the original time-series to generate the time matrix presented in Table 1. Such matrix is the basic element used to calculate the two generic measures presented in this paper: S-time-distance and S-time-step.

Table 1. Time matrix transformation of a conventional time-series

Time when a specified level of the variable is achieved by each unit

Level	**Time** $t_i(X_L)$	**Time** $t_j(X_L)$
X_{L1}		$t_j(X_{L1})$
X_{L2}	$t_i(X_{L2})$	$t_j(X_{L2})$
X_{L3}	$t_i(X_{L3})$	$t_j(X_{L3})$
…	…	…
X_{Ln}	$t_i(X_{Ln})$	

5. Box 1 describes the two operators that, when applied to the time matrix, allow deriving the S-time-distance and S-time-step measures, as well as their definitions and the relationship between the two measures.[2] Both measures can be derived from the time matrix in Table 1.

Box 1. Definitions of S-time-distance and S-time-step

S-time-distance measures the distance (proximity) in time between two time-series (i, j) being compared, e.g. the year when the two series reach a specified level of the variable X, where $X = X_i(t)$ and $X = X_j(t)$ and, using the inverse relations, $t = t_i(X)$ and $t = t_j(X)$ (Sicherl, 2004a, 2007a). S-time-distance for a given level of X_L is defined as:

$S_{ij}(X_L) = \Delta t(X_L) = t_i(X_L) - t_j(X_L)$ (1)

where $X_i(t_i(X_L)) = X_L$ and $X_j(t_j(X_L)) = X_L$ (2)

The sign of the S- time distance between two units indicates whether we are dealing with time lead (-) or time lag (+)

$S_{ij}(X_L) = -S_{ji}(X_L)$ (3)

S-time-distance is calculated from the time matrix; no other information than levels of the variable and time subscripts enter its computation. In this sense, time distance provides an additional (n+1) dimension to describe a multidimensional space of n variables (X_i, i=1, …, n).

S-time-step measures the time elapsed between two realisations of a time-series, and provides an alternative description of its growth rate. S-time step measures the growth of a series, using the inverse relation to the conventional $\Delta X/\Delta t$ growth rate metrics. S-time-step is expressed in units of time and is defined as:

$S_i(\Delta X_L) = [t_i(X_L+\Delta X) - t_i(X_L)]/\Delta X$ (4)

The relationship between S-time-distance and S-time-step for a selected $\Delta X_L=(X_{L2}-X_{L1})$ can be written as:

$S_{ij}(X_{L2}) = S_{ij}(X_{L1}) + \Delta X_L [S_i(\Delta X_L) - S_j(\Delta X_L)]$ (5a)

or $S_{ij}(X_{L2}) = S_{ij}(X_{L1}) + (X_{L2}-X_{L1}) [S_i(X_{L2}-X_{L1}) - S_j(X_{L2}-X_{L1})]$ (5b)

S-time-step and *S-time-distance* can be derived from the time matrix in Table 1. S-time-distance between two series can be derived by subtracting *horizontally* the respective times for a given level in the time matrix. Conversely, subtracting the years in the time matrix for consecutive levels of the variable for each column *vertically* allows deriving the S-time-step. When the levels of the variable in time matrix are increasing or decreasing by one unit, $S_i(\Delta X_L)$ is simply the difference between the years shown in the time matrix $S_i(\Delta X_L) = [t_i(X_L+\Delta X) - t_i(X_L)]$. In cases when ΔX is different from 1, $\Delta X \cdot S_i(\Delta X_L) = [t_i(X_L+\Delta X) - t_i(X_L)]$.

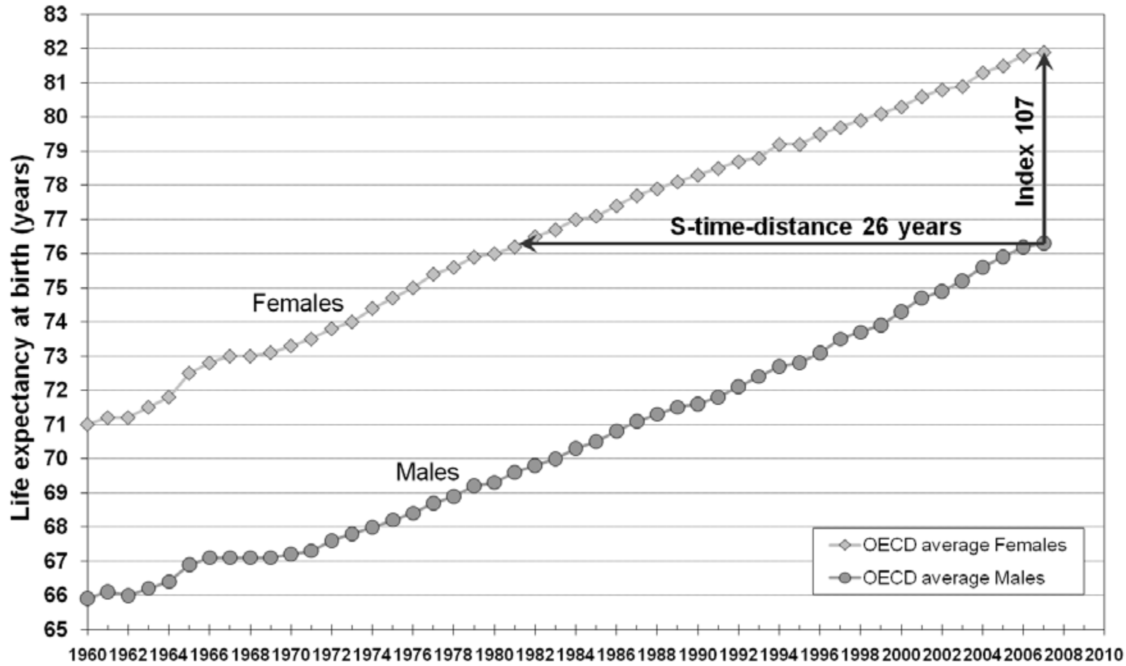
6. Box 2 shows how time-series referring to life expectancy of women and men can be compared by looking at both static difference and time distance to derive a better appreciation of gender differences in life expectancy. (Other examples are available on www.gaptimer.eu).

2 Other procedures to calculate S-time-distance are described in Sicherl (1978, 2004a) and in Granger and Jeon (1997).

Box 2. A graphical illustration of how to compare two time-series

Time-series can be compared in two ways: first, by looking at the static gap between the two series at a given point in time; second, by considering the distance in years for a given reference level of the variable. The figure below shows that, for the case of gender differences in life expectancy, perceptions of the size of this gap depend on which perspective is used. For example, the static difference between the two lines in 2008 is 7 percent (which may appear to be small) while the time-distance is 26 years (which gives a very different perception).

Gender disparities in life expectancy at birth, OECD average in 2007: static and time distance



Source: Calculations from data in *OECD Factbook 2010*.

7. Box 3 shows the correspondence between the conventional table-format for time-series data, and the complementary presentation based on the time distance approach. The comparison refers to the level of the indicators, to their dynamics and to comparisons of levels relative to a benchmark.

Box 3. Schematic presentation of correspondence between conventional time series tables and the time distance approach: presentation over many units and over time

1. Levels of the indicators (example: life expectancy)

Table					Level-time matrix			
A1	Time				**B1**	Indicator value		
	1960	**…**	**2007**			**68**	**…**	**82**
Countries (units)	Values in different points in time				**Countries (units)**	Time when the selected value was achieved		

2. Dynamics of the indicators

Growth rates or other measures of dynamics					S-time-step			
A2	Time				**B2**	Indicator value		
	1961	**…**	**2007**			**69**	**…**	**82**
Countries (units)	Annual growth rate or others indexes				**Countries (units)**	Time needed to achieve the next level of the indicator		

3. Comparison of levels

Index: benchmark = 100 by years					S-time-distance (in years) from benchmark			
A3	Time				**B3**	Indicator value		
	1960	**…**	**2007**			**68**	**…**	**82**
Countries (units)	Index values by years				**Countries (units)**	- time lead, + time lag (in years) from benchmark		

Source: P. Sicherl (2011c)

3. Analysis, presentation and knowledge building

8. This section presents several examples of how the time-distance approach can be used as a tool for analysis and visualization of time-series data. These examples are drawn from a more comprehensive analysis by the author of 14 indicators referring to the 34 OECD countries over several decades and included in the 2010 edition of the *OECD Factbook* (OECD 2010b)

3.1. Comparisons of life-expectancy between countries

9. The starting point for all these illustrations is a time matrix, showing in which year various countries achieved different levels of a given variable. Table 2 shows the time matrix for life expectancy at birth for the total population. Each column shows in what year a given level of life-expectancy was attained by each of the countries shown in the table's rows (e.g. a life-expectancy of 80 was attained in 1996 in Japan; in 2000 in Switzerland and Iceland; in 2002 in Australia and Spain; in 2003 in Italy, Israel and Norway; in 2004 in Spain, France and Norway; in 2006 in New Zealand; and in 2007 in Austria, the Netherlands and Germany). In general, deriving the years shown in Table 2 from a conventional time-series requires using interpolation techniques: while this may imply some inaccuracies, the values shown in a time matrix still contain the most important information of the original data. The shaded fields in Table 2 indicate the range of values of life expectancy achieved by each country over the period shown: this allows for an immediate comparison of the situation across countries and of the improvements that each country has achieved. The years in bold refer to the latest available observation available for each country.[3]

[3] One problem with the conventional tabular presentation of time-series data is that full matrix cannot be presented when these data span very long periods. Hence, a time-matrix presents in a more parsimonious way the available evidence. Two limits of the presentation provided in Table 2 should, however, be noted. First, the range of levels presented needs sometimes to be shortened, and the steps between neighbouring levels to be increased, which makes the time matrix less accurate. Second, when the time span covered differs across countries, it is more difficult to compare the number of steps achieved by various countries.

