Is Forecasting Future Suicide Rates Possible?

Application of the Experience Curve

Yu Sang Chang[1] & Jinsoo Lee[1]

[1] KDI School of Public Policy and Management, Seoul, Korea

Correspondence: Yu Sang Chang, KDI School of Public Policy and Management, 85 Hoegiro Dongdaemun Seoul, 135-898, Korea. Tel: 82-2-3299-1063. E-mail: ysc123@kdischool.ac.kr

Received: March 5, 2012 Accepted: April 6, 2012 Published: May 1, 2012

doi:10.5539/emr.v1n1p77 URL: http://dx.doi.org/10.5539/emr.v1n1p77

Abstract

Many OECD (Organization for Economic Co-operation and Development) countries have implemented national suicide prevention strategies. An accurate forecast of future suicide rate, if available, will be useful for planning and evaluation of a suicide prevention strategy. Therefore, we have developed a simple forecasting model of suicide rate for 15 OECD countries. We use the experience curve model with the data from 1960 to 2005 to forecast suicide rate for each of the 15 countries. In the experience curve analysis, the independent variable is the cumulative population size and the dependent variable is suicide rate for each country. For the 15 countries, the application of the experience curve generates the averaged experience slope of 61.2%, implying a reduction of 38.8% in suicide rate as the cumulative population size is doubled. Using the estimated experienced equation, we forecast both suicide rate and the number of deaths from suicide in years 2010, 2020 and 2030 for each of the 15 countries. The use of the experience curve generates long-term future suicide rate which may be useful input in developing a national prevention strategy.

Keywords: forecast of suicide rate, experience curve analysis

1. Introduction

According to the World Health Organization (WHO), approximately one million people worldwide die from suicide every year, which is equivalent to a global suicide rate of 16 people per 100,000 or to one death for every 40 seconds.

Many OECD countries have implemented national suicide prevention strategies to reduce their suicide rates. Historically, systematic suicide prevention programs were launched as early as 1906 in both New York and London (Bertolote, 2004). After the WHO and UN (1996) published a document on Prevention of Suicide: Guidelines for the Formulation and Implementation of National Strategies in 1996, a number of OECD countries have responded by initiating or consolidating existing prevention activities into their own national strategies. Subsequently, the Suicide Prevention in Europe report (2002) listed 38 European countries with their national suicide prevention strategies.

A number of experts (Bertolote (2004), Hawton (1998)) recommend that such prevention programs must clearly spell out their objectives and targets in a given time frame in order to generate a significant reduction in suicide rate. However, a majority of countries appear not to have set specific quantitative suicide reduction targets in their strategies.[1] Why, then, a majority of strategies are without specific reduction targets? It may be due to "the difficulty of predicting suicide, and the pressure that targets might place on psychiatric services."[2]

The difficulty of forecasting is directly related to the fact that suicide is influenced by an extremely large number of complex and interacting factors ranging from social, economic, health, mental health and cultural to even seasonal and climate factors (Gunnell and Frankel (1994); Hawton (1998); Bertolote (2004); Mann, et al. (2005)). Thus, empirical analysis of historical suicide rates requires multivariate models where a large number of these factors are used as independent variables (Agerbo, et al. (2006); Begley and Quayle (2007); Kung, et al. (2003); Lee, et al. (2006); Lin, et al. (2008); Lorant, et al. (2005); Qin, et al. (2003); Smith, et al. (1988); Virén (1999); Yang (1992); Yang and Lester (2009)). To apply a multivariate model for long-term forecasting, however, all of the independent variables need to be predicted. However, it is not likely that such predictions can be made precisely. Elvik (2010) concludes that "even trend lines that fit past trends very closely are usually worthless for predictive purpose".[3] As for the results from the complex models, Elvik concludes that "although a multivariate model may fit historical data better than a simple trend line, it may not provide a better basis for prediction. To apply a multivariate model for prediction all explanatory variables need to be predicted." "It is very unlikely that a meaningful basis for such prediction could be developed."[4]

Thus, we have searched for a simple forecasting model as alternate to multivariate models. We have selected what is known as experience curve forecasting model which has been used successfully in many areas including industrial, health care and renewable energy sectors. Specifically, we use an experience curve with the data from 1960 to 2005 to forecast suicide rate for 15 OECD countries. In our experience curve analysis, the independent variable is the cumulative population size and the dependent variable is suicide rate per population size of 100,000 for each country. For independent variable, cumulative number of people who tried to commit suicide will be ideal, but such data is not available that we used cumulative population as our independent variable instead. Moreover, projected number of independent variable is necessary to forecast the dependent variable that population was the most suitable independent variable that we could use.

