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Quality & Quantity
International Journal of Methodology

ISSN 0033-5177
Volume 47
Number 2

Qual Quant (2013) 47:1143-1161
DOI 10.1007/s11135-011-9608-9

Springer

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Testing the Durkheim's suicide theory: a suicide study in Italy

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Published online: 9 October 2011

Abstract The identification of change points in a sequence of suicide rates is one of the fundamental aspects of Durkheim's theory. The specification of a statistical standard suitable for this purpose is the main condition for making inferences about the causes of suicide with distinctive trends of persistency and variability just as Durkheim theorized. At present, the statistical 'strategy' employed by the French social scientist is too 'rudimentary'. A hundred years later, I take the opportunity to test Durkheim's theory through modern methodological instruments, specifically the *Bayesian change-point analysis.* First of all, I analyzed the same suicide data which Durkheim took into consideration. *Change-point analysis* corroborates the Durkheimian analysis revealing the same change-points identified by the author. Secondly, I analyzed Italian suicide rates from 1864 to 2005. The *change-point analysis* was very useful. Durkheim's theory 'works' until 1961: suicides rates increased as industrial development increased. However, after 1961 and the *economic boom*, they declined, and when they *began increasing again*, after 1984, they did not reach the same level as before. This finding obliges us to 'adjust' the Durkheim's theory giving space to Halbwach's *convergence law.* Therefore, as high economic and social development levels are attained, suicide rates tend *to level-off*: People *adapt* to the stress of modernization associated to low social integration levels. Although we are more 'egoist', individualism does not destroy identity and the sense of life as Durkheim had maintained.

Keywords Bayesian change-point analysis · Durkheimian suicide analysis · *Convergence law* · Italian suicide rates

1 Introduction

That*Le suicide* is one of the most prominent works ever to be produced within the Social Sciences is widely agreed upon. Although other social scientists had already shown, before

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Durkheim, that suicide rates changed according to the degree of urbanization (Cazauvieilh 1840), religious affiliation (Wagner 1864), sex, age, civil state, seasons, day of the week, and even the time of the day (Morselli 1879), no author before him had ever dared to build a theory explaining nearly all the existing correlations. According to Giddens, Durkheimian *originality* and *vitality* lies in the successful explanation of these correlations in the framework of "a coherent sociological theory" (Giddens 1965, p. 5). According to Merton, *Le Suicide* is likely to be the greatest sociological research ever carried out (1967, p. 63). The *Suicide's* basic premise is well known: suicide is conceived as the product of 'suicide currents', as the 'symptom' of states of a collective conscience constituted by *egoism* and *anomy.* The weakening of social cohesion, derived from that cultural revolutions originated from industrialization, raises suicide rates in unlimited progression. The result was an obsessive search for 'remedies' in order to stop this otherwise explosive increase.

Ever since then, a vast amount of research has attempted to identify the suitable indicators for measuring the *degree* of social integration and anomy and to correlate these indicators with suicide rates (e.g., Danigelis and Pope 1979; Tiryakian 1981; Wasserman 1984; 1990; Breault 1986; Simpson and Conklin 1989; Pescosolido 1990; Trovato and Voss 1990; Trovato 1991; Stack 1980, 1981, 1983, 1985, 1990, 1993; Kposowa et al. 1995; Breault and Kposowa 2000; Stockard and O'Brien 2002; Cutright et al. 2006, 2007). Sociologists have generally supported the Durkheimian theory: they found a significant positive correlation between suicide rates and urbanization rates, divorce rates, unemployment rates, religious, commitment, etc., and they concluded that domestic/religious individualism had positive effects on suicide.

Although interest in Durkheim is deserving, in my opinion the Durkheimian theory should be re-tested in a more systematic way by taking into account another very basic point that the literature has neglected perhaps because it takes its foundation for granted. In fact, one of the focal points of the whole Durkheimian theory is the study of the suicide variability rates from which Durkheim infers the effect of the industrialization process on the rise of suicide rates. This aspect represents the foundation of the whole theory, so much so that testing is indispensable. Durkheim had provided an empirical systematization with the methodological tools available in his lifetime. In this article, I test the Durkheimian hypothesis by examining its fundamental aspect with the more modern methodological tools at our disposal. In other words, I focus on the question of whether or not the use of these tools confirm the author's findings and his consequential conclusions.

2 Change of suicide data in the Durkheimian analysis

Durkheim studied the variability of suicide rates by analyzing suicide data in France, Prussia, England, Saxony, Bavaria and Denmark from 1841 to 1872. In Table 1, I report some of these time series (Durkheim [1897] 1969, p. 66):

Durkheim shows the following trend from the time sequence of this data:

> In a series of years where the figures have fluctuated with similar values there is a sudden increase. After opposite oscillations, it grows and finally stabilizes. It is a fact that every break in social equilibrium, even if it breaks out, takes some time to produce all of its consequences. So, the progress of suicide has a trend with consecutive and distinct flows. These flows appear as waves, develop for some time, then stop to start again at a later time (tr. 1969, p. 67).

In other words, Durhkeim delineates the significant traits of an evolutionary process where the figures are substantially persistent and appear at a certain point to be interrupted by an

Table 1 Suicide time series in France, Prussia, Saxonie and Denmark 1841–1872 (for the significance of italics see note 1)

Years	France	Prussia	Saxony	Denmark
1841	2814	1630	290	337
1842	2866	1598	318	317
1843	3020	1720	420	301
1844	2973	1575	335	285
1845	3082	1700	338	290
1846	3102	1707	373	376
1847	(3647)	(1852)	377	345
1848	(3301)	(1649)	398	(305)
1849	*3583*	(1527)	(328)	337
1850	*3596*	*1736*	390	340
1851	*3598*	*1809*	*402*	*401*
1852	*3676*	*2073*	*530*	*426*
1853	*3415*	*1942*	*431*	*419*
1854	*3700*	*2198*	*547*	*363*
1855	*3810*	*2351*	*568*	*399*
1856	*4189*	*2377*	*550*	*426*
1857	*3967*	*2038*	*485*	*427*
1858	*3903*	*2126*	*491*	*457*
1859	*3899*	*2146*	*507*	*451*
1860	*4050*	*2105*	*848*	*468*
1861	4454	*2185*	(*643*)	
1862	4770	*2212*	*557*	
1863	4613	*2374*	*643*	
1864	4521	2203	(*545*)	*411*
1865	*4946*	*2361*	*619*	*451*
1866	*5119*	*2485*	704	*443*
1867	*5011*	3625	752	*469*
1868	(*5547*)	3658	800	*498*
1869	*5114*	3544	710	*462*
1870		3270		*486*
1871		3135		
1872		3467		

abrupt change in time series level. This change steadies up to the next breaking off point. From this perspective, after the brief drop recorded in Europe because of historical events in 1848, one of these 'waves' was found by Durkheim in France towards 1860 connected to the apogee of imperial government, in Germany just after the war of 1866, in England in 1868 because of the commercial revolution, and all over Europe after the 1870 war.[1] Of course, it is an *increasing* evolutionary trend connected to the relentless expansion of the social tie disintegration process and anomy theorized by the author.

According to Durkheim this peculiar trend constitutes the clear and incontestable 'proof' of the structural character that permeates a phenomenon only apparently anchored to the most

[1] Figures written in italics and not italics mark different 'waves' of suicides. The figures within brackets instead represent 'exceptional' and temporary variations concomitant with momentary social crisis situations.

intimate sphere of subjective motivations. If the suicide figure is invariable it*is* "because from year to year the development condition of people's life is notably the same" (*cit*.: p. 65); likewise, if it undergoes 'serious' changes it *is* because "society's constitutive features have profoundly changed" (*cit.*: p. 67).