Table 2. Time matrix for life expectancy at birth, 1960-2007

Level	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82
Japan			1960	1962	1963	1966	1970	1971	1975	1976	1979	1983	1986	1991	1996	2000	**2005**
Switzerland							1964	1970	1973	1976	1981	1985	1992	1996	2000	**2004**	
Iceland								1961	1969	1974	1975	1983	1995	1997	2000	**2004**	
Italy					1962	1966	1971	1976	1980	1984	1986	1990	1994	1998	2003	**2005**	
Australia						1970	1974	1976	1979	1982	1986	1990	1995	1999	2002	**2006**	
Sweden									1968	1976	1981	1988	1992	1996	2002	**2007**	
Spain					1961	1965	1970	1974	1977	1979	1982	1990	1994	1999	2004	**2007**	
France						1964	1970	1975	1978	1983	1987	1991	1996	2000	2004	**2007**	
Canada							1966	1972	1976	1979	1982	1988	1994	1999	**2003**		
Israel									1980	1984	1989	1993	1996	2000	**2003**		
Norway									1969	1974	1981	1991	1995	2002	**2004**		
New Zealand							1974	1979	1985	1989	1992	1996	1999	2002	**2006**		
Austria				1960	1970	1973	1977	1982	1985	1988	1993	1996	2000	2003	**2007**		
Netherlands									1973	1977	1981	1993	2000	2004	**2007**		
Germany					1963	1972	1976	1980	1984	1987	1992	1996	1999	2004	**2007**		
Greece					1960	1965	1970	1974	1978	1982	1985	1989	2000	**2004**			
Luxembourg					1971	1976	1978	1982	1985	1989	1993	1997	2003	**2004**			
Ireland					1960	1968	1979	1983	1987	1991	1997	2001	2002	**2004**			
United Kingdom						1963	1972	1979	1982	1987	1991	1996	2000	**2005**			
Finland				1963	1968	1973	1976	1978	1981	1990	1993	1997	2001	**2005**			
Belgium					1960	1970	1974	1978	1983	1986	1990	1995	2001	**2005**			
Korea	1980	1982	1984	1986	1987	1989	1991	1994	1996	1998	2000	2002	2004	**2006**			
Portugal	1969	1971	1974	1976	1977	1979	1981	1985	1988	1993	1998	2001	2004	**2007**			
Denmark								1968	1976	1990	1997	2001	**2005**				
Chile			1979	1981	1982	1984	1986	1989	1992	1995	1999	2001	**2005**				
Slovenia						1984	1987	1989	1995	1999	2002	2003	**2005**				
United States					1963	1970	1974	1976	1981	1989	1996	2001	**2006**				
Czech Republic					1971	1984	1991	1993	1997	2000	2005	**2007**					
Poland			1963	1964	1971	1992	1995	1999	2000	**2004**							
Mexico	1978	1980	1982	1984	1986	1991	1993	1997	2000	**2007**							
Slovak Republic					1971	1991	1992	1999	**2005**								
Turkey	1989	1990	1992	1994	1997	2000	2002	**2005**									
Hungary			1962	1963	1995	1999	2001	**2006**									
Estonia		1994	1995	1996	1999	2002	2004	**2007**									
OECD average				1964	1966	1973	1977	1981	1986	1990	1995	1999	2003	**2006**			
China			1984	1991	1994	1997	2002	**2005**									

Source: P. Sicherl (2011a), own calculations from data in *OECD, Factbook 2010.*

10. Table 2 shows that life expectancy at birth increased in all OECD countries, with the OECD average rising by 10 years (from 69 in 1964, to 79 in 2006) in little more than four decades. Table 2 also shows large differences between countries: in 2007, for example, the absolute difference between the top-performing country (Japan, at 82) and the worse-performing one (Estonia, at 73) was about 9 years, i.e. a difference of about 13 percent. Among countries with time-series going back to 1960, Japan is the only one that reached the level of 82 years by 2007; Japan also achieved one of the largest gains, from 68 years in 1960 to 82 years in 2007, i.e. an improvement of 14 steps.

11. Table 2 allows deriving the two statistical measures, S-time step and S-time distance. Table 3 presents values of the S-time-step, which show the number of years needed in the past to increase life expectancy by one year between the two neighbouring levels. These values are calculated by subtracting horizontally the respective years for two neighbouring levels of life-expectancy in Table 2: for example, the OECD average needed about 4.2 years to increase life expectancy by one year. This measure is easier to understand than saying that the average rate of growth of life expectancy was about 0.3 percent per year.

The countries recording the highest absolute gains in life-expectancy in Table 2 are also those with the lowest average values of S-time-step over the period analysed: Korea, with 1.7 years; Turkey, with 1.8 years; Mexico, with 2.7 years; and Portugal, with 2.8 years.

Table 3. S-time-step for life expectancy at birth, 1960-2007

Number of years that were needed in the past to move from one level of life-expectancy to the next

LEXP Level	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82
Japan				1.9	1.1	2.6	4.0	1.3	3.2	1.9	2.2	4.4	2.8	4.7	5.1	4.1	5.3
Switzerland								6.0	2.9	3.5	5.1	3.7	7.0	3.8	4.5	3.4	
Iceland									8.8	4.3	1.3	7.9	12.3	2.1	2.7	4.2	
Italy						4.5	4.5	5.3	3.7	4.0	2.3	3.3	4.5	3.5	5.6	2.2	
Australia							3.9	2.2	2.2	3.9	3.4	4.2	5.3	3.7	3.0	3.5	
Sweden										8.0	4.7	7.3	3.8	4.3	6.3	4.7	
Spain						4.5	4.5	3.8	2.8	2.4	2.5	8.5	3.8	5.6	4.2	3.5	
France							6.2	5.2	3.3	5.1	3.3	4.3	4.5	4.3	3.9	3.3	
Canada								5.5	4.8	2.5	3.6	5.7	6.0	5.0	4.3		
Israel										3.9	4.4	4.0	3.2	4.7	3.0		
Norway										4.8	7.0	9.8	4.5	6.8	1.8		
New Zealand								5.3	5.7	3.5	3.2	4.0	3.3	3.0	3.7		
Austria					9.7	2.8	4.2	5.0	3.4	2.2	5.1	3.6	3.4	3.7	3.1		
Netherlands										4.0	4.5	12.0	7.0	3.7	2.8		
Germany						9.0	4.3	4.0	3.2	3.5	5.0	4.4	2.9	4.3	3.3		
Greece						4.8	4.8	4.0	4.0	3.7	3.3	4.0	11.0	3.5			
Luxembourg						4.9	1.9	4.4	2.8	4.1	3.9	3.9	6.1	0.7			
Ireland						8.3	10.3	4.0	3.9	4.0	6.5	3.7	1.6	1.9			
United Kingdom							8.4	6.9	3.1	4.8	4.8	5.1	4.0	4.2			
Finland					5.4	4.2	3.4	2.0	3.2	8.8	3.3	3.3	4.3	3.8			
Belgium						9.4	4.1	4.7	4.6	3.3	3.4	5.5	5.4	4.3			
Korea		2.0	1.8	1.5	1.7	1.8	2.4	2.1	2.5	2.3	1.7	2.0	2.0	1.8			
Portugal		2.2	2.5	2.3	0.8	1.7	2.8	3.6	3.3	5.1	4.6	3.0	2.7	2.8			
Denmark									8.0	14.3	6.5	4.3	3.5				
Chile				1.4	1.4	1.8	2.5	2.8	3.0	3.3	3.4	2.5	3.8				
Slovenia							2.5	2.9	5.6	3.5	3.0	1.4	2.4				
United States						7.3	3.5	2.2	4.8	7.8	7.3	4.9	5.0				
Czech Republic						12.6	7.0	2.3	3.2	3.0	5.0	2.5					
Poland				1.9	6.9	20.3	3.4	4.3	1.0	3.8							
Mexico		1.9	1.9	2.2	2.5	4.2	2.8	3.7	3.3	6.7							
Slovak Republic						19.8	1.1	6.6	6.3								
Turkey		0.5	1.8	2.8	2.5	2.9	2.7	2.7									
Hungary				1.0	32.0	4.0	1.3	5.0									
Estonia			0.7	0.5	3.0	3.4	2.0	3.0									
OECD average					2.3	7.3	3.4	4.6	4.3	4.7	4.7	4.0	4.0	3.0			
China				7.1	2.7	3.5	4.6	3.1									

Source: P. Sicherl (2011a), own calculations from data in *OECD, Factbook 2010.*

12. Table 4 presents the second descriptive measure, S-time-distance, which compares different countries for a given level of life-expectancy. The values shown in Table 4 compare the life-expectancy for each country relative to the OECD average, which is used as a benchmark, showing its lead (-) or lag (+). These values are derived by subtracting vertically from the time-matrix in Table 2. Of course, one could compare countries by selecting another benchmark, e.g. the best performing country; Table 4 shows, for example, that Japan improved its lead against the OECD average from 1 to 16 years, while Korea, Portugal, Chile and Slovenia have almost closed their lag relative to the OECD average (reducing their lag

by more than 10 years). In Table 4, Japan, Switzerland and Sweden are the countries with the highest lead (10 or more years), while Turkey, Hungary, Estonia and China have the highest lag (at around 25 years).

Table 4. S-time-distance from the OECD-average benchmark for life expectancy at birth, 1960-2007

Lead (-) or lag (+) in years

LEXP Level	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**
Japan	-1	-3	-7	-7	-10	-11	-14	-16	-16	-17	-16
Switzerland				-13	-12	-13	-14	-14	-14	-11	-10
Iceland					-21	-16	-17	-20	-16	-8	-9
Italy		-4	-7	-6	-5	-6	-6	-9	-10	-9	-9
Australia			-3	-3	-5	-7	-8	-9	-9	-8	-7
Sweden						-18	-14	-14	-11	-11	-10
Spain		-5	-8	-7	-7	-9	-11	-14	-9	-9	-7
France			-10	-7	-6	-7	-7	-8	-8	-8	-6
Canada				-11	-10	-9	-12	-13	-11	-9	-7
Israel						-5	-6	-6	-6	-7	-6
Norway						-16	-16	-14	-8	-8	-4
New Zealand				-3	-2	-1	-2	-3	-3	-4	-4
Austria	-3	4	-1	0	1	0	-3	-2	-3	-3	-3
Netherlands						-13	-14	-14	-6	-3	-2
Germany		-3	-1	0	-1	-2	-3	-3	-3	-4	-2
Greece		-6	-8	-7	-7	-8	-9	-10	-10	-3	-3
Luxembourg		5	3	1	1	0	-1	-2	-2	0	-2
Ireland		-6	-5	2	1	1	0	2	2	-1	-2
United Kingdom			-10	-5	-3	-4	-4	-4	-3	-3	-2
Finland	-1	2	-1	-1	-3	-5	0	-2	-3	-2	-2
Belgium		-6	-4	-3	-3	-3	-4	-5	-4	-2	-1
Korea	22	21	16	15	12	10	8	5	3	1	0
Portugal	12	11	5	5	4	3	3	3	2	1	1
Denmark					-13	-10	0	2	2	2	
Chile	17	16	10	10	8	6	5	4	2	2	
Slovenia			11	10	8	9	8	7	4	2	
United States		-3	-3	-3	-5	-5	-2	1	2	3	
Czech Republic		5	11	14	12	11	9	10	8		
Poland	1	5	18	18	18	15	14				
Mexico	20	20	17	17	16	15	17				
Slovak Republic		5	18	15	17	19					
Turkey	31	31	26	26	24						
Hungary		29	26	24	24						
Estonia	32	33	29	27	26						
OECD average	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
China	27	28	24	25	24						