The rest of this paper is made up of the following four parts. In Section 2, we briefly review a literature on the use of experience curve for forecasting and explain the methodologies of experience curve analyses. In Section 3, we use the classical experience curve to analyze the historical data on suicide rate for 25 OECD countries. Then, we examine the historical pattern of suicide rate for 15 selected OECD countries by using two types of experience curve models, classical and kinked.

In section 4, we make forecast of suicide rate as well as the number of suicides for the year of 2010, 2020, and 2030. For our forecasting model, we use the second type of kinked experience curve. In section 5, we summarize the results of our forecast, discuss the limitations of our study and suggest areas of future research.

2. Materials and Methods

Beginning with the study of the man-hours required for manufacturing Boeing aircrafts by Wright (1936), experience curve models have been applied widely in industrial sectors (Day (1977); Day and Montgomery (1983); Dutton and Thomas (1984); Lieberman (1984); Stern and Deimler (2006)). Recently, the experience curve analysis has attracted renewed interest, especially in new technology areas such as health care, alternative energy, and climate control (Brahami (2008); Chambers and Johnston (2000); Ethana and Clara (2002); Grantcharov, et al. (2003); Hopper, et al. (2007); Horowitz and Salzhauer (2006); Nemet (2006); Weiss, et al. (2010); Yeh, et al. (2005)). In a recent review article on the application of experience curve, Weiss et al. (2010b) identifies 124 cases of applications in manufacturing industry and 207 cases of applications in energy industry, totaling 331 application cases reported in the literature.

As for the medical application, there is a large body of literatures to document that improvement of success rate of many medical practices, particularly surgical procedures, may be explained by the principle of past learning and experience (Bach et al., 2001; Begg and Scardino, 2003; Earle et al., 2006; Halm et al., 2002; Hassan et al., 2000; Hellinger, 2008; Kaul et al., 2006; Lipscomb, 2006; Meehan and Georgeson, 1997; Poon et al., 2004; Schrag et al., 2000, 2002; Tekkis et al., 2005; Vickers et al., 2007; Yohannes et al., 2002). In short, the central idea is that practice can make it perfect.

In general, performance measure such as unit cost, fatality rate, or suicide rate becomes dependent variable and cumulative experience such as cumulative volume of production, miles driven, energy used, etc. becomes independent variable. The important concept in experience curve is that the greater is the amount of experience, the better becomes the performance measure. Many hundreds of empirical studies have demonstrated that the relation between the cumulative volume and the performance measure follows a constant percentage change. For example, 100% increase in cumulative experience often generates a constant 20% improvement in performance measure. The experience curve has an 80% slope. If doubling of cumulative volume generates 30% improvement in performance measure, the experience curve has a 70% slope.

This type of percentage relationship can cover a wide range of data. For example, 200% increase in the cumulative experience will generate 36% [1-(0.8x0.8)] performance improvement with the 80% slope and 51% [1-(0.7x0.7)] performance improvement with the 70% slope. Another doubling of cumulative experience or 400% increase will generate 48.8% [1-(0.8x0.8x0.8)] performance improvement and 800% increase in cumulate experience will generate 59.04% [1-(0.8x0.8x0.8x0.8)] performance improvement with the 80% slope.

More generally, the relationship between independent variable and dependent variable is linear when each variable is expressed as a logarithmic function. Therefore, it should be obvious that the use of experience curve model for long-term forecasting can be very effective under some circumstances.

There are two major assumptions underlying the use of experience curve for successful forecasting model. First, strong evidence needs to exist which suggest that the estimated experience slope will remain valid throughout the entire forecasting period. Second, cumulative experience need to be measured by a metric which accurately represents the reality of experience.

Dealing with the issue of valid experience slope first, it has been well known that the experience slope may change over time. Boston Consulting Group (1968) may have been the first to observe a piece-wise linear experience slope as a function of the product life cycle. For example, they observed a flat 90% slope for the initial period of new product introduction to be followed by a steeper 70% slope during the period of maturity. They call the second steep slope as “kinked” slope.