That being stated, the most important aspect is idea of *change* in suicide rates. Which methodological approach allows Durkheim to affirm this fundamental assertion? This is a very important question because the empirical identification of change points in suicide rates time series represents the necessary condition for a *verifiable* treatment of the causes giving rise to change. In other words, according to Durkheim the development of the industrialization process with its consequential individualism and weakening of social cohesion is supposed to have had repercussions on the suicide curve producing abrupt 'upsurges'; if so, this hypothesis can be verified only through a criterion attesting *when* there is a real *abrupt upsurge*, an *objective* variability in voluntary deaths level.

At this point, Durkheim faced the question by using the statistic tools available in his times, namely the difference between the means. The author proceeds in a very simple way: if beginning from a certain year *y* suicide rates seem to exhibit an increase and this increase in turn persists for a certain number of years, he calculates the mean of two adjacent seriations. If the means differ then he concludes that the two distributions are different and therefore a change is verified in suicide rates level. Obviously, the boundary between the preceding seriation and the immediately subsequent seriation constitutes the *variability point* or *change point* of time series.

With this method Durkheim believed he found three change points in the French series of suicide rates connected to 1846, 1860 and 1864; two change points in the Prussian time series connected to 1849 and 1866; and two for Saxony in 1848 and 1865. The changes recorded were *incremental* variations, and they suggested a strong tie between the collectivity's moral constitution and the suicide curve. In fact, Durkheim sustained that change points corresponded to crucial historical and social conditions. For instance, 1866 marked Prussia's collective rebirth; being at the head of the Northern confederation in 1866, its industrial takeoff had already started since 1850: in 1865 Prussia already possessed 2/3 of steam cars in the German area and produced all of its coal and steel; its banks dominated the whole financial system; its railroads placed it at the center of the middle-European market. Then in 1870, Prussia's victory over France caused a substantial boost to industrial and commercial activity and public economic wealth through a huge war indemnity. In France, after 1948,Napoleon III carried out economic modernization by supporting industrial development, strengthening the financial apparatus, expanding the railways and other public works. While in 1865the French commercial revolution began.

Therefore, Durkheim provided an empirical support for his hypothesis through the *difference between the means.* However, at present this 'strategy' is certainly too 'rudimentary'. So, it is necessary to test the Durkheim's theory through more 'modern' methodological tools.

3 Research and method

In this article, I test the validity of the Durkheimian hypothesis by using a modern statistic technique: the *change-point analysis*. Particularly, I adopt the *Bayesian approach to the change-point problem* and I analyze two groups of data: (1) suicide data in France, Prussia and Saxony taken into account by Durkheim from 1841 to 1872; (2) suicide rates in Italy from 1864 to 2005.

3.1 The change-point analysis: a brief treatment

The change-point analysis answers to the following question: given a chronologically ordered data sequence, *when* it is possible to say there have been a *change* in the trend of this data sequence? Obviously the solution of such a question needs a criterion by which it is possible to identify in a *scientifically univocal way* one or more points in time series where a change in the underlying data generation process occurred. In this regard, the *change-point analysis* assumes that a sequence of independent, identically distributed n random variables shows a change in an unknown point r *if* the probability distribution of $x_1, x_2, x_3, \ldots x_r$ variables differs from the probability distribution of $x_{r+1}, x_{r+2}, x_{r+3,} \ldots x_n$ variables. This differentiation doesn't regard the functional form of the probability distribution: it is identical and known in both the series in which the original sequence divides. It regards the characteristic parameters driving the system. Schematically, the sequence of $x_{1,} \ldots x_n$ random variables exhibits a *change-point* in r if

$$\begin{aligned} \mathrm{X}_i &\sim F_1(x_i|\theta_1) \qquad i = 1, 2, \ldots, r, \\ \mathrm{X}_i &\sim F_2(x_i|\theta_2) \qquad i = r+1, \ldots, n \\ F_1(x_i|\theta_1) &\neq F_2(x_i|\theta_2) \text{ or } \theta_1 \neq \theta_2 \end{aligned}$$

F is the *specific probability function* (i.e. binomial, normal, gamma, poisson, etc.) by which the data X_i are distributed and θ_1 e θ_2 are the parameters characterizing the probability distribution of the two time series. If $r = n$, there is no change: all random variables are identically distributed with $\theta_1 = \theta_2$.

That being stated, we can make inferences about the location of one or more change points r in the data sequence or about the parameters driving the system if they are unknown. In this regard there are different approach: (1) non-parametric approach: it doesn't need to make assumptions about the stochastic process generating the data (e.g., Pettitt 1979; Wolfe and Schechtman 1984; Carlstein 1988); (2) maximum likelihood approach: inferences are based on the maximum likelihood estimates of the change points r and of the model's parameters (e.g., Hinkley 1970; Hsu 1979; Worsley 1986); (3) Bayesian approach (Bayes in Pearson and Kendall 1970). The Bayesian solution is the most used approach. Inferences are based on the *posterior probability distribution* of possible change points r. It is exactly equal to the *prior probability distribution* of r multiplied by the maximum likelihood, all divided by the summation of all products like this obtained for every possible change point from 1 to N:

$$p_n(r) = p_0(r)\, L(\mathbf{X}_\mathrm{i}|r) / \sum_{r=1}^{n} p_0(r)\, L(\mathbf{X}_\mathrm{i}|r).$$

More simply, a change point r is the point maximizing the likelihood and therefore it shows the highest posterior probability. If the highest probability is on the extreme points of the series ($r = n$), there is not a change. Same analytic rules are applied when the analysis is generalized to incorporate multiple change-points. Obviously, formal computation of the *posterior probability distribution* of r differs according to whether data exhibit a normal (Smith 1975), binomial (Broemeling 1982), gamma (Diaz 1982) or poisson (Raftery and Akman 1986) probability distribution.

The Bayesian approach to retrospective identification of change-points has been treated in numerous studies many of which focused on the Bayesian estimation of structural changes both in linear and not-linear regression models and ARIMA models (e.g., Moen et al. 1985; Singpurwalla and Soyer 1992). At present the Bayesian analysis of change-point problems is

successfully used in different fields, e.g. industrial system control, economics, medicine, biology, epidemiology. For instance, a Bayesian procedure has been applied to analyze matters as Watergate effects on U.S. industrial production level (Menzefricke 1981), the coal-mining disasters (Raftery and Akman 1986), the volatility of U.S. gasoline market (Tsurumi 1980), the volatility of stock indexes of emerging latin american markets (Loschi et al. 2005), the publicity effect on consumer decision making (West and Harrison 1986), the monitoring of renal transplant data (Smith and Cook 1980), the development of a bacteriological infection (Whittaker and Frühwirth-Schnatter 1994; Achcar et al. 2008), the fatal crashes involving young badly drivers (Tay 2007). In short, there is a very diffused application, promoted also by methodologies to facilitate the calculation, prohibitive especially for long data sequences and in the multiple-changepoint case, of the marginal posterior densities of possible change points r (the Gibbs sampler, namely an iterative *Monte Carlo* method reducing the computational load to obtain the desidered marginal posterior densities by avoiding sophisticated analytic and high dimensional numerical integration procedures; e.g., Gelfand et al. 1990; Carlin et al. 1992; Smith and Roberts 1993; Stephens 1994).