Source: P. Sicherl (2011a), own calculations from data in *OECD, Factbook 2010.*

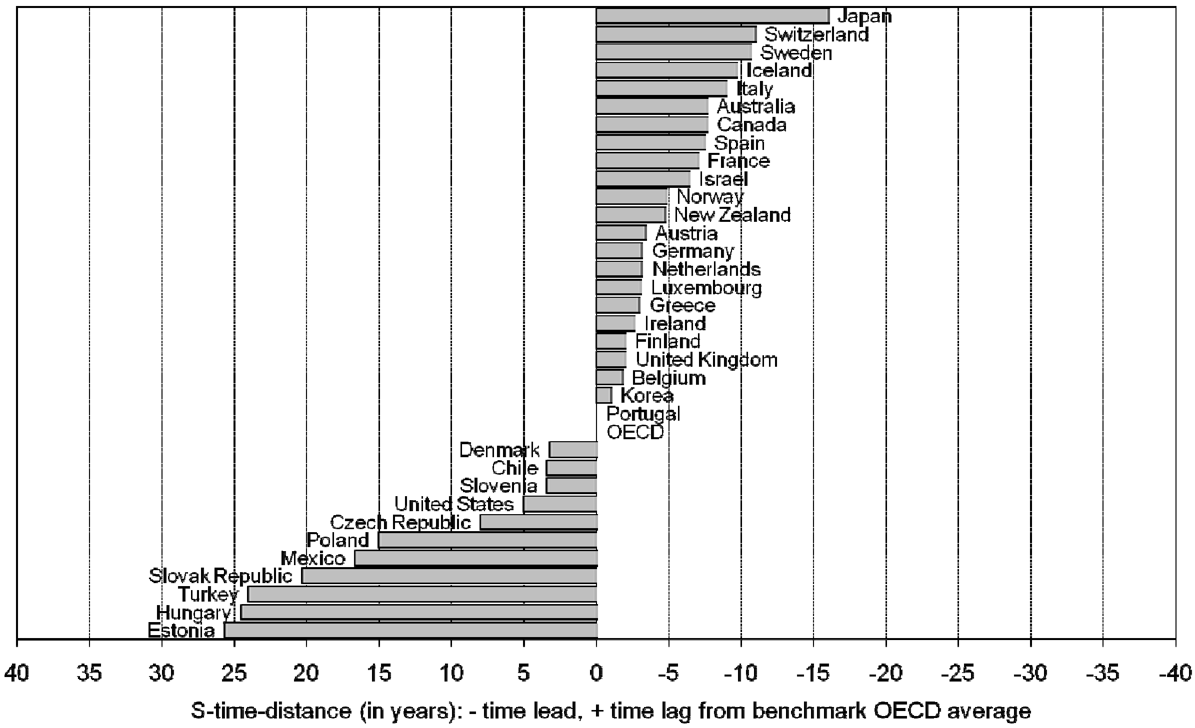
13. The relationship between S-time-distances and changes in S-time-steps can be illustrated by comparing, for example, Korea to the OECD average. The change of S-time-distance from 69 to 70 years can be calculated from the corresponding values of the S-time-step, according to equation 5a in Box 1. Starting from 21.8 years (the S-time-distance between Korea and the OECD average for a level of life-expectancy of 69) then adding 1.7 years (the S-time-step between levels 69 and 70 for Korea) and subtracting 2.3 years (the S-time-step between levels 69 and 70 for the OECD average) one gets 21.2

years, which is the value of the S-time-distance between Korea and the OECD average for the level of 70 years.[4]

14. Values of S-time-distances can be presented in two ways. In Table 4, the time distances for life expectancy are expressed relative to the OECD benchmark. Another possibility, however, is to calculate S-time-distances referring to the values of the indicator in a selected year, usually the latest available year. In this case, the time distances from the OECD benchmark are calculated by looking, for countries below the benchmark, at the year when the OECD-average attained the level currently prevailing in the country considered and, for countries above the benchmark, at the year when these countries attained the life-expectancy currently prevailing in the OECD average. Figure 1 illustrates this second method.

Figure 1. An alternative presentation of the S time-distances for life-expectancy at birth, 2007

Time lead or lag relative to the OECD average



Source: Author's calculations from data in *OECD, Factbook 2010.*

3.2 Demographic projections for share of the elderly population

15. Table 5 presents the time-matrix for the share of the elderly population (people aged 65 and over) as percentage of the total population, with values covering both historical data and projections to 2050. This time matrix, spanning over a period of 100 years, conveys in a very parsimonious way the same amount of information provided by a time-series tabulation with 3400 entries, i.e. 34 countries across 100 years (Sicherl 2011c). In Table 5, countries are ranked in decreasing order of the share of the elderly

[4] The relationship can be also established also for other levels of life-expectancy. For instance, to compare life expectancy of 69 and 79, one can start from 21.8 years (the S-time-distance between Korea and the OECD average corresponding to 69 years), then add 20.3 years (the time needed to move level 69 to 79 for Korea) and subtract 42.3 years (the time needed to move from 69 to 79 for the OECD average) and obtain - 0.2 years (which is the S-time-distance for the level 79 between these two units). This means that, over the range between 69 and 79 years, Korea has diminished its time lag from the OECD average from nearly 22 years to broad equality.

population projected by 2050. In ten countries (including Japan, Korea, Spain, Italy and Greece) the share of the elderly population is projected to be 30 percent or more by 2050; Japan is expected to reach the level of 30 percent already in 2023, while Germany, Italy and Finland could reach a share of 26 percent by 2030. In Korea, where the share of the elderly population is projected to be 24 percent in 2030 (the 10th highest among OECD countries) this share is projected to rise to 38 percent by 2050 (the 2nd highest). [5]

Table 5. Time matrix for the share of the elderly population, 1960-2050

People aged 65 and over as a percentage of total population

Level	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38
Japan		1962	1976	1984	1990	1994	1998	2001	2005	2008	2012	2014	2017	2023	2031	2036	2039	2044
Korea	1983	1996	2002	2007	2013	2017	2021	2023	2025	2027	2030	2032	2035	2037	2039	2043	2046	2050
Spain			1957	1973	1985	1991	1997	2013	2020	2025	2028	2032	2035	2038	2041	2044		
Italy				1965	1975	1988	1993	1999	2007	2015	2022	2028	2031	2035	2040			
Greece			1959	1969	1974	1991	1998	2004	2015	2022	2028	2033	2037	2041	2047			
Germany				1952	1963	1972	1999	2004	2008	2018	2023	2027	2030	2034				
Portugal			1962	1975	1986	1992	1999	2013	2020	2026	2030	2035	2040	2044				
Czech Republic				1963	1987	2004	2011	2015	2020	2028	2035	2039	2042	2046				
Slovenia			1961	1971	1993	2000	2008	2015	2019	2024	2029	2035	2042	2049				
Slovak Republic			1965	1988	2007	2014	2018	2021	2026	2032	2038	2042	2046	2050				
Poland		1962	1969	1990	1999	2012	2016	2019	2023	2027	2037	2043	2047					
Finland			1965	1973	1980	1994	2005	2011	2014	2018	2023	2029						
Belgium					1960	1986	1996	2012	2018	2023	2028	2033						
Switzerland				1958	1973	1984	2006	2013	2019	2025	2030	2035						
Austria					1959	1970	2005	2014	2022	2027	2031	2038						
Hungary			1952	1964	1972	1994	2007	2015	2020	2034	2040	2045						
France					1964	1990	2000	2014	2019	2026	2032	2046						
Denmark				1957	1969	1978	2008	2012	2017	2024	2030	2047						
New Zealand				1982	2005	2012	2017	2022	2026	2030	2036	2047						
Canada			1971	1984	1995	2010	2015	2020	2024	2028	2034	2048						
Ireland					2010	2017	2023	2029	2034	2039	2044	2049						
Australia				1983	1996	2009	2014	2019	2024	2029	2037							
Sweden					1962	1971	1979	2009	2014	2026	2042							
Netherlands			1952	1969	1985	2004	2011	2015	2021	2026	2047							
United Kingdom					1964	1975	2007	2015	2024	2030	2049							
Estonia					1991	1996	2003	2017	2026	2040	2050							
Norway				1954	1965	1977	2013	2020	2028	2035								
Luxembourg				1951	1967	2007	2018	2025	2030	2037								
Chile		1988	2005	2013	2020	2024	2028	2033	2039	2050								
Iceland			1959	1983	2008	2016	2021	2026	2033									
United States				1972	1986	2014	2020	2025	2045									
Mexico	1969	2011	2020	2026	2030	2035	2039	2043	2047									
Israel	1950	1966	1976	2008	2017	2026	2037	2045										
Turkey	1965	2007	2021	2029	2035	2040	2045											
OECD total			1953	1974	1992	2006	2014	2020	2026	2032	2039							
World		1989	2014	2023	2031	2039	2049											
EU27 total				1961	1972	1991	2002	2012	2018	2024	2029	2034	2042					

Notes: Periods: 1950-2010, 2011-2030, 2031-2050.

Source: P. Sicherl (2011a), own calculations from data in *OECD, Factbook 2010.*

16. The population projections included in the *OECD Factbook* for the period 2009-2050 also highlight continuous declines in the growth rates of the total population. This is shown in Table 6. All OECD countries are expected to experience a downward trend in their rate of population growth over the

5 When considering time-distances that include both past realisations and future projections, it is important to distinguish between backward looking (*ex post*) and forward looking (*ex ante*) S-time-distances; while the first type of measure belongs to the domain of descriptive statistics based on known facts, the second type may allow describing the results of alternative policies in the future. While the time distance approach is not a forecasting tool, it provides a useful presentation of complex data sets.

next four decades. By 2040, only traditional immigration countries are expected to experience population growth rates above 0.4 percent (0.8 in the United States, 0.6 in Israel and Luxembourg, 0.4 percent in Australia and Canada). Over the same period, 13 OECD countries are projected to exhibit negative population growth, with population contracting by about 1 percent per year in Japan and Korea. Mexico, Switzerland, Denmark, the Netherlands and Belgium are projected to experience stagnant population, while population in the OECD area as a whole is expected to increase by only 0.2 percent.

Table 6. Time matrix for population growth rates, 2009-2050

Annual growth in percentage

Level	-1.0	-0.8	-0.6	-0.4	-0.2	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6
Israel									**2045**	2038	2029	2018	2014	2010
Ireland							**2049**	2041	2026	2019	2014			
Turkey							**2044**	2037	2031	2023	2014			
Australia								**2043**	2033	2026	2014			
Mexico						**2042**	2034	2027	2019	2010				
New Zealand							**2041**	2033	2023	2011				
Canada								**2039**	2029	2012				
Chile							**2041**	2033	2025	2017				
Luxembourg									**2041**	2030				
United States										**2043**				
Iceland							**2038**	2029	2020					
United Kingdom								**2045**	2025					
Norway								**2040**	2028					
Spain				**2045**	2038	2023	2015	2010						
Switzerland						**2037**	2025	2016						
France							**2040**	2017						
Sweden							**2039**	2025						
Denmark						**2037**	2011							
Korea	**2048**	2043	2038	2034	2028	2019	2012							
Slovenia					**2038**	2022	2013							
Greece				**2045**	2033	2020	2013							
Netherlands						**2035**	2014							
Belgium						**2037**	2023							
Austria							**2028**							
Finland							**2029**							
Portugal			**2049**	2038	2019	2011								
Germany				**2040**	2026	2014								
Italy					**2040**	2015								
Czech Republic				**2050**	2027	2016								
Slovak Republic				**2036**	2028	2018								
Japan	**2042**	2033	2024	2017	2011									
Hungary				**2032**	2021									
Poland				**2039**	2030									
Estonia					**2048**									
OECD total							**2034**	2017						
World								**2046**	2035	2026	2018			
EU27 total					**2043**	2026								

Note: Data range for projections 2009-2050.