Some energy modeling groups also discovered kinked experience slope (McDonald and Schrattenhilzer (2001); Kouvaritakis, et al. (2000); Nakicenovic, et al. (1999)). More recently, Van Sark (2008) has summarized the empirical kinked price slopes which show steeper slope during the later stages in photovoltaic, ethanol and wind technologies. Weiss et al. (2010) reported the kinked experience curve analysis on the energy consumption rate of five major home appliances in two successive time periods before and after the introduction of an energy policy in the Netherlands. The results show significantly higher experience slopes for the later time period. For example, the experience slope of 83% for refrigerators during the first time period (from 1964 to 1994) had increased to 51% during the second period (from 1995 to 2008).

Therefore, we are alerted to look for historical patterns of data during the more recent time period which may follow a steeper kinked slope. If such patterns were to exist, the resulting kinked slope represents more recent historical trend and thus more likely to remain valid throughout the future forecasting time period.

As for the second assumption relating to the selection of an appropriate metric to represent the cumulative experience, it becomes a major challenge, since we are dealing with such a complex social issue as suicide in this paper. It has already been stated that suicide is influenced by a large number of factors varying from social, economic, health, mental health, culture, etc.

One possible candidate for such metric may be the cumulative number of attempted suicides. Another candidate may be the number of new mental patients admitted in institutions. First of all, historical data for these types of metrics is not readily available. Even if it were available, such measure may not reflect the true complexity of varying factors influencing suicide.

The complex and interacting factors may be viewed as social or national learning and experience (Minder, 1987, Oppe, 1989). The higher is the level of social and national experience of coping with suicide, the greater will be the reduction of suicide rate.

Another important issue deals with projecting the future level of social or national experience. The metric used to represent national experience needs to be forecasted for the future year such as 2030 in this study.

Searching for the appropriate measure for independent variable, we have settled on the use of population as the most practical measure. One important reason for our selection is the availability of data. Accurate historical population data for each country is available for the period during 1960 to 2005. Also, the projection of population data is available yearly through 2050 from the International Data Base (IDB) of the US Census Bureau.

When we use cumulative population as the independent variable in the experience curve model, the logarithmic function of cumulative population means that growth rate of cumulative population is relevant rather than cumulative population itself.

For this reason, the annual growth rate of cumulative population of a given country may be viewed as a broad indication of increasing rate of social and national learning to cope with major social issues like suicide.

Now we specify two types of experience curves, classical and kinked experience curves, to be used in this study. In both experience curves, the independent variable is the cumulative population size and the dependent variable is suicide rate for a country. Although the case of more than one kinked curve is theoretically possible, we are not aware of any reported empirical cases of multiple kinked curves. Thus, unless the history of suicide rates to be studied displays a multiple kinked pattern, we will limit our analysis to a single kinked curve analysis.

For the classical experience curve:

$$Y(xt) = Y(x1)xt\text{-}b \quad (1)$$

where t = 1, 2, 3, …., T

xt = cumulative population size through year t

b = experience slope

Y(xt) = suicide rate per 100,000 at cumulative population through year t

Y(x1) = suicide rate per 100,000 at cumulative population through year 1

For kinked experience curve:

$$Y(xt) = Y(x1)xt\text{-}b1 \quad (2)$$

for the year of 1960 through one year before the kinked year

where t = 1, 2, 3, …., k-1

b1 = experience slope for equation (2)

$$Y(xt) = Y(xk)xt\text{-}b2 \quad (3)$$

for the time period from the kinked year through 2005

where T = k, k+1, …., T

Y(xk) = suicide rate per 100,000 at cumulative population through year t

b2 = experience slope for equation (3)

It should be noted that x2, cumulative population size for the second period, is also counted from 1960, the beginning year of our study period.

Selection of the kinked year is made by identifying the year when the break in trends is observed. And then, R^2 from the kinked equation beginning with the selected year is calculated. The selected year is finally determined to be the kinked year if R^2 calculated above exceeds the values of other R2s associated with alternative equations which begin with adjacent years. For example, if the initial year selected is 1990, then R^2 from 1990 will be compared with R^2s from adjacent years of 1988, 1989, 1991, 1992, etc. Finally, the year with maximum R^2 will be determined as the kinked year.

For our analysis, we use historical suicide rate from 1960 to 2005 available from the OECD (2009) and annual population size available from the U.S Census Bureau's International Data Base (IDB) for 25 OECD countries.