Its heuristic potentialities being considered, I propose here to apply the Bayesian procedure to identify change points in chronologically ordered suicide data.

4 Application of the change-point analysis to the Durkheimian data

First I analyze suicide data in France, Prussia and Saxony taken into account by Durkheim, leaving out England, Bavaria, Denmark because their suicide time series have too many missing values to be adequately treated. I computed the *posterior probability* of possible change-points when I have specified (1) the *probability distribution* of suicide data, (2) the *prior probability distribution* of the change-point r, (3) the *prior probability distribution* of the unknown parameters.

In regard to French suicide data (1841–1869) Durkheim identified 3 change-points connected to 1846, 1860 and 1864.

I applied the *Bayesian change-point analysis* 'sequentially' (Model with 1, with 2, with 3, etc. change-points). This sequential application permits us to satisfy the 'exhaustivity' criterion.

A normal distribution fits observed data ($\chi^2 = 2.61871$, $1g.l.$, $p < .11$; Kolmogorov–Smirnov Test $DN = 0.107$, $p < .89$: the maximum discrepancy between empirical cumulative distribution and theoretical cumulative distribution is not significant and therefore the theoretical distribution fits satisfactorily the observed distribution). Therefore the *posterior distribution* of r in the case of 1 change-point is computed for $3 \leq r \leq 26$ by assuming (1) a *prior uniform distribution* of r(in fact there is no information to prove that a point is more probable than another) with $p_0(r) = 1/24$ for $3 \leq r \leq 26$ and $p_0(r) = 0$ for the remaining points of the series, (2) *a prior uniform distribution* for μ_i and σ_i (the universe's parameters are not known and they should be estimated by the empirical data).

Model with 1 change-point: the posterior probability of the change point r is obtained by the following equation:

$$p(r) \propto p_0(r)\Gamma\frac{1}{2}(r+1)\Gamma\frac{1}{2}(n-r+1)\{r(n-r\}^{-\frac{1}{2}} \times \left\{\sum_{i=1}^{r}(x_i-\overline{x_r})^2\right\}^{-\frac{1}{2}(r+1)} \left\{\sum_{i=r+1}^{n}(x_i-\overline{x}_{n-r})^2\right\}^{-\frac{1}{2}(n-r+1)}$$

Table 2 French suicides: posterior probability of r and cumulated probabilities

Time point (r)	Years	Suicides (i)	$p_0(r)\cdot$ max.likelihood	$p(r) = \frac{p_0(r)\cdot\text{m.likel.}}{\Sigma p_0(r)\cdot\text{m.likel.}}$	$\Sigma p(r)$
1	1841	2814	–	–	–
2	1842	2866	–	–	–
3	1843	3020	0.042 · 4.8910E−97	0.000	0.000
4	1844	2973	0.042 · 9.6752E−96	0.000	0.000
5	1845	3082	0.042 · 4.7637E−95	0.003	0.003
6	1846	3102	0.042 · 4.0483E−94	0.027	0.030
7	1847	3647	0.042 · 1.7557E−96	0.000	0.030
8	1848	3301	0.042 · 9.0338E−96	0.000	0.030
9	1849	3583	0.042 · 7.6636E−96	0.000	0.030
10	1850	3596	0.042 · 1.0198E−95	0.000	0.030
11	1851	3598	0.042 · 1.9056E−95	0.001	0.031
12	1852	3676	0.042 · 2.8502E−95	0.002	0.033
13	1853	3415	0.042 · 2.6376E−94	0.018	0.051
14	1854	3700	0.042 · 6.0198E−94	0.040	0.091
15	1855	3810	0.042 · 8.8116E−94	0.058	0.149
16	1856	4189	0.042 · 1.0420E−94	0.007	0.156
17	1857	3967	0.042 · 1.1837E−94	0.008	0.164
18	1858	3903	0.042 · 3.1093E−94	0.020	0.184
19	1859	3899	0.042 · 1.7123E−93	0.113	0.297
20	1860	4050	0.042 · 8.6045E−93	0.567	0.864
21	1861	4454	0.042 · 1.9458E−93	0.128	0.992
22	1862	4770	0.042 · 6.2043E−95	0.004	0.996
23	1863	4613	0.042 · 1.5467E−95	0.001	0.997
24	1864	4521	0.042 · 4.0620E−95	0.003	1
25	1865	4946	0.042 · 2.9138E−96	0.000	1
26	1866	5119	0.042 · 1.0442E−97	0.000	1
27	1867	5011	–	–	–
28	1868	5547	–	–	–
29	1869	5114	–	–	–

Highest posterior probability appears in correspondence of $r = 20$ with $p(r) = 0.60$ (Table 2). It constitutes the predominant 'spike' (the posterior probability is from 4 to 30 times greater than it is in all other points). $p(r) = 0$ indicates lack of change (no shift in the parameters). The mode at $r = 20$ corresponds to 1860. Nevertheless, the results permit us to assume that another change point is in $r = 6$ or $r = 15$. To test this hypothesis, I applied a model with two change points.

Model with 2 change-points: Assuming *prior uniform distribution* for every possible couples of points r_1, r_2, the *posterior probability* of r_1, r_2 is proportional to

Table 3 French suicides: posterior probability of r_1, r_2 for some selected values

r_2	r_1							
	3	4	5	6	7	8	–	23
6	0.000	–	–	–	–	–	–	–
7	0.000	0.000	–	–	–	–	–	–
8	0.000	0.000	0.000	–	–	–	–	–
9	0.000	0.000	0.000	0.000	–	–	–	–
10	0.000	0.000	0.000	0.000	0.000	–	–	–
11	0.000	0.000	0.000	0.000	0.000	0.003	–	–
12	0.000	0.000	0.000	0.000	0.000	0.000	–	–
13	0.000	0.000	0.000	0.002	0.000	0.000	–	–
14	0.000	0.000	0.000	0.013	0.000	0.000	–	–
15	0.000	0.000	0.000	0.030	0.000	0.000	–	–
16	0.000	0.000	0.000	0.000	0.000	0.000	–	–
17	0.000	0.000	0.000	0.001	0.000	0.000	–	–
18	0.000	0.000	0.000	0.007	0.000	0.000	–	–
19	0.000	0.001	0.005	0.084	0.000	0.000	–	–
20	0.000	0.007	0.041	0.700	0.000	0.004	–	–
21	0.000	0.001	0.006	0.075	0.000	0.000	–	–
22	0.000	0.000	0.000	0.001	0.000	0.000	–	–
23	0.000	0.000	0.000	0.000	0.000	0.000	–	–
24	0.000	0.000	0.000	0.001	0.000	0.000	–	–
25	0.000	0.000	0.000	0.000	0.000	0.000	–	–
26	0.000	0.000	0.000	0.000	0.000	0.000	–	0.000

$$p(r_1, r_2) \propto p_0(r_1, r_2)\Gamma\tfrac{1}{2}(r_1+1)r_1^{-\frac{1}{2}}\left\{\sum_{i=1}^{r_1}(x_i-\overline{x}_{r_1})^2\right\}^{-\frac{1}{2}(r_1+1)}$$
$$\cdot\Gamma\tfrac{1}{2}(r_2+1)r_2^{-\frac{1}{2}}\left\{\sum_{i=r_1+1}^{r_2}(x_i-\overline{x}_{r_2})^2\right\}^{-\frac{1}{2}(r_2+1)}$$
$$\cdot\Gamma\tfrac{1}{2}(n-r_1-r_2+1)(n-r_1-r_2)^{-\frac{1}{2}}\left\{\sum_{1=r_2+1}^{n}(x_i-\overline{x}_{(n-r_1-r_2)})^2\right\}^{-\frac{1}{2}(n-r_1-r_2+1)}$$

Therefore, the exact values of the *marginal posterior density* are obtained by dividing by the sum of all products between *prior distribution* and *maximum likelihood* obtainable for every possible combination of two points (231 combinations beginning from a minimum $n = 3$, for instance: $r_1, r_2 = 3$-6; $r_1, r_2 = 3$-7; $r_1, r_2 = 3$-8, etc.; $r_1, r_2 = 4$-7; $r_1, r_2 = 4$-8; $r_1, r_2 = 4$-9, $r_1, r_2 = 5$-8; $r_1, r_2 = 5$-9; $r_1, r_2 = 5$-10, etc., Table 3). The data seem to confirm the hypothesis: the highest posterior probability is connected to the couple $r_1, r_2 = 6$-20 (1846 and 1860 respectively) $p(r) = 0.70$. But it seem also that $r = 15$ may be a further *change-point*.