Source: P. Sicherl (2011a), own calculations from data in *OECD, Factbook 2010.*

3.3. Long-term perspectives on differences in living standards in the world

17. Disparities in average living standards across countries in the world are typically described through static measures of absolute or relative disparities, such as the Gini coefficient or the Theil index. A complementary perspective on world inequalities across many countries, fields of concern, and units of

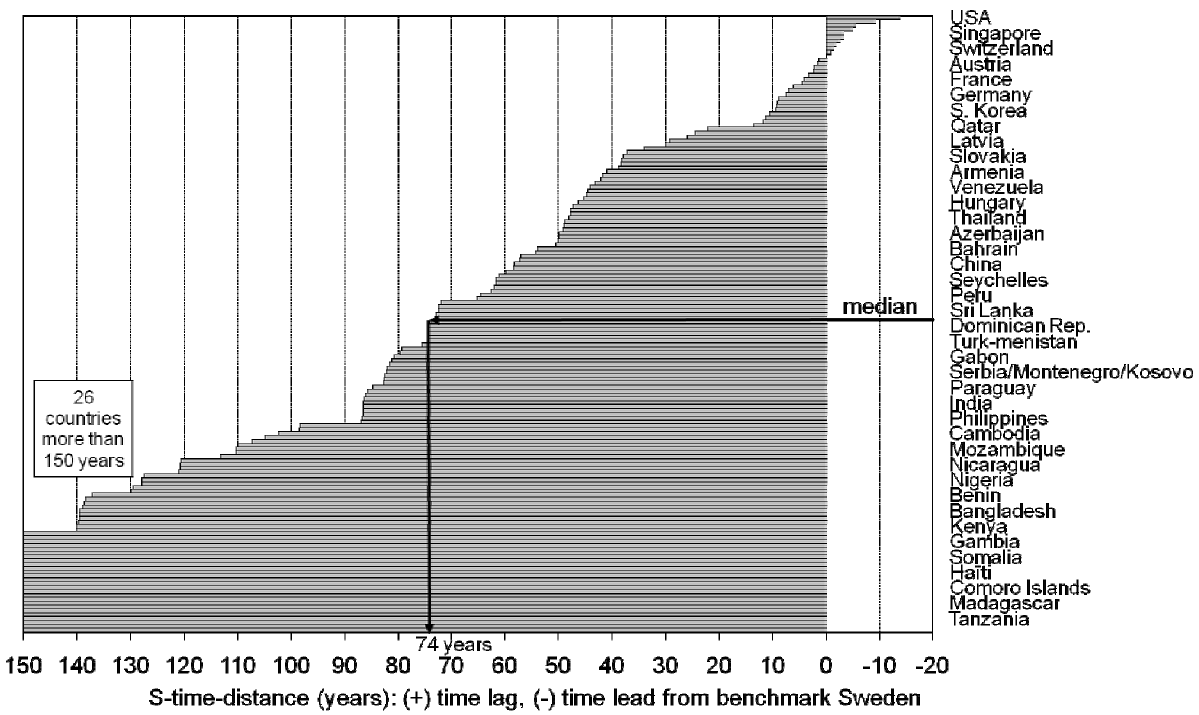
comparison can be gained through the time-distance method. This section provides an overview of time-distance comparison for GDP per capita, life-expectancy at birth, and penetration of mobile phones. In the three cases, Sweden was chosen as benchmark because of the availability of long time-series for this country in a wide range of fields. The analysis covers between 160 and 200 countries in each case: because of the high number of countries included, country-names on the vertical axis of Figures 2 to 4 are not presented in full (in general, only the fifth country-name is shown) while values for all countries are displayed.

18. Figure 2 shows time-disparities in GDP per capita across 160 countries over a period of 150 years. In 2008, around half of the countries considered were lagging Sweden by more than 74 years, while for 26 countries the lag exceeded 150 years. The Gini coefficient, a commonly used statistic measure of world disparities in GDP per capita, is around 0.53, but this value has no intuitive meaning for most non-expert readers. While both measures are valid, time-distance provides a more intuitive metric of world disparities.

19. The value of GDP per capita achieved by the median country in 2008 was only 18 percent of the Swedish level, corresponding to the level attained in Sweden in 1934. Similarly, when looking at the 26 countries with the lowest GDP per capita in 2008, their average income was in the range of 1 to 4 percent of the Swedish level, corresponding to the income level attained by Sweden in 1858 or earlier. Whether we look at S-time-distance gap or at the percentage gap, these data highlight huge disparities across countries.

Figure 2. S-time-distance for GDP per capita of different countries relative to Sweden, 2008

Difference in years between the 2008 level of GDP per capita in each country and the year when the same level was achieved in Sweden



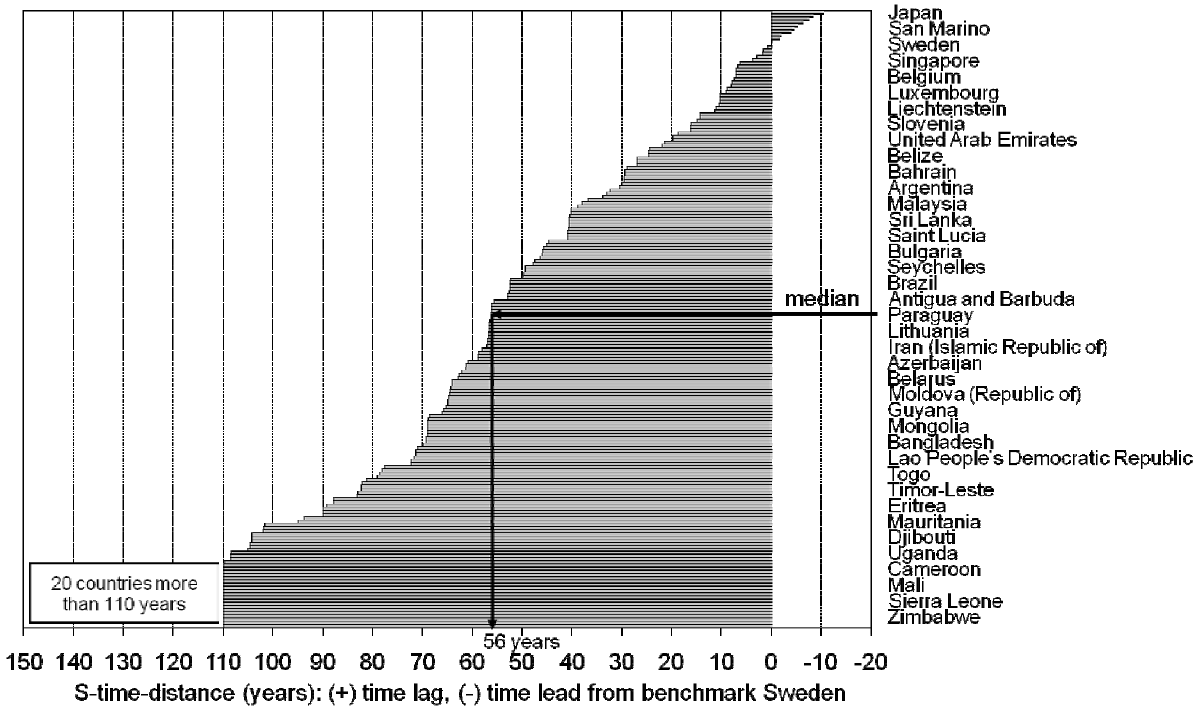
Source: Author's calculations based on data from Maddison (2010).

20. Another dimension of living standards is health status, as measured by mortality statistics. Figure 3 shows time-distance for life expectancy at birth for 194 countries in 2010, always relative to

Sweden. The time distance in life-expectancy for the median country (Turkey) relative to Sweden, at 56 years, is less than in the case of GDP per capita (74 years). Overall, 97 countries have time distances in life-expectancies of 56 years or more, with 20 countries recording differences of more than 110 years. In the case of infant mortality rates, where 2007 data are available data for 194 countries from the UN Millennium Database and long-time series for Sweden are provided by Mitchell (2003), the median value of the S-time-distance from the Swedish benchmark (computed as a 3-years moving average) is 56 years, which is similar to that computed for life expectancy at birth; around 100 countries have large time lags relative to Sweden, with such lag exceeding 110 years in 10 of them.[6]

Figure 3. S-time-distance for life expectancy at birth relative to Sweden, 2010

Difference in years between the 2010 level of life expectancy at birth in each country and the year when the same level was achieved in Sweden



Source: Own calculations based on data from UN (2010), World Population Prospects: 2008 Revision, New York.

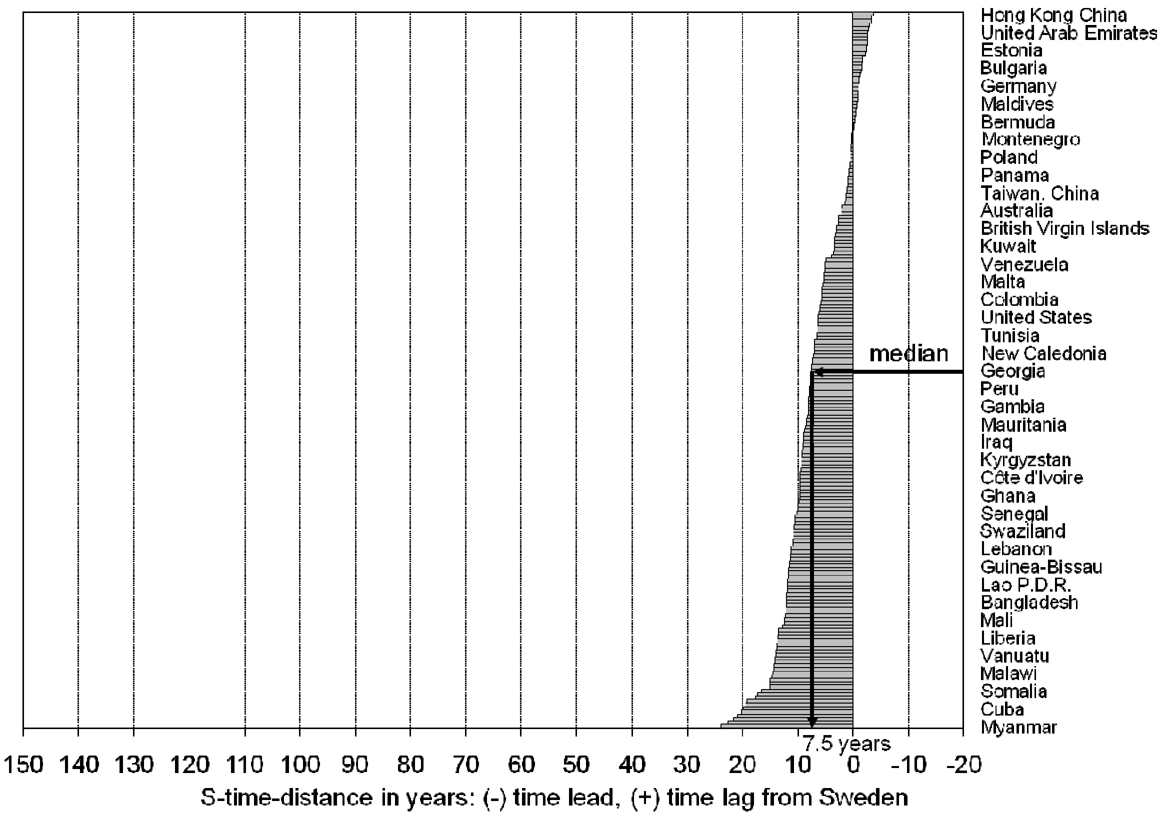
21. While the time lags relative to Sweden are very large for the GDP per capita and the health measures described above, they are much lower for some technological and communication indicators. Figure 4 shows time-distances in the case of the diffusion of mobile telephones. While the median S-time-distance for GDP per capita and life-expectancy is between 74 and 56 years, that for mobile telephones penetration for 200 countries it is only 7.5 years (i.e. about ten times lower than in the case GDP per capita). For 100 countries, their lag relative to Sweden is less than 7.5 years, while for 61 countries this lag exceeds 10 years. As mobile phones are a recent technology, even countries with lowest penetration rate