3. Results

3.1 Analysis of Suicide Rates for 25 OECD Countries

We have used historical suicide rates published by the OECD (2009) for 25 OECD countries from 1960 to 2005 to analyze general trends of suicide rates. As Table 1 shows that the highest suicide rate was 21.0 per 100,000 persons for Hungary and the lowest rate was 2.9 per 100,000 persons for Greece in 2005. A comparison of suicide rates between 1960 and 2005 for each country exhibits that fourteen countries recorded decrease, nine countries showed increase, and two countries posted virtually no change over this period.

Table 1. Suicide rates for 25 OECD countries, 1960 and 2005

No	Country	2005	1960	Suicide rate change(%)	Suicide rate status
1	Hungary	21.0	25.6	0.82	Decrease
2	Japan	19.4	25.1	0.77	Decrease
3	Belgium	18.4	13.3	1.38	Increase
4	Finland	16.5	21.6	0.77	Decrease
5	France	14.6	15.0	0.98	Stable
6	Switzerland	14.1	18.6	0.76	Decrease
7	Poland	13.8	8.9	1.56	Increase
8	Austria	13.8	21.2	0.65	Decrease
9	New Zealand	11.9	10.7	1.11	Increase
10	Denmark	11.3	19.7	0.57	Decrease
11	Sweden	11.1	15.9	0.70	Decrease
12	Norway	10.9	6.2	1.76	Increase
13	Iceland	10.4	9.5	1.10	Increase
14	Germany	10.3	17.5	0.59	Decrease
15	Australia	10.2	11.3	0.90	Decrease
16	Canada	10.2	8.8	1.16	Increase
17	United States	10.1	11.4	0.89	Decrease
18	Luxembourg	9.5	8.7	1.09	Increase
19	Ireland	9.2	3.0	3.06	Increase
20	Portugal	8.7	9.8	0.89	Decrease
21	Netherlands	7.9	7.3	1.09	Increase
22	Spain	6.3	6.0	1.04	Stable
23	United Kingdom	6.0	9.7	0.62	Decrease
24	Italy	5.5	6.2	0.89	Decrease
25	Greece	2.9	4.1	0.72	Decrease
	Average	11.4	12.6		
※	Increased countries	9			
	Decreased countries	14			
	Stable countries	2			

We present the result of a classical experience curve analysis for the 25 OECD countries using annual suicide rates and cumulative annual population size in Table 2. The experience slope ranges from the highest of 149.48% (Ireland) to the lowest of 89.69% (Germany). The averaged experience slope is 102.74%, which may suggest that there has been no significant reduction in suicide rate over this period.

Table 2. Classical experience curve analysis for 25 OECD countries

No	Country	Experience equation	Slope(%)	R^2
1	Hungary	$y = 25.84x^{0.017}$	101.19	0.01
2	Japan	$y = 42.84x^{-0.06}$	95.93	0.20
3	Belgium	$y = 3.213x^{0.136}$	109.89	0.61
4	Finland	$y = 20.23x^{0.009}$	100.63	0.01
5	France	$y = 7.847x^{0.053}$	103.74	0.19
6	Switzerland	$y = 22.053x^{-0.015}$	98.97	0.01
7	Poland	$y = 2.349x^{0.124}$	108.98	0.86
8	Austria	$y = 42.08x^{-0.06}$	95.93	0.13
9	New Zealand	$y = 3.936x^{0.100}$	107.18	0.46
10	Denmark	$y = 49.58x^{-0.08}$	94.61	0.08
11	Sweden	$y = 67.22x^{-0.12}$	92.02	0.34
12	Norway	$y = 0.776x^{0.233}$	117.53	0.67
13	Iceland	$y = 11.03x^{0.009}$	100.63	0.00
14	Germany	$y = 145.0x^{-0.157}$	89.69	0.39
15	Australia	$y = 27.47x^{-0.06}$	95.93	0.28
16	Canada	$y = 4.225x^{0.080}$	105.70	0.27
17	United States	$y = 18.28x^{-0.03}$	97.94	0.17
18	Luxembourg	$y = 3.849x^{0.143}$	110.42	0.35
19	Ireland	$y = 0.010x^{0.580}$	149.48	0.75
20	Portugal	$y = 52.14x^{-0.153}$	89.94	0.32
21	Netherlands	$y = 3.307x^{0.078}$	105.56	0.29
22	Spain	$y = 1.471x^{0.100}$	107.18	0.22
23	United Kingdom	$y = 49.28x^{-0.13}$	91.38	0.72
24	Italy	$y = 3.097x^{0.048}$	103.38	0.19
25	Greece	$y = 8.380x^{-0.08}$	94.61	0.32
		Average	**102.74**	**0.31**

However, as we observe the patterns of experience curves for individual countries such as Figures 1, 2, and 3, we have discovered that a majority of countries exhibit significantly greater declining pattern of suicide rate in a later period. Therefore, we have decided to run the kinked experience curve analysis by dividing the whole sample period into two sub-periods. For the kinked experience curve analysis, we have selected 15 OECD countries among the original group of 25 OECD countries. Seven countries for which the experience slope is greater than 106% (Belgium, Poland, New Zealand, Norway, Luxembourg, Ireland, and Spain) and three countries showing extremely unstable fluctuating suicide rates (Japan, Portugal, and Iceland) are eliminated in our kinked experience curve analysis.