In the *model with 3 change-points* an ulterior factor is added to the previous formula since the series is now divided into four parts. As Table 4 shows, the analysis produces the expected result: it seems possible to incorporate into the system the point immediately preceding to

Table 4 French suicides: posterior probability of r_1, r_2, r_3 for some selected values

r_1, r_2, r_3	$p(r_1, r_2, r_3)$
–	–
6-14-17	0.000
6-14-18	0.000
6-14-19	0.010
6-14-20	0.310
6-14-21	0.025
6-14-22	0.000
6-14-23	0.000
6-14-24	0.005
6-14-25	0.000
6-14-26	0.000
6-15-18	0.000

$r = 15 (r = 14$; mode at $r_1, r_2, r_3 =$ 6-14-20 $p(r_1, r_2, r_3) = 0.31)$. During 1854–1855 'something' happened which was able to exert an influence on suicides rates up to 1860, until to beginning of a new 'wave' of suicides.

Another final aspect regards point 24 (namely 1864), although it appears characterized by small values of posterior probability. I developed a *Model with 4 change-points.* And in fact the modal value of the posterior probability appears at $r_1, r_2, r_3, r_4, =$ 6-14-20-24 $p(r_1, r_2, r_3, r_4) = 0.23$. These results indicate that suicides in France underwent continuous changes from 1841 to 1869; the first beginning from 1846, then from 1854, and also from 1860 and finally, with a new upsurge, from 1864.

It is clear that there is a substantial coincidence between these findings and the findings obtained by Durkheim. The French sociologist seems to have committed only one error: the author did not report a further upsurge of suicides from 1854 to 1860, while he had correctly identified the other three change points.

In regard to prussian suicide data (1841–1872), Durkheim identified only 2 change-points, 9 and 26 connected with 1849 and 1866. A normal distribution fits observed data ($\chi^2 =$ 2.50104, *1 g.l.,* $p < .28$; $DN = 0.21$ $p < 0.12$) so that, assuming a *prior uniform distribution* of r, the posterior probability of r is computed by the same formula applied to French suicides.

First, the *Model with 1 change-point* assumes $p_0(r) = 1/27$ for $3 \leq r \leq 29$ and $p_0(r) = 0$ for the remainder points. There is a 'spike' at $r = 11$ (Table 5 reports some values of r, from 6 to 27; the other probabilities are null). Moreover, it is possible to justify the application of a *Model with two change-points*, the second point included between 21 and 26. And in fact the analysis shows the highest posterior probability connected to the couple $r_1, r_2 =$ 11-26: $p(r) = 0.393$ (Table 6). Finally, it is possible to detect two other change points: $29 (r_1, r_2, r_3, =$ 11-26-29 $p(r_1, r_2, r_3) = 0.837)$, and $22 (r_1, r_2, r_3, r_4 =$ 11-22-26-29 $p(r_1, r_2, r_3, r_4) = 0.18)$.

Durkheim's results partially coincide with these findings. The analysis shows that the first 'wave' of suicides took place in 1851, after 1848 events. Rates appear stable until 1862, when a further increase begins to stabilize until 1866. In this year a new disruption of the equilibrium previously reached appears. A last wave of suicides finally appears beginning from 1869. Durkheim had set the first upsurge of suicides in 1849 and a following wave after

Table 5 Prussian suicides 1841–1872: posterior probability of r

r	6	7	8	9	10	11	12	13	14	15	16
$p(r)$	0.001	0.000	0.005	0.017	0.148	0.54	0.015	0.031	0.003	0.000	0.000
r	17	18	19	20	21	22	23	24	25	26	27
$p(r)$	0.000	0.000	0.000	0.003	0.007	0.015	0.016	0.049	0.077	0.069	0.000

Table 6 Prussian suicides 1841–1872: posterior probability of r_1, r_2 for some selected values

r_1, r_2	11–14	11–15	11–16	11–17	11–18	11–19	11–20	11–21	11–22
$p(r_1, r_2)$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.005
r_1, r_2	11–23	11–24	11–25	11–26	11–27	11–28	11–29		
$p(r_1, r_2)$	0.011	0.107	0.392	0.393	0.000	0.000	0.000		

1866 war. No other change was found by the author. These discrepancies are probably due to certain—inevitable—limitations of the technique used by him.

Finally, I used the *Bayesian change-point analysis* in regard to saxon suicides data from 1841 to 1869. In this case, after having verified that probability distribution was normal ($\chi^2 = 1.61821 g.l., p < .20$; $DN = 0.12\, p < 0.80$), 1 change-point was identified at $r = 11 p(r) = 0.82$. Subsequently, the distribution of the posterior probability suggested the inclusion of other four change points in the system. The final model includes 5 change-points: $r_1, r_2, r_3, r_4, r_5 =$ 10-13-16-19-25. Highest marginal density connected to these points is $p(r) = 0.16$.

In short, the suicide curve 'shows' a significant increase from 1850 to 1855, and then a brief fall from 1856 to 1859, and finally there is a new and more consistent rise in the figures. There are two points of coincidence with Durkheim: the wave of suicides post 1848, beginning from 1850; and the further outburst of voluntary deaths since 1865.

In conclusion, comparing my results with Durkheim's, the analysis seems to present a pleasant 'surprise'. The most significant 'waves' of suicides occur exactly when the French sociologist had predicted even by using more 'rudimentary techniques'. On the other hand, however, he had analyzed only 'short' time series: the Prussian series consisted of 32 elements, while the French and Saxon series had 29 elements both. It is not therefore unfounded to believe that Durkheim, through the technique at his disposal, would have meet with insurmountable difficulty if he had had to analyze a *'long'* time series (100 or more data).

5 Application of the change-point analysis to the suicide rates in Italy

In second and more decisive step in my analysis, I applied the*Bayesian change-point analysis* to time series of suicide rates in Italy from 1864 to 2005 (142 elements. There is no definitive data from 2006 to 2009, Fig. 1).[2] Obviously, with the modern instruments available today,

[2] Suicide rates in Italy from 2006 to 2008 (*Source*: Italian statistical Institute, ISTAT) are still provisional: 5.2 (2006), 4.8 (2007), 4.7 (2008).