[6] One characteristic of the S-time-distance is that it is invariant to a monotonic transformation of the original variable. This implies, for example, that the time distances for the infant mortality rate and for the infant survival rate will be the same. Conversely, static disparities for the same two variables are very different.

are not more than 25 years behind Sweden. Time distances are small also for other fast growing technologies.[7]

Figure 4. S-time-distance for the penetration of mobile telephones in 2008

Difference in years between the 2008 level of mobile telephone penetration in each country and the year when the same level was achieved in Sweden



Note: The penetration rate for mobile telephones is expressed as the number of telephones per 100 inhabitants in each country.

Source: Own calculations based on data from ITU (2009).

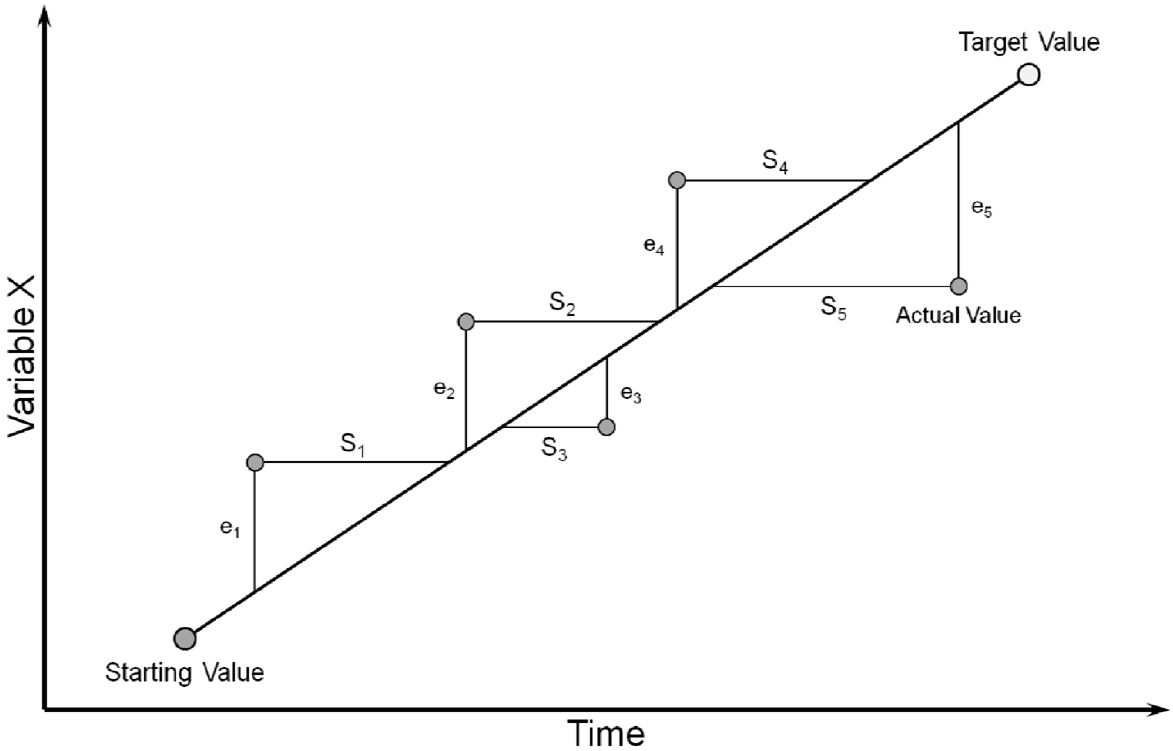
3.4. Monitoring of implementation of policy targets

22. S-time-distance can also be used to compare actual with target values of a variable of interest, such as those set by policy makers or managers. This is illustrated in Figure 5, which shows the deviations between the realisation of a variable and the line connecting its starting and target level in the future. Based on this information, two measures of deviation can be computed: the percentage deviation (where e_i are static measures of deviation, either absolute or relative, at a given point in time) and S-time-distance (where S_i indicates the time lead or lag of actual values relative to the line-to-target). One advantage of the concept of S-time-distance when applied to deviations from the line-to-target is that people have an intuitive understanding of the notion of time: for each unit, the S-time distance measures the lead or lag of actual developments against the line-to-target for the selected indicator. (This is a bit like tracking the arrival of a train or bus through a timetable, the difference being that the geographical space is in our

[7] Figure 4 is an update of the analysis contained in Chapter 3 of the International Telecommunication Union study 'Measuring the Information Society (ITU 2010, p. 43-52). For an application of the time-distance methodology to the measurement of the digital divide, see Vehovar, Sicherl, Huesing and Dolnicar, 2006.

application replaced with the indicator space). This characteristic allows comparisons across variables, fields of concern and units of comparison.

Figure 5. Comparing actual values with target (or estimated) values in two dimensions

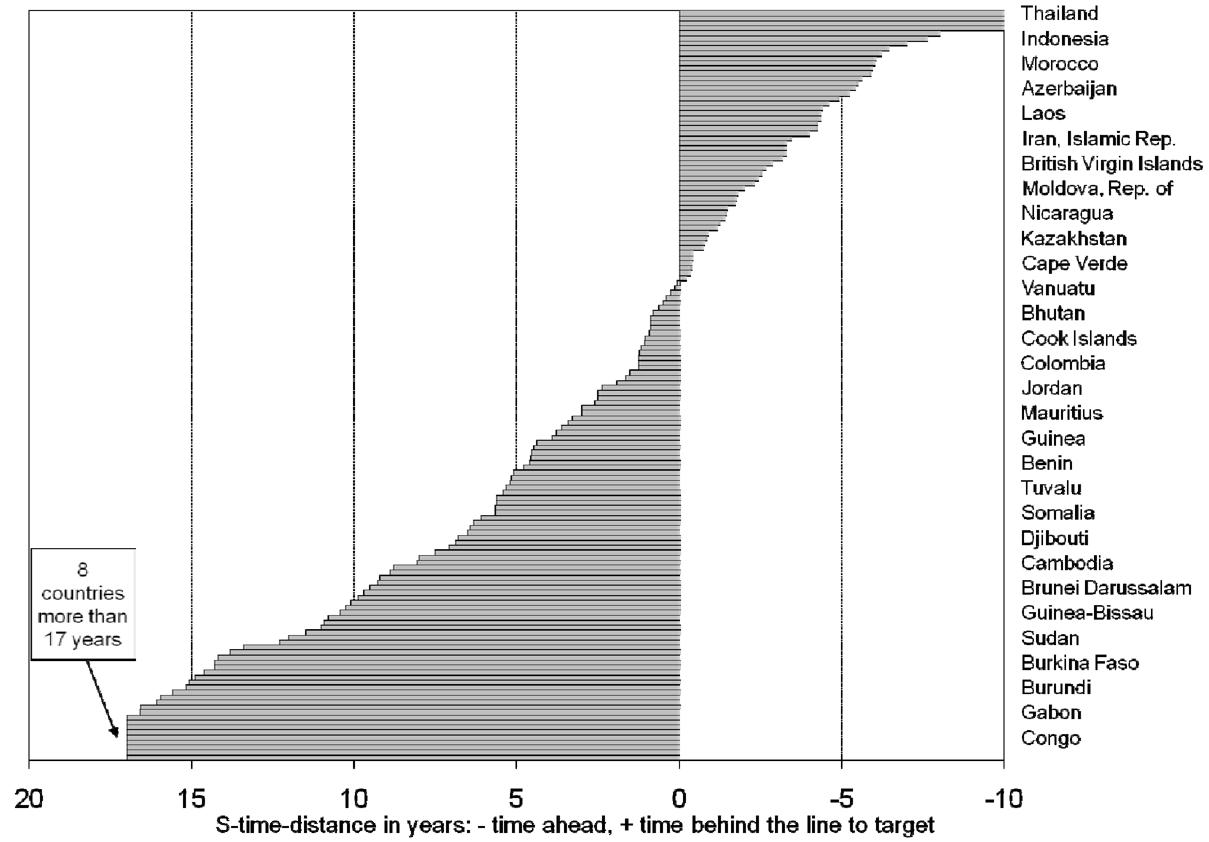


Source: P. Sicherl (2010a).

23. The empirical example presented below deals with monitoring implementation of the Millennium Development Goals, and is based on a simple comparison of actual values of a variable and its line-to-target. The S-time-distance is the difference between the year when various levels of a variable of interest were achieved and the hypothetical values on the line to the 2015 MDGs target. Empirical results obviously depend on whether a linear or exponential line-to-target is assumed: in this example, a linear line is used in the case of variables where the target level is below the current one (e.g. mortality) and an exponential line in the case of variables where the target level is above the current one (e.g. school enrolment). For instance, the 2008 value of under-five mortality rate for all developing regions was, according to UNSD, 72; hence, on the (declining) straight line to the 2015 target of 33.3, the value of 72 is expected to be achieved in the middle of 2000, implying a time lag of 7.5 years (2008 – 2000.5).

24. This application can be repeated for many countries. Figure 6 shows the S-time-distance deviation of the under-five mortality rate in 2007 from its line-to-target, for 150 countries. In 2007, among these countries, 54 countries were ahead of their line-to-target and 96 countries were behind. Five countries (Thailand, Vietnam, Peru, Maldives and Turkey) had already achieved their 2015 target by 2007, while eight countries (seven of them in Africa) had a time lag exceeding 17 years (implying that their under-five mortality rate in 2007 was worse than their position in 1990).