3.2. Kinked Experience Curve Analysis for 15 OECD Countries

How much change in slope, R^2 and standard error will result from the kinked experience curve analysis? We will use Hungary as an example to answer this question.

As Figure 1 shows, in the kinked experience curve, the kinked year for Hungary is 1988 and the slopes for the first and second periods are estimated to be 113.68% and 42.04%, respectively. Thus, according to the kinked experience curve analysis, there was no reduction in suicide rate for the first period, but the doubling of the cumulative population in Hungary would lead to a reduction of 57.96% in suicide rate for the second period. The result for the second period is a sharp contrast to the result of the classical experience curve analysis. In addition, a kinked experience curve fits far better to the historical data than a classical experience curve. The R^2's (0.90 for the first period and 0.97 for the second period) in the kinked experience curve are much higher than R^2 (0.01) in the classical analysis. Also, the standard errors (0.05 for the first period and 0.03 for the second period) in the kinked experience curve are much smaller than standard error (0.20) in the classical analysis.

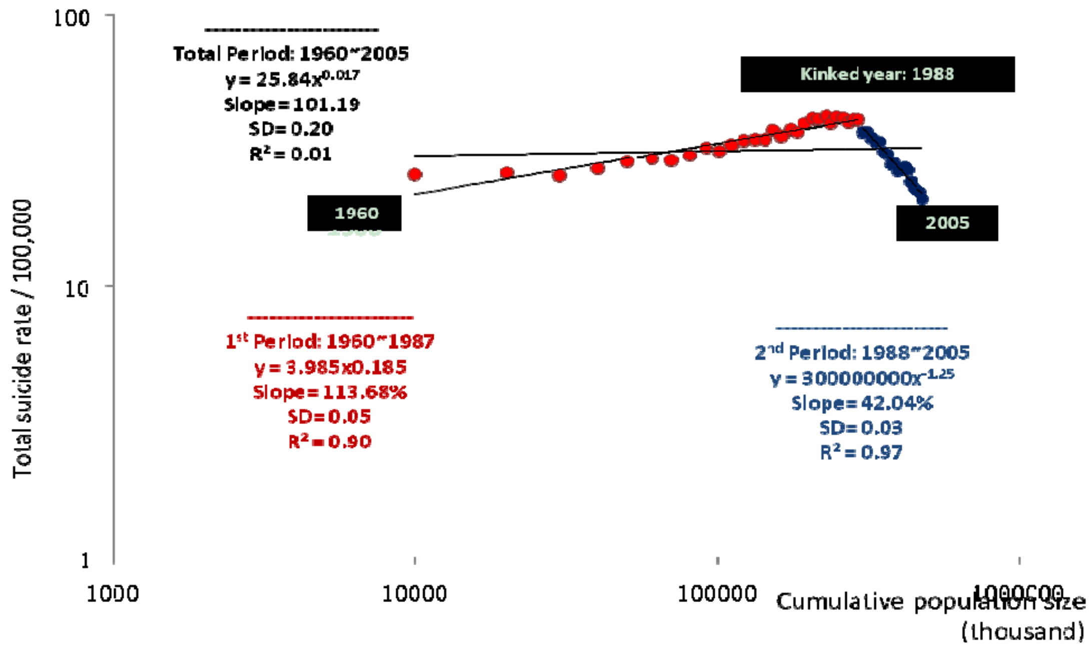

Figure 1. Historic experience curve of suicide rate for hungary

In Figures 2 and 3, we show the patterns of both classical and kinked experience curve analyses for Finland and the United Kingdom. The kinked years for Finland and Great Britain are 1992 and 1982, respectively. Again, in Finland and the United Kingdom, we also observe that although the slope for the first period is similar to the slope from the classical experience curve analysis, the slope for the second period is much lower than the slope from the classical experience curve analysis. The R^2 and standard error for the second period are much better than R^2 and standard error from the classical analysis.