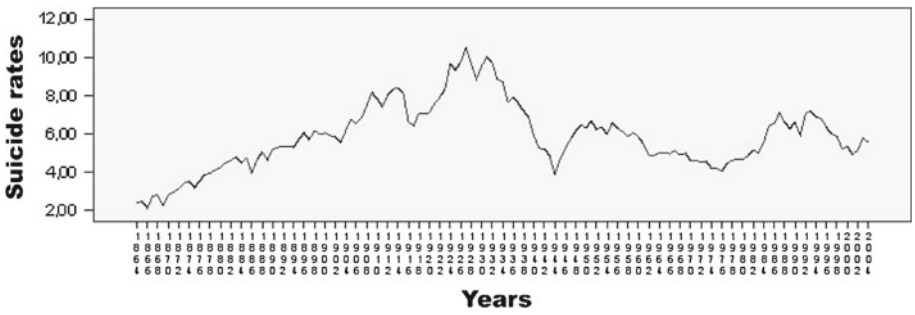

Fig. 1 Suicide rates in Italy: 1864–2005. *Sources*: Somogyi (1967): suicides from 1864 to 1886; *ISTAT*: 1887–2005 (ISTAT 1958, 1993, 1955–2005)

I intend to verify if this data confirms the Durkheim's interpretative hypotheses or what relationship it has to his theory.

First of all, a normal distribution fits data satisfactorily ($\chi^2 = 13.4047\,10\,g.l.\ p < 0.20$; $DN = 0.0642\ p < 0.66$). The data appear to distribute according to *Random Walk* and it certainly constitutes a further guarantee for the reliability of results. So, I assume a*prior uniform distribution* for $r(3 \leq r \leq 142)$ and for the unknown parameters, and first of all I apply a model with 1 change-point (Table 7).

The posterior probability of r shows a change-point at $r = 24 p(r) = 0.120$. This point corresponds to 1887. The peculiar trend of suicide rates seems to suggest nevertheless the hypothesis that there can be other change points. So, I apply a *multiple change-point analysis* (2, 3,4, 5, etc. change-points). From this perspective, the most meaningful aspect is the evidence of a *systematic* recurrence of the points $r = 13$ and $r = 98$ corresponding to 1876 and 1961 in every combination of possible change-points identified. The analysis suggests a *Model with 5 change-points*: mode at $r_1, r_2, r_3, r_4, r_5 = 13\text{-}31\text{-}98\text{-}121\text{-}133$ corresponding to 1876–1893–1961–1984–1996 $p(r_1, r_2, r_3, r_4, r_5) = 0.0324$ (considering with 5 change-points the number of obtainable combinations exceeds the million and most $p(r)$ is almost null, a 3% posterior probability constitutes an acceptable value).

These results show a very complex picture.

The data represents a confirmation of the Durkheimian theory until the change-point corresponding to 1961: suicide rates increase as industrial development increases. The first change-point (and therefore the '*first wave*' of suicides) is found just after the "*feverish triennium*", that is the period from 1871 to 1873. In these years considerable initiatives of industrial development were taken to reduce the italian under-development compared to other European nations. Up to now Corbino's '*old*' thesis, which states that great industrialization in Italy originates in 1871–1873, seems to be generally accepted (Corbino 1936, p. 94; Romeo 1972; Romani 1976; Mori 1977; De Rosa 1980, p. 9). From the Durkheimian perspective, therefore, this transformation explains the wave of suicides after 1876, 1889, etc.

Furthermore, always in accordance with the Durkheim's theory, suicides reach the lowest values during the war and soon afterwards begin increasing again until 1961, with the contemporary rise of the industrial production index. The index was 29 in 1945, it rose to 71 in 1946, quickly reached 140 in 1951, 159 in 1953, 191 in 1955, reaching 358 in 1962 (*Source*: Istat).

We come now to the most interesting—and perhaps most 'amazing'—aspect of the analysis. Beginning from 1961, in connection to the Italian *economic boom*, suicide rates decrease, and they do not increase as expected from a Durkheimian theoretical perspective. According

Table 7 Posterior probability of r and cumulated probabilities

Time point (r)	Year	Suicides (i)	Suicide rates	$p(r)$	$\Sigma\, p\,(r)$
1	1864	646	2.40	–	–
2	1865	676	2.49	–	–
3	1866	588	2.15	0.000	0.000
4	1867	753	2.74	0.000	0.000
5	1868	784	2.84	0.000	0.000
6	1869	633	2.28	0.000	0.000
7	1870	788	2.82	0.000	0.000
8	1871	836	2.97	0.000	0.000
9	1872	890	3.14	0.000	0.000
10	1873	975	3.43	0.000	0.000
11	1874	1015	3.55	0.000	0.000
12	1875	922	3.21	0.013	0.013
13	1876	1024	3.54	0.051	0.064
14	1877	1139	3.90	0.054	0.118
15	1878	1158	3.95	0.080	0.198
16	1879	1225	4.14	0.081	0.279
17	1880	1261	4.27	0.076	0.355
18	1881	1343	4.51	0.044	0.399
19	1882	1389	4.63	0.026	0.425
20	1883	1456	4.82	0.012	0.437
21	1884	1370	4.49	0.020	0.457
22	1885	1459	4.74	0.016	0.473
23	1886	1225	3.96	0.090	0.563
24	1887	1449	4.65	0.120	0.685
25	1888	1590	5.07	0.067	0.752
26	1889	1463	4.63	0.118	0.870
27	1890	1652	5.20	0.063	0.933
28	1891	1697	5.30	0.031	0.964
29	1892	1723	5.35	0.016	0.980
30	1893	1737	5.36	0.010	0.990
31	1894	1732	5.31	0.007	0.997
32	1895	1874	5.72	0.003	1
33	1896	2000	6.07	0.000	1
34	1897	1895	5.71	0.000	1
35	1898	2059	6.17	0.000	1
”	”	”	”	0.000	1
137	2000	3096	5.35	0.000	1
138	2001	2819	4.95	0.000	1
139	2002	2949	5.14	0.000	1
140	2003	3361	5.80	0.000	1
141	2004	3265	5.58	0.000	1
142	2005	2892	5.20	0.000	1

to historians this same economic boom after 1955 really changed "Italy into a truly industrial nation" (De Rosa 1980, p. 87). The industrial production index rose from 358 in 1962 to 459 in 1966, 529 in 1968, 546 in 1969 (*cit.*, p. 78). Italian industrial production "from 1949 to 1969 increased five times" (*cit*., p. 78). At the same time, through this industrial development and the consequent changes in agriculture and in tertiary activities and despite the increase of the population, per-capita national income doubled in comparison to per-capita national income before the Second World War (Barberi 1971, p. 115). Finally, such an increase induced a considerable increase in total and per-capita consumption (*cit.*, p. 117). In short, there was a very huge development. Here lies the very strong dissonance with the Durkheimian theoretical prediction. To complete the picture, the suicide trend beginning from 1984 must be highlighted: suicide rates increase twice within 10 years but they do not increase beyond the maximum levels attained formerly.

In any case, the most important aspect in suicide trend remains the observable change since 1961: how can we interpret this 'anomalous datum'? Immediately, a first conclusion seems quite clear: *beginning from a certain point*, the Durkheimian theory *doesn't work any more*. Durkheim believed that the more modernization level would have increased, the more suicide rates would increase in an endless spiral. This would be the tragic destiny of modern society unless man found a 'solution' to stop this unlimited increase. Instead, recent data seem to show this forecast to be *groundless* as suicide rates do not exhibit the inexorable rise postulated by the author. In addiction, there is a second comment to be made: seeing that consumption has increased beginning from 1955, might higher consumption, although vituperated, be a deterring factor in suicides?