Figure 6. Time lead or time lag from the line to the MDGs target for under-five mortality rate



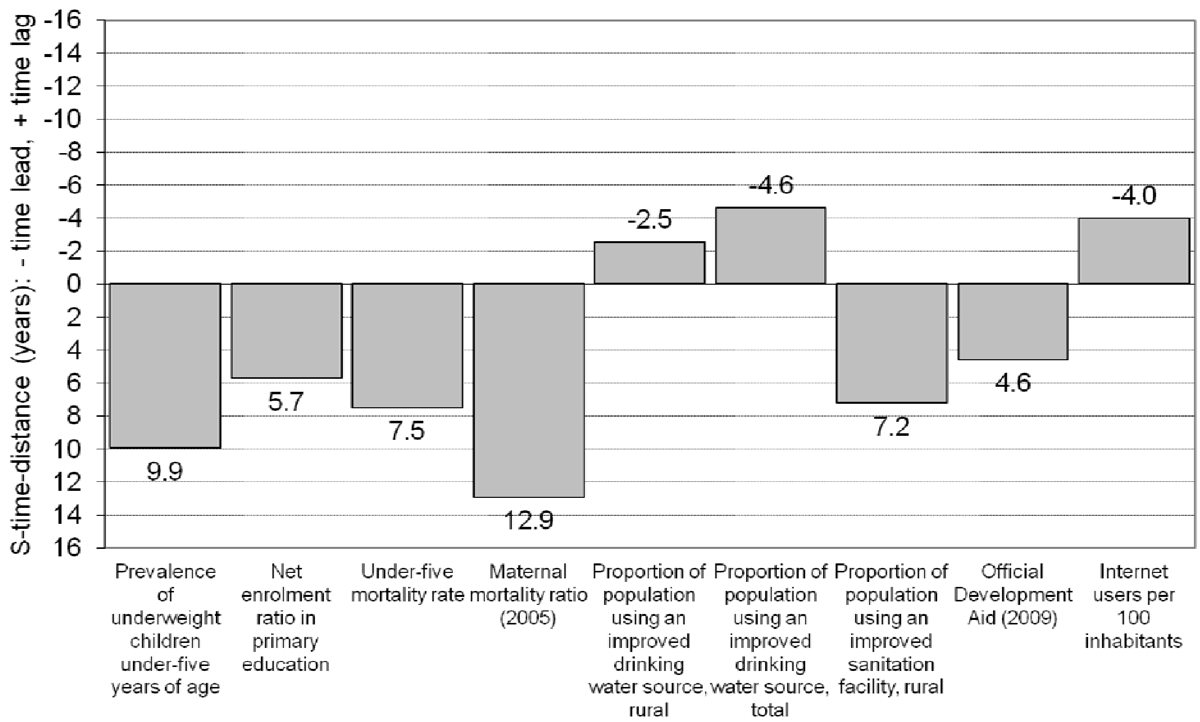
Source: Own calculation based on MDG data from UNSD.

25. This methodology can be applied for monitoring MDGs across many indicators, both for individual countries and for world regions.[8] Figure 7 provides a visualisation of the time distance perspective across 9 indicators, using values from the statistical annex of the MDG Report 2010 (United Nations 2010).[9] Figure 7 shows that the degree of implementation of MDGs is far from satisfactory. Among the nine selected indicators, only for three them (proportion of population using an improved drinking water source, total and rural, and Internet user per 100 inhabitants) implementation of the MDGs targets in the aggregate of developing countries is ahead of their line-to-targets (between 2.5 and 4.6 years ahead). For the other six indicators, the time lag relative to the-line-to-targets varies between 4.6 years for Official Development Aid (ODA) and 12.9 years for maternity mortality rate. When looking at individual countries, China shows extraordinary progress in eradicating extreme poverty and hunger. (Results for seven world regions for the same selection of MDG indicators are presented in Sicherl, 2010b).

8 The Philippine National Statistical Coordination Board uses the time distance methodology to compare implementation across 23 MDG indicators (MDG Watch, Philippine Progress based on the MDG indicators, July 2010, www.nscb.gov.ph)

9 Both the data in the UNSD report and the numerical results in this paper are affected by problems in both national data and in methodologies used to reconcile national and international data.

Figure 7. S-time-distance deviation from the line to target for developing regions, 2008



Source: Author's calculations based on data from United Nations (2010).

26. S-time-distance measure can also be used to get an overview of whether the 22 DAC countries are on-track to achieve their goal to raise their Official Development Assistance (ODA) to the UN target level of 0.7 percent of GNI (although several DAC countries are not officially committed to this target). This analysis shows that in 2009 the delay of the DAC countries was 4.6 years, implying that the ODA/GNI value in 2009 was at the level that they should have reached in 2004, with a time lag ranging between 1.4 and 9 years across countries. Similarly, time-distance has been applied to monitoring implementation of EU Lisbon strategy (Sicherl 2010c): this analysis shows that, by 2008, actual developments were lagging behind their respective line-to-target by 2.7 years for GDP growth, by 3.1 years for the total employment rate and by more than 7 years for the share of R&D in GDP.[10]

3.5. Goodness-of-fit

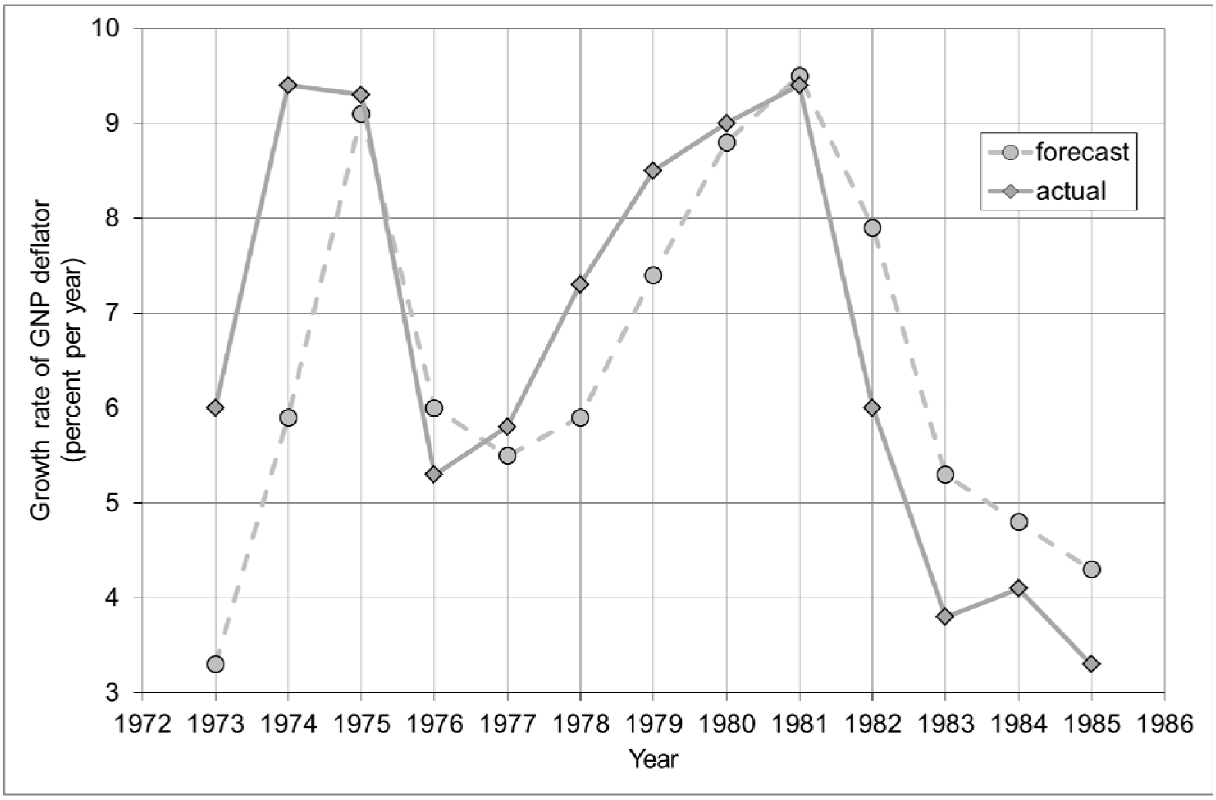
27. The time-distance approach can also be applied to description and to optimizing procedures in regression analysis. While the development of a full methodology in this field is a long-term goal, this section provides an example of how analysing deviations in both static and in the time dimension can lead to new procedures for testing goodness-of-fit. The general idea is again provided by Figure 5, where the straight line is now interpreted as the estimated line, and data points express deviations of observations from the regression line. The usual criterion used to estimate the regression parameters is to minimise the

10 The S-time-distance Monitoring Tool is included in the OECD Measuring the Progress of Societies, Knowledge Base under 'All countries and Initiatives – Innovative solutions', http://www.measuringprogress.org/knowledgeBase. This tool allows users to monitor the lead or lag in a range of fields, based on their own data and assumptions. The tool is also available at http://www.gaptimer.eu/s-t-d_monitoring_tool.html.

sum of squared deviations between the actual and predicted values of the variable at different points in time. An alternative criterion, however, could be to minimise the sum of squared time deviations of time distances, or to use a combination of the two approaches. Granger and Jeon (1997, 2003a) elaborate on the use of S-time-distance as a criterion for evaluating forecasting models of leading and lagging indicators.

28. The example used here refers to errors in the forecasting of inflation in the United States, where these forecasts are based on expert opinions (i.e. the average of the forecasts of leading institutions, as published by Consensus Forecast, Sicherl 1997). Figure 8 shows the forecast and actual growth rates of GNP deflator for the United States over the period 1973-1985; while Figure 9 shows the deviations between forecast and actual inflation in two dimensions: errors in timing, as measured by S-time-distances (- time lead, + time lag) on the horizontal axis; and static errors in inflation rate at a given point in time on the vertical axis. This presentation allows distinguishing between four types of errors: estimates that are too high and too late, in the first quadrant; estimates that are too high and too early, in the second quadrant; estimates that are too low and too early, in the third quadrant; and estimates that are too low and too late, in the fourth quadrant.

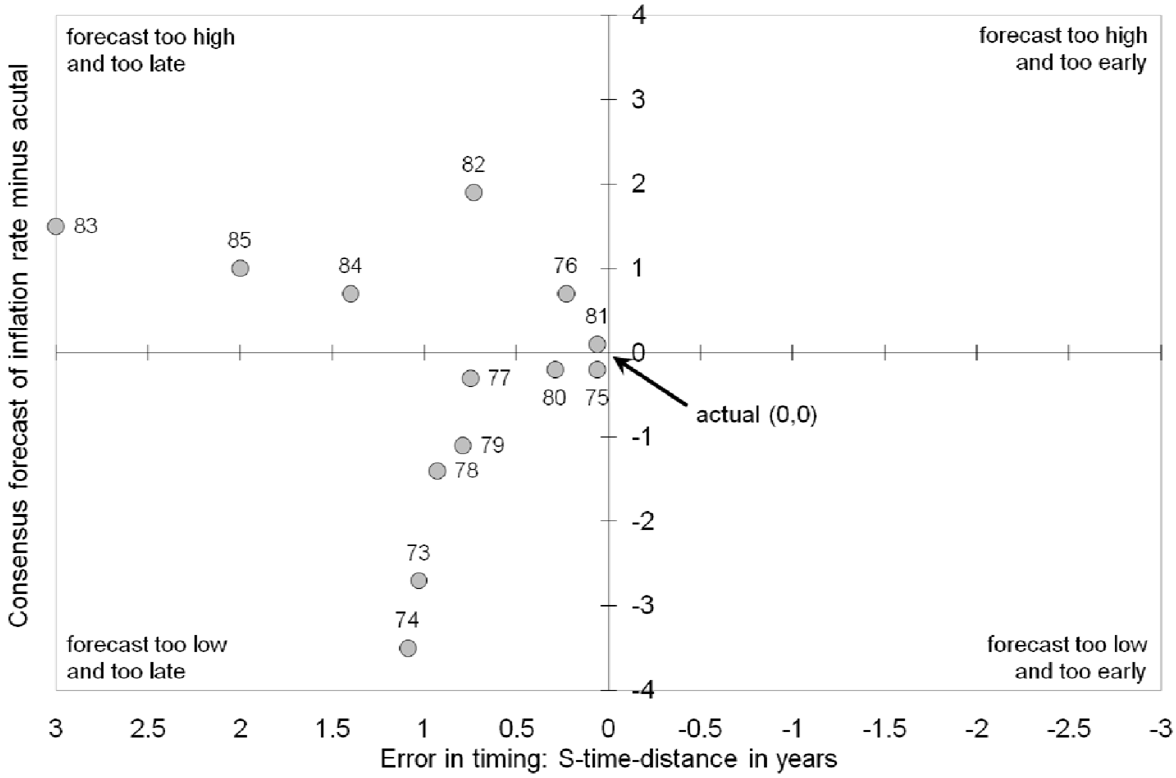
Figure 8. Consensus forecast and actual growth rate of the GNP deflator, United States, 1973-1985



Source: Chart based on data from Artis (1988), Staff Studies, IMF, Washington, July 1988.

Figure 9. Static and dynamic differences between forecasts and actual inflation in the United States, 1973-1985

GNP deflator



Note: Inflation projections based on *Consensus Forecast.*

Source: Own calculations based on data from Artis (1988), Staff Studies, IMF, Washington, July 1988.

29. In this example, the conventional approach would conclude that these consensus forecasts are unbiased. However, the time-distance methodology would shows that these forecasts are always too late, for a given level of the inflation rate. This implies that these forecasts cannot be considered satisfactory, either from a statistical or a logical standpoint (Sicherl 1994). While errors of this size may be uncommon, this example suggests that the time-distance methodology could provide a useful input into all forecasting evaluations.

3.6. Strengths and weaknesses of the time-distance method

30. We can now summarise what we have learned from these different examples. The strength of the time distance concept lies in the fact that it enables additional exploitation of data and visualization for time-series data. A new dimension is added while earlier results are neither lost nor replaced. The method allows simultaneous comparisons of time-series data in two dimensions: vertically (standard measures of static difference) as well as horizontally (S time distance), providing a new dimension of analysis to a variety of problems. Results from the two-dimensional analysis, static and time distance measures, can provide new perspectives and insights.

31. Another advantage of the time-distance methodology is that the concepts of time and of time distance apply across variables, fields of concern, and units of comparison. This makes it a useful analytical, presentation and communication tool. Since S-time-distance and S-time-step are expressed in

time units, they are intuitively understood by policy-makers, professionals, managers, media and the general public and they can help them in forming their subjective perception of the situation. Applied to social, business and technical fields, S-time-distance and S-time-step are presentation and communication tools useful to different players in a variety of contexts.

32. One possible weaknesses of the method is that calculating entries of a time matrix through interpolations may introduce small inaccuracies. Also, for a given level of the variable, the two time-series considered may not both have reached the selected level of the variable, or they may intersect the selected level more than once in case of time-series that change directions: in these situations, one has to decide which intersection to consider (the first, the last, etc.)[11]. In the empirical examples shown here we have taken the last intersection (the year marked in bold in the time matrices shown above). Also, if the two units being compared do not reach the same level(s) of the variable, time distance for this level cannot be calculated directly. However, one could extend the time-series backward or forward by extrapolation; or set the time distance for that level above the lengths of the relevant series.[12]

4. The concept of 'overall degree of disparity'

33. Measuring broad concepts such as well-being and progress is a complex undertaking, which requires confronting questions on both what should be measured and on which measures should be used to present and communicate evidence (Sicherl 2006, 2007a). Confronting these questions requires considering three types of issues (Sicherl 1992):

- choices about which measures of "position" and "progress" to use, which implies deciding which notion of distance in time and space should be applied to a set of indicators;
- value judgements that are associated with these measures and that give subjective weights to the 'objective' measures within and across various dimensions and fields of concern; and
- analysis of behaviours related to reactions of people to the perceptions formed with respect to the level and change in their position.

34. This section deals with the first issue, concentrating on the inter-temporal aspect. To that end, it defines the concept of 'overall degree of disparity' (or proximity), which is based on a simultaneous perception of disparity/proximity in both the indicator space and in time. It argues that the overall degree of disparity should be measured in two dimensions, complementing existing static measures of disparity in the indicator space with measures of disparity in time, and that this concept can lead to a different perception of the extent of disparity than that conveyed by conventional static measures.

35. Figure 10 presents a simple comparison of income disparities between two countries, regions or social groups under two scenarios, which differ in terms of the pace of income growth: Scenario A (corresponding to the two steeper lines, assumes a (constant) income growth rate of 4%, and Scenario B (corresponding to the two flatter lines) assumes a slower growth rate of 1%. For simplicity, the income of both units is supposed to increase at the same rate.

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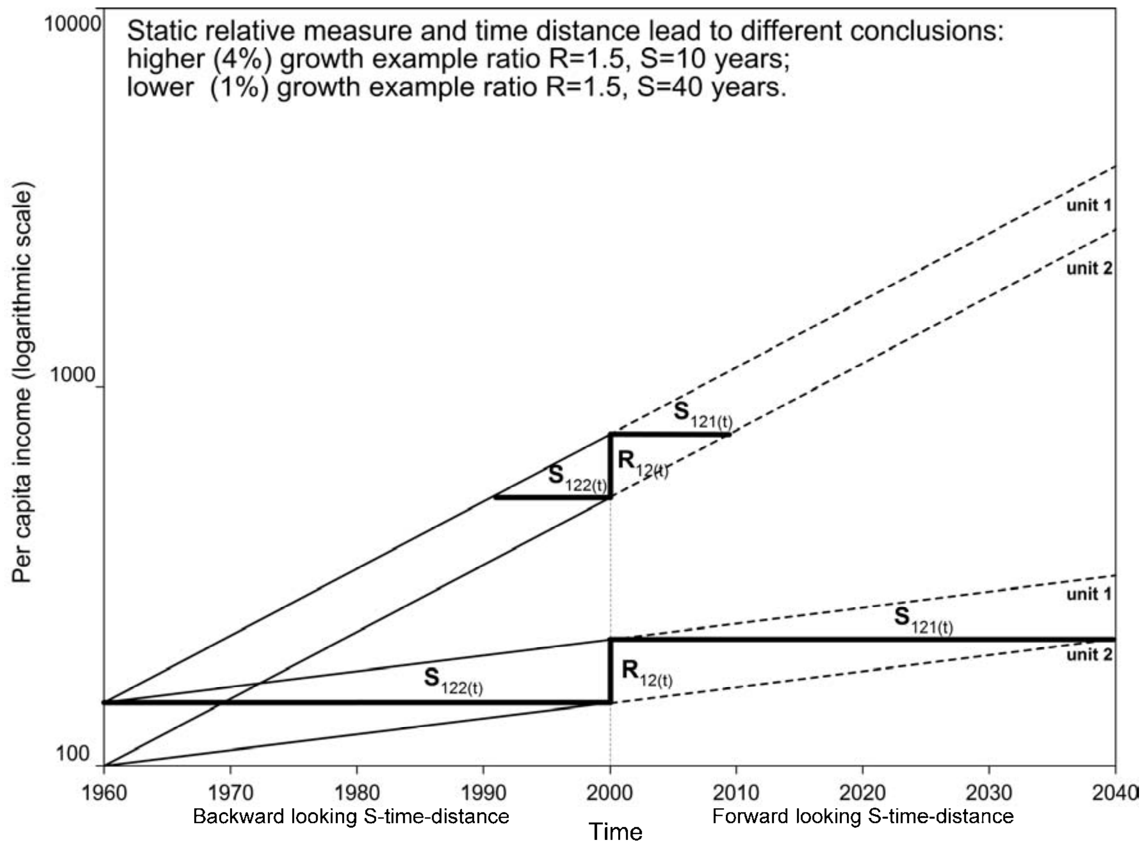
11 The evaluation of S-time-distance also depends on the selection of the benchmark, on the range of change of the benchmark, and on the length of the time-series.

12 For instance, time-series of real median household income of white and black people over the period 1967-2009 from the U.S. Census Bureau (2010) never reached the same level. In this case, one could say that in 2009 the median household income of the black population was only 60 percent of that of white households and that the white median household income was at least 42 years ahead of that of the black population.

Figure 10. Assessing disparities in the indicator space and in time



Source: P. Sicherl (2010a).

36. Under both scenarios, the income level of the first unit is 50% higher than the one for the second unit. However, the time-distance approach suggests a very different conclusion compared to differences in the indicator space. In Scenario A, the one characterised by a 4% income growth rate, the 50% static disparity translates into a time distance between the two units of 10 years, while in Scenario B, with 1% growth rate, the time distance between the units is 40 years. It is highly unlikely that ordinary people would perceive the two scenarios as being characterised by the same degree of disparity, and yet this is the conclusion suggested by conventional static analysis.[13]

37. In this example, higher growth rates lead to smaller time distances, and have an important effect on the overall degree of disparity. In other terms, the relation between average income growth and income inequality differs when based on the concept of overall degree of disparity. This is important for both policy strategies and for people's perceptions: it suggests that we should look at the two dimensions of disparity simultaneously (Sicherl 1989) and that, when failing to do so, various interest groups would favour the measure which better suit their interests. For instance, when the income rate of growth changes from 1 to 4 per cent, different measures on income disparities would move in different directions with i)

[13] While the value judgment that people would attach to disparities in the indicator space and in time is an open question, it may be safe to assume that a situation with 50 per cent static difference and time distance of 10 years is preferable to the situation with the same static difference and time distance of 40 years indicated in the example above. Conventional analyses based on static disparities do not distinguish such situations.

unchanged relative static measures; ii) higher absolute static measures; and iii) lower time distances. The different measures convey very different messages about how income disparities are evolving.