In conclusion, the Durkheim's theory has to be in some way integrated or however corrected by a theoretical perspective able 'to explain' what *Le Suicide* can no longer explain. Curiously enough, the answer seems to come from a Durkheimian as Maurice Halbwachs.

6 A 'change' of prospective

Like Durkheim, Halbawchs believes that modernization has produced certain pernicious consequences, 'shreding' traditional life systems and immolating ever more victims on the altar of modernity. But unlike Durkheim, he believes that these effects are produced by modernization primarily in *its first phase*. In the long term, as high economic and social development levels are attained, suicide rates tend *to level-off*: People *adapt* to the stress of modernization associated with low social integration levels of the industrial society. (1930, pp. 484–490).

Obviously, according to Halbawchs, this trend implied that in more industrialized countries the increase of suicides would have had to slow down, while in countries in initial industrial development, involved in progressive depopulation, steady weakening of traditions, and difficult financial circumstances, the growth of voluntary deaths would have had to accelerate, still far from stabilization. This process is known as *law of convergence.*

A measure of degree of convergence among suicide rates in more industrialized nations and in developing nations, the *coefficient of dispersion,* allowed Halbwachs to prove the validity of his hypothesis.

To explain Italian suicide data to the light of this 'new' theoretical frame, four points should be verified. *First*, national suicides should increase at a lower rate in most recent periods. *Second*, in regions industrialized for some time (regions forming the *Italian industrial triangle,* that is Lombardy, Piedmont, Liguria) rates should show a slowdown in comparison to the trend recorded in former time. *Third*, suicide rates relating to regions involved in a more recent development process (regions in the South of Italy) should be on the increase. While the

Table 8 Italian suicides

Years	Mean rates	Relative numbers 5.38 = 100	Suicide growth rate
1864–1876	2.89	54	−46
1877–1893	4.64	86	−14
1894–1961	7.84	146	+46
1962–1984	4.77	89	−11
1985–1996	6.65	124	+24
1997–2005	5.46	102	+2
General mean	5.38		

Relative numbers: general mean = 100

Northern industrial districts already showed rather advanced development, industrialization of the South had only started since 1957. Southern Italy had a mainly agricultural economy, and insufficient industrial development based primarily on small semi-artisan firms. Therefore, *Southern Italy Development Fund* tried to promote and to develop the growth of an efficient industrial sector through fiscal benefits and economic incentives, and public works to promote the development of new industrial plants (although wrong strategic choices prevented investments from producing all expected results) (Graziani 1972; Salvati 1982). *Fourth*, consequently we should have an increase in*convergence* or a reduction in dispersion in suicide rates of Northern and Southern regions in time. That being stated, the analysis revealed:

(a) a reduction in the growth rate of national suicides particularly since 1961. By equalizing to 100 the general mean of mean rates in each historical period identified by change-points, it is easy to observe that after 1961 the growth rate appears to decrease (Table 8).

(b) a reduction, since 1961, in rise of suicide rates relating to the *industrial triangle regions* (Piedmont, Lombardy, Liguria), the first regions to be transformed by the industrialization process. To obtain a more precise idea on variations in suicide rates, I calculated the ratio between mean rates of five years periods from 1864 to 1995 (I stopped at 1995 because data from 1995 to 2005 are sometimes lacking) and the general mean of mean rates (equalized to 100). These ratios or *relative numbers* measure the deviation of mean rates from the general mean, denoting in substance the suicide growth rate from a period to another in the respective regions. The results show that the growth rate decreases gradually but with continuity (Tables 9, 10). This trend, particularly accentuated from 1961 to 1985, unequivocally reveals that the number of suicides of industrial regions were '*favourably*' influenced by 1960's economic boom.

(c) a constant increase of suicide growth rate in the Central and Southern Italian regions, such as Umbria, Marche, Abruzzo-Molise, Basilicata, Puglia, Calabria, which are still considered in an initial phase of the industrialization-modernization process. Unlike the Northern industrial regions, their growth rate accelerates precisely in the years of the *economic boom*. In the Center of Italy the ratio between mean rates calculated for five year periods from 1864 to 1995 and the general mean (=100) is 87 in 1886–1890, 111 in 1901–1905, 109 in 1961–1965, 118 in 1981–1985 and 106 in 1990–1995. The same findings regards the Southern regions as well. Here suicides increase without interruption: growth rate is 38 in 1886–1890, 45 in 1901–1905, 64 in 1961–1965, 71 in 1981–1985, and again 64 in 1990–1995 (Tables 9, 10).

Table 9 Mean suicide rate in Italy for groups of regions

	1864–1865	1866–1870	1871–1875	1876–1880	1881–1885	1886–1890	1890–1895
P.-Lom.-Lig.	4.00	3.80	4.50	5.10	6.60	9.40	7.90
U.-M.	2.80	2.90	3.60	4.40	4.30	4.70	5.42
A.M.-B.-P.-C.	2.00	1.20	1.25	1.60	1.80	2.10	2.70
General mean	2.9	2.6	3.1	3.7	4.2	5.4	5.3
Stand. Dev.	0.82	1.1	1.4	1.5	1.96	3.02	2.1
	1896–1900	1901–1905	1906–1910	1910–1915	1916–1920	1921–1925	1926–1930
P.-Lom.-Lig.	8.50	9.70	11.70	12.50	10.20	12.10	12.8
U.-M.	6.40	7.35	7.15	7.85	6.50	8.50	8.20
A.M.-B.-P.-C.	4.40	3.00	3.80	4.15	4.00	4.50	4.77
General mean	6.4	6.6	7.5	8.1	6.9	8.4	8.6
Stand. Dev.	1.7	2.7	3.2	3.4	2.5	3.1	3.2
	1931–1935	1936–1940	1941–1945	1946–1950	1951–1955	1956–1960	1961–1965
P.-Lom.-Lig.	12.00	9.50	6.50	8.20	9.20	8.70	7.00
U.-M.	10.20	7.00	5.00	5.70	6.60	6.60	6.00
A.M.-B.-P.-C.	5.00	4.08	2.87	4.00	4.00	4.00	3.50
General mean	9.0	6.8	4.8	5.9	6.5	6.4	5.5
Stand. Dev.	2.9	2.2	1.4	1.7	2.1	1.9	1.5
	1966–1970	1971–1975	1976–1980	1981–1985	1986–1990	1991–1995	
P.-Lom.-Lig.	6.50	5.88	5.58	7.20	9.50	11.10	
U.-M.	6.20	6.50	7.00	7.70	8.60	8.95	
A.M.-B.-P.-C.	3.60	3.30	3.60	4.60	5.00	5.37	
General mean	5.4	5.2	5.3	6.5	7.7	8.4	
Stand. Dev.	1.3	1.4	1.4	1.3	1.9	2.4	

These results already give valid support to the *law of convergence.* It appears definitely confirmed by the last important finding:

(d) an increase of degree of convergence among mean rates of the 9 regions considered from 1864 to 1995. Up to 1935 the dispersion of rates constantly increases. After the Second World War, however the coefficient of standard deviation lowers as time passes, and this contraction appears even more evident during the *economic boom* because of the decrease of suicides in the Northern regions (Table 11). It is interesting to note that in the last twenty years the coefficient of dispersion no longer shows the same consistency shown in the first period of industrial development. This finding appears very significant from the perspective of the *law of convergence*

In short, Halbwachs seems 'to be really right'. This affirmation, applied to the Italian case, is evident: in a modern society, and therefore also in Italian modern society, there is a gradual adaptation to 'stress' of modernization due to low social integration levels.