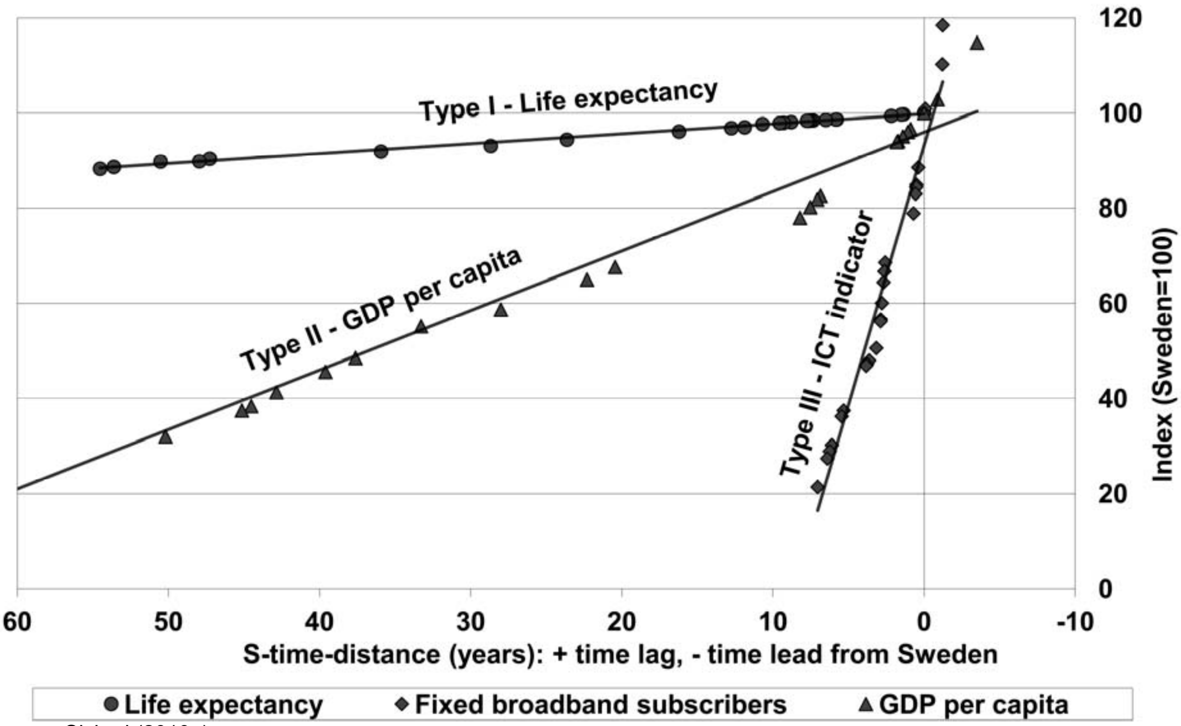
38. The time-distance methodology can be applied to disparities in economic, social, environmental, technological and business indicators, providing new insights based on existing data. Concepts of inequality and convergence are broadened when considering the pace of growth of the variable considered: the higher the difference in the growth rates of the indicator under different scenarios, the greater the disparity between static and time distance measures. These differences will be especially important when comparing variables characterised by different pace of growth (Sicherl 1978, 1980).

39. This last point is illustrated by Figure 10, which shows static and time-distance disparities in the case of variables characterised by a very low pace of change (such as life-expectancy at birth), labelled as Type I processes; variables characterised by an intermediate pace of change (e.g. GDP per capita), labelled as Type I processes; and variables characterised by a very fast pace of change (such as ICT penetration), labelled as Type III processes. Figure 10, which shows examples of Type I, Type II and Type III processes for EU27 countries relative to Sweden, visually highlights the difference between the three types of processes. Type I processes are characterised by low static disparities, low growth rates and large time distances. In contrast, Type III processes are characterised by high static disparities expressed in percentage terms, and small time distances.

40. The large discrepancy between measures of disparity in the static and in the time dimensions in this example confirms the theoretical conclusions that perceptions of disparities might be very different depending on the measure used. The broader framework presented here broadens the horizon for decision-making and introduces improved semantics for analysis and policy debate. An important policy question is to what extent differences in growth rates between Type I, Type II and Type III processes are either inherent to their nature or they can be changed through appropriate policies. While for some aspects of development, especially those related to demographic and human factors, policies cannot produce large changes in their pace of change in a short period, in other cases policies can impact quickly if they are supported by the necessary financial resources and organisational efforts. The main issue is to establish the right priorities within the framework of available material and human resources (Sicherl 1980).

Figure 11. Differences between static and dynamic disparities for in the case of three variables characterised by different growth rates

Disparities of EU27 countries relative to Sweden for life expectancy (type I), GDP per capita (type II) and ICT penetration (fixed broad band subscribers, type III)



Source: Sicherl (2010a).

5. An overview of the potential for applications

41. The applications of the time-distance methodology fall in two main categories. The first is application in statistics, by adding two generic measures (S-time-distance and S-time-step) that can be used both as descriptive tools and in analysis of goodness-of–fit; with possible further applications in stochastic models and in decision making models. The second application is in allowing a better understanding of the information embodied in time-series data to wider audiences, thus providing new perceptions for building knowledge and for discussing policy and business issues. Thus, beyond its use as descriptive statistics, the concept of time-distance allows multidimensional comparisons and evaluations, presentations, visualisation and semantics for policy and management.

42. The time-distance methodology has potential for *telling new stories*:

- *An additional view* in terms of:
  - *types of analysis* (benchmarking, target setting, monitoring and goodness-of-fit);
  - *different fields of concern* (like income and wealth, employment, education, health, poverty, consumption, productivity, wages, key performance indicators);
  - *types of indicators* (economic, social, environment, technological, business, etc.);

  - *at various levels* (world, countries, regions, urban and rural areas, cities; economic, social or ethnic groups; sectors, industries, corporations, projects).

- *Enhanced semantics* for policy analysis and public debate; a broader framework for interrelating growth, efficiency, inequality and convergence.

- A *presentation and communication tool* available to decision makers, civil society, and management to describe situations, challenges and scenarios.

- *Additional exploitation* of databases and indicator systems, including simple visualisation.

43. The list of possible applications is therefore long, and which of them will be pursued will depend on the priorities and imagination of different users. The descriptive measures can also serve as introductory representations of the issues and hypotheses best suited for more in depths examination and presentation by other models and other visualisation tools. There is no need to collect new data: one can start using existing data and indicator systems from international, national, regional, business and local sources.

6. Conclusions

44. The time-distance approach, which uses levels of the variable(s) as identifiers and time as the focus of comparison and numeraire, is universal, easy to understand and applicable to a wide variety of fields at both the macro and micro levels. This paper has argued that present state-of-the-art approach neglects some of the information available in time-series, leading to an information loss that is not justified. The time perspective, which people conventionally use when comparing different situations, can be introduced in statistics through the S-time-distance method both as a concept and as a quantifiable measure.

45. The applications of the time-distance approach fall in two broad categories:

- The first application is in statistic, by adding two generic measures (S-time-distance and S-time-step) to those already available. These measures can be applied as descriptive tools but also in analysis of goodness-of–fit. The strength of the time-distance concept is that it enables additional exploitation of data and visualization of time-series. Time distance is a generic concept, in the same way as static difference and growth rates, rather than a methodology oriented towards some specific substantive problem; it provides an additional view to many problems and applications.

- The second application is to better understand the information contained in statistical data, to build knowledge and to allow discussing policy and business issues in a new perspective. In other terms, the two statistical measures presented in this paper (S-time-distance and S-time-step) can provide new understanding of a variety of situations in economics, management, research and statistics: they lead to new questions, new hypotheses, new semantics and new conclusions.

46. In graphical terms, the usual way to compare time-series is to look at the *vertical* dimension, i.e. for a given point in time. The time-distance approach provides an additional perspective, comparing time-series in the *horizontal* dimension, i.e. for a given level of the variable. The time-distance approach has two advantages: first, expressed in time units, it is easy to understand by policy-makers, professionals, managers, media and the general public; second, time-distance can be compared across variables, fields of concern, and units of comparison. Since time distance view provides an additional dimension of temporal

disparity between two time series, results by other methods are left unchanged but new conclusions can be reached.[14]

47. In its simpler form, the time-distance approach can be applied to time-series that are continuously increasing or decreasing; in such cases there is no need to deal with possible multiple crossings at a given level of the variable. More complex procedures are needed for other cases, as illustrated by Granger and Jeon (2003a)in the case of forecasting and regression models. The S-time-distance approach could also be applied to decision-making models. It is hoped that researchers will test, apply this methodology also in fields beyond social sciences, and that they will develop softwares to facilitate its use.

48. Statistical offices of international organisations as well as national statistical offices could also use the time-matrix presentation to complement their usual time-series data tables covering many years and units. As illustrated in this paper, a time-matrix condenses such information in much smaller number of entries, which is a great advantage for presentation. By itself (i.e. even without calculating the two statistical measures S-time-distance and S-time-step) such matrices can be used in publications, web pages and other softwares as a first-level visualisation tool to 'turn statistics into knowledge'. The time matrix allows an introductory visualisation of what issues and hypothesis could be best suited for presentation through other visualisation tools such as OECD eXplorer, Google Public Data Explorer and Gapminder.

49. Measuring broad notion such as 'progress' also require dealing with inequalities between rich and poor, between groups and communities at different geographic scales, ranging from the entire world to individual countries. The time-distance methodology has several advantages when applied to this task. First, it provides two new measures to assess one of the dimensions of these disparities. Second, such broad examination of different perspectives can help to build better perceptions of the situations in a dynamic context and raise questions on whether the existing concepts are in line with the subjective perceptions of people and decision makers.

50. Empirically, when comparing across indicators and periods of time, static and time distance measures of disparities can differ significantly. The greater the difference in the growth rates of the indicators, the greater is the possibility of such divergence. The paper has proposed a typology of processes and argued that the notion of convergence or divergence should be viewed and analysed in the two dimensions. To that end, the concept of the overall degree of disparity (proximity) has been defined as the simultaneous perception of proximity in both the indicator space and in time. Both of them matter. It follows that existing static measures of disparity (proximity) in the indicator space should be complemented by measures of proximity in time.

51. The empirical examples included in this paper demonstrate how the method could be applied to three indicators (life expectancy at birth, the share of the elderly population, and projections of population growth) drawn from the *OECD Factbook.* These examples were drawn from an earlier presentation by the author referring to 14 variables ('Visualisation of 50 years of OECD countries at a glance', which is available on wikiprogress.org). The paper has also applied the methodology for monitoring Millennium Development Goals across many indicators, either for the world regions or at the country level.

52. Perceptions of well-being and progress are inherently subjective. An individual may assign different weights to various dimensions of well-being as well as to different measures referring to the same dimension. The concepts of well-being and progress need to deal not only with heterogeneous dimensions, measures and data sources but also with interpersonal and inter-temporal comparisons of the selected

14 James Backhouse, of the Information Science Department of the London School of Economics, argued that: "Time distance is a generic concept. That means that, as it has been the case e.g. with spreadsheet, one cannot in advance specify all the uses to which a generic framework can be put by imaginative users in numerous fields".

elements. While the OECD ‘Your Better Life Index’ is a tool that allows addressing differences in subjective opinions among fields of concern and indicators, an open question is the weight that people assign to the two dimensions of disparity discussed in this paper (static measure and time distance) to arrive at a overall evaluation of their position in society and globally.

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