But, who *adapts*? In other words, does the stabilization of suicide rates regards all social categories indiscriminately or can we find differences? A preceding research paper applied the *Bayesian change-point analysis* to suicide rates of young people from 1951 to 1993

Table 10 Relative numbers: 100 = general mean of mean suicide rates for five year periods

	1864–1865	1866–1870	1871–1875	1876–1880	1881–1885	1886–1890	1890–1895
P.-Lom.-Lig.	137	146	145	138	157	174	149
U.-M.	96	111	116	119	102	87	102
A.M.-B.-P.-C.	69	46	40	43	42	38	51
	1896–1900	1901–1905	1906–1910	1910–1915	1916–1920	1921–1925	1926–1930
P.-Lom.-Lig.	133	146	156	154	147	144	148
U.-M.	94	111	95	97	94	101	95
A.M.-B.-P.-C.	68	45	50	51	58	54	55
	1931–1935	1936–1940	1941–1945	1946–1950	1951–1955	1956–1960	1961–1965
P.-Lom.-Lig.	133	140	135	139	141	136	127
U.-M.	113	103	104	97	100	103	109
A.M.-B.-P.-C.	55	60	60	68	61	62	64
	1966–1970	1971–1975	1976–1980	1981–1985	1986–1990	1991–1995	
P.-Lom.-Lig.	120	113	105	110	123	132	
U.-M.	115	125	132	118	112	106	
A.M.-B.-P.-C.	66	63	68	71	65	64	

(Condorelli 1998). In this case, also, the analysis showed that 1961 constituted a crucial date: after 1961, juvenile suicide rates decreased till they reached 1986, then they increased during the last decade, but they never reached the maximum level attained formerly between the two great wars. The same trend was found in the suicides of the elderly, of people in intermediate age (25–45 and 45–65 years), of young and elderly people without gender difference, and of married and single people. Therefore, there is an undeniable general trend: in conclusion, in time, people seem to commit less suicides as industrial development progresses.

7 Conclusions

The main goal of this study was to test the Durkheimian hypothesis which states that suicides increase progressively due to the progress of industrial development and its cultural implications. Durkheim's main characteristic was to have efficaciously painted the *other* face of the medal or the darker side of freedom. Like a new 'Faust', the modern man appears to be ever animated by a thirst for new knowledge and experience or, to express it in a single word, by a unlimited need of freedom. But freedom has a price. Better than any other author before him, and certainly in a more systematic way, Durkheim delineated the terms of a dramatic process. If it is true that the unstoppable progress of individualism frees man from the snares of tradition that force him to sacrifice his own self-fulfilment, then it is also true that freedom has a high price tag. This price is isolation, and paradoxically the loss of identity and sense of life. Life no longer has any sense because it does not have purpose, and likewise it has no purpose because society—the family, the Church and country—becomes more and more extraneous to the individual. The advent of individualism coincides with the revelation of a deceptive 'happiness'. In this context existential anguish ultimately leads to suicide. So,

Table 11 Coefficient of dispersion for the nine selected regions

Years	Suicide mean rates	Standard deviation
1864–1865	2.8	1.09
1866–1870	2.4	1.20
1871–1875	2.8	1.50
1876–1880	3.4	1.70
1881–1885	3.9	2.16
1886–1890	4.3	2.26
1891–1895	5.0	2.40
1896–1900	5.5	2.68
1901–1905	6.2	3.30
1906–1910	7.2	3.70
1911–1915	7.7	4.02
1916–1920	6.6	3.00
1921–1925	7.9	3.60
1926–1930	8.2	3.90
1931–1935	8.4	3.40
1936–1940	6.5	2.70
1941–1945	4.5	1.80
1946–1950	5.7	2.20
1951–1955	6.3	2.67
1956–1960	6.1	2.59
1961–1965	5.2	2.01
1966–1970	5.1	1.70
1971–1975	4.9	1.88
1976–1980	5.0	1.85
1981–1985	6.1	1.97
1986–1990	7.2	2.50
1991–1995	8.1	3.00

suicide is a "pathological phenomenon assuming daily a more and more threatening character" (*Il Suicidio*, 1969, p. 437). That being stated, in light of our results, the theoretical picture is notably complicated.

If Halbwachs, and so it seems, 'is right', then it is clear that at present individualism is so strong that it loses and therefore neutralizes the disruptive effects of lack of identity and sense of life that are, according to Durkheim, the prime cause of suicide. In other words, the modern man learns to live with the disruptive strengths of modernization. In short, *people adapt*.... For instance, divorcees discover the positive side to their newly acquired free conditio. Singles no longer fear being lonely, etc., ... Durkheim had not foreseen that our egoism, like an "bottomless abyss that nothing can fill", would have increased to such a point that it would ensures immunization against social ties weakening.

In conclusion, even if we can show that suicides regress at a certain point in time after industrial development, because of adaptation we can not however 'shout victory'. For in fact, man has become more and more 'selfish', indifferents, and cynical. So paradoxically Durkheim, in a certain extent, finally found the solution to the problem that had obsessed him for ages, the problem of 'prevention.' What is so paradoxical about this issue is that prevention seems to be connected, to a certain extent, to the major causes of suicide!

References

Achcar, J.A., Martinez, E.Z., Ruffino-Netto, A., Paulino, C.D., Soares, P.: A statistical model investigating the prevalence of tuberculosis in New York City using counting processes with two change-points. Epidemiol. Infect. **17**, 1–7 (2008)

Barberi, B.: I consumi nel primo secolo dell'Unità d'Italia (1861–1960). Giuffrè, Milano (1971)

Bayes, T.: An essay towards solving a problem in the doctrine of chances. In: Pearson, E.S., Kendall, M. (eds.) Studies in the History of Statistics and Probability, pp. 131–153. Charles Griffin & Co. Ltd., London (1970)

Breault, K.D.: Suicide in America: a test of Durkheim's theory of religious and family integration. Am. J. Sociol. **92**, 628–656 (1986)

Breault, K.D., Kposowa, A.J.: Social integration and marital status. A multivariate individual-level study of 30,157 suicides. In: Pickering, W.S.F., Walford, G. (eds.) Durkheim's Suicide: A Century of Research and Debate, pp. 156–179. British Centre for Durkheimian Studies, Routledge (2000)

Broemeling, L.D.: Bayesian procedures for detecting a change in a sequence of random variables. Metron **30**, 1–14 (1982)

Carlin, B.P., Gelfand, A.E., Smith, A.F.M.: Hierarchical Bayesian analysis of changepoint problems. Appl. Stat. **41**, 389–405 (1992)

Carlstein, E.: Non-parametric Change-point estimation. Ann. Stat. **16**, 188–197 (1988)

Cazauvieilh, J.B.: Du suicide, de l'aliénation mentale e des crimes contre les personnes, comparés dans leur rapports réciproques. Recherches sue ce premier penchant chez les abitants des champagnes. Baillière, Paris (1840)

Condorelli, R.: Al fondo dell'abisso. Un approccio bayesiano alla fenomenologia del suicidio. Bonanno Editore, Acireale-Roma (1998)

Corbino, E.: Annali dell'economia italiana. Leonardo da Vinci, Città di Castello (1936)

Cutright, P., Stack, S., Fernquist, R.: The age structures and marital status differences of married and not married male suicide rates: 12 developed countries. Arch. Suicide Res. **10**, 365–382 (2006)

Cutright, P., Stack, S., Fernquist, R.: Marital status integration, suicide disapproval, and societal integration as explanations of marital status differences in female age-specific suicide rates. Suicide Life Threat. Behav. **37**, 715–724 (2007)

Danigelis, N., Pope, W.: Durkheim's theory of suicide as applied to the family: an empirical test. Soc. Forces **57**, 1080–1106 (1979)

De Rosa, L.: La rivoluzione industriale in Italia. Laterza, Bari (1980)

Diaz, J.: Bayesian detection of a change of scale parameter in sequences of indipendent gamma random variables. J. Econom. **19**, 23–29 (1982)

Durkheim, É.: Le suicide: étude de sociologie. Alcan, Paris (1897) (transl. Il suicidio e l'educazione morale. UTET, Torino (1969))

Gelfand, A.E., Hills, S.E., Racine-Poon, A., Smith, A.F.M.: Illustration of Bayesian inference in normal data models using Gibbs sampling. J. Am. Stat. Assoc. **85**, 972–985 (1990)

Giddens, A.: The suicide problem in French sociology. Br. J. Sociol. **16**, 3–18 (1965)

Graziani, A.: L'economia Italiana dal 1945 ad oggi. Il Mulino, Bologna (1972)

Halbawachs, M.: Les causes du suicide. Alcan, Paris (1930)

Hinkley, D.: Inference about the change-point in a sequence of random variables. Biometrika **57**, 1–17 (1970)

Hsu, D.A.: Detecting shifts of parameter in gamma sequences with applications to stock price and air traffic flow analysis. J. Am. Stat. Assoc. **74**, 31–40 (1979)

ISTAT: Cause di morte, 1887–1955. Roma (1958)

ISTAT: Popolazione e movimento anagrafico dei comuni. Elaborazioni particolari. Roma (1993)

ISTAT: Annuario Statistico Italiano. Roma (from 1955 to 2005)

Kposowa, A.J., Breault, K.D., Singh, G.: White male suicide in the United States: a multivariate individual-level analysis. Soc. Forces **74**, 315–325 (1995)

Loschi, R., Moura, C.R., Iglesias, P.L.: Bayesian analysis for change points in the volatility of Latin American emerging markets. J. Data Sci. **3**, 101–122 (2005)

Menzefricke, U.: A Bayesian analysis of a change in the precision of a sequence of indipendent normal random variables at an unknow time point. Appl. Stat. **30**, 141–146 (1981)

Merton, R.K.: On Theoretical Sociology. Free Press, New York (1967)

Moen, D.H., Salazar, D., Broemeling, L.D.: Structural changes in multivariate regression models. Communs Stat. A **14**, 1757–1768 (1985)

Mori, G.: L'industrializzazione in Italia (1861–1900). Il Mulino, Bologna (1977)

Morselli, E.: Il suicidio: saggio di statistica morale comparata. Dumolad, Milano (1879)

Pescosolido, B.: The social context of religious integration and suicide. Sociol. Quat. **31**, 337–357 (1990)

Pettitt, A.N.: A non-parametric approach to the change-point problem. Appl. Stat. **28**, 126–135 (1979)
Raftery, A.E., Akman, V.E.: Bayesian analysis of a Poisson process with a change-point. Biometrika **73**, 85–89 (1986)
Romani, M.: Storia economica d'Italia nel secolo XIX (1815–1914). Giuffrè, Milano (1976)
Romeo, R.: Breve storia della grande industria in Italia (1861–1961). Universale Cappelli, Bologna (1972)
Salvati, M.: Economia e politica in Italia dal dopo guerra ad oggi. Garzanti, Milano (1982)
Simpson, M.E., Conklin, G.H.: Socioeconomic development, suicide and religion: a test of Durkheim's theory of religion and suicide. Soc. Forces **64**, 945–964 (1989)
Singpurwalla, N.D., Soyer, R.: Non-homogeneous autoregressive processes for tracking (software) reliability growth and their Bayesian analysis. J. R. Stat. Soc. B **54**, 145–156 (1992)
Smith, A.F.M.: A Bayesian approach to inference about a change-point in a sequence of random variables. Biometrika **62**, 407–416 (1975)
Smith, A.F.M., Cook, D.G.: Straight lines with change-point: a Bayesian analysis of renal transplant data. Appl. Stat. **29**, 180–189 (1980)
Smith, A.F.M., Roberts, G.O.: Bayesian computation via the Gibbs sampler and related Markov chain Monte Carlo methods. J. R. Stat. Soc. B **55**, 3–23 (1993)
Somogyi, S.: Il suicidio in Italia (1864–1962). Collana di studi demografici, Università di Palermo (1967)
Stack, S.: The effect of marital dissolution on suicide. J. Marriage Fam. **43**, 83–92 (1980)
Stack, S.: Divorce and suicide: a time-series analysis, 1933–1970. J. Fam. Issues **2**, 77–90 (1981)
Stack, S.: The effect of the decline in instituzionalized religion on suicide. J. Sci. Study Relig. **22**, 239–252 (1983)
Stack, S.: The effect of domestic/religious individualism on suicide 1954–1978. J. Marriage Fam. **47**, 431–447 (1985)
Stack, S.: The effect of divorce on suicide in Denmark 1951–1980. Sociol. Quat. **31**, 359–370 (1990)
Stack, S.: The effect of modernization on suicide in Finland 1800–1984. Sociol. Perspect. **36**, 137–148 (1993)
Stephens, D.A.: Bayesian retrospective multiple-change-point identification. Appl. Stat. **43**, 159–178 (1994)
Stockard, J., O'Brien, R.M.: Cohort effects on suicide rates: international variations. Am. Sociol. Rev. **67**, 854–872 (2002)
Tay, R.: Fatal crashes involving young male drivers: a continuous time Poisson change-point analysis. Aust. N. Z. J. Public Health **25**, 21–23 (2007)
Tiryakian, E.A.: Sexual anomie, social structure, societal change. Soc. Forces **59**, 1025–1049 (1981)
Trovato, F.: Sex, marital status and suicide in Canada 1951–1981. Soc. Perspect. **34**, 427–445 (1991)
Trovato, F., Voss, R.: Domestic/religious individualism and youth suicide in Canada. Fam. Perspect. **24**, 69–82 (1990)
Tsurumi, H: A Bayesian estimation of structural shifts by gradual switching regressions with an application to the U.S. gasoline market. In: Zellner, A. (ed.) Bayesian Analysis in Econometrics and Statistics, pp. 213–240. North-Holland, Amsterdam (1980)
Wagner, A.: Die Gesetzmassigkeit in den scheinbar willkuhrlichen menschlichen Handlungen vom Standpuntkte der Statistik. Boyse & Geisler, Amburgo (1864)
Wasserman, I.M.: A longitudinal analysis of the linkage between suicide, unemployment, and marital dissolution. J. Marriage Fam. **46**, 853–859 (1984)
Wasserman, I.M.: A longitudinal analysis of the linkage between divorce and suicide. Fam. Perspect. **24**, 513–530 (1990)
West, M., Harrison, J.: Monitoring and adaptation in Bayesian forecasting models. J. Am. Stat. Assoc. **81**, 741–750 (1986)
Whittaker, J., Frühwirth-Schnatter, S.: A dynamic changepoint model for detecting the onset of growth in bacteriological infections. Appl. Stat. **43**, 625–640 (1994)
Wolfe, D.A., Schechtman, E.: Non-parametric statistical procedures for the change-point problem. J. Stat. Plan. Inference **9**, 389–396 (1984)
Worsley, K.J.: Confidence regions and tests for a change-point in a sequence of exponential family random variables. Biometrika **73**, 91–104 (1986)