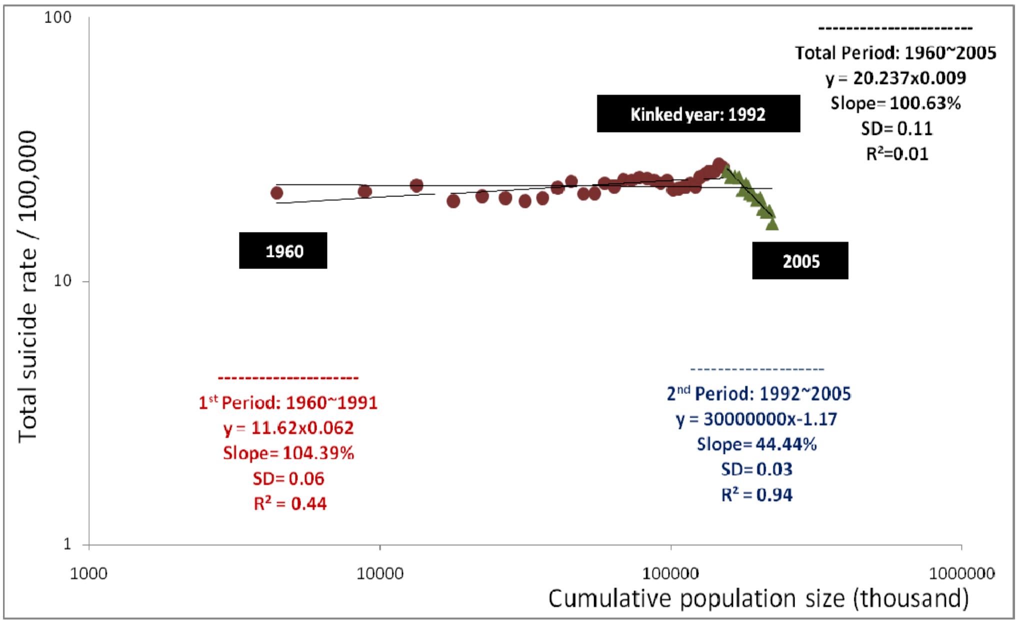

Figure 2. Historic experience curve of suicide rate for Finland

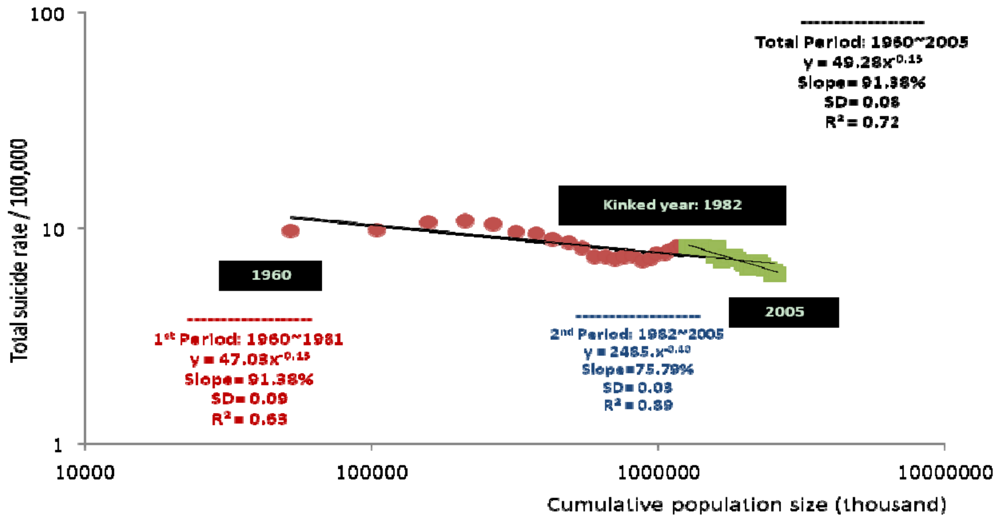

Figure 3. Historic experience curve of suicide rate for the United Kingdom

We show the difference between classical patterns versus kinked patterns for the remaining 12 countries of France, Switzerland, Austria, Denmark, Sweden, Germany, Australia, Canada, United States, Netherland, Italy, and Greece in Figures 4 through 15, which are mentioned in Appendix. It is remarkable that all these remaining 12 countries also show a clear-cut kinked pattern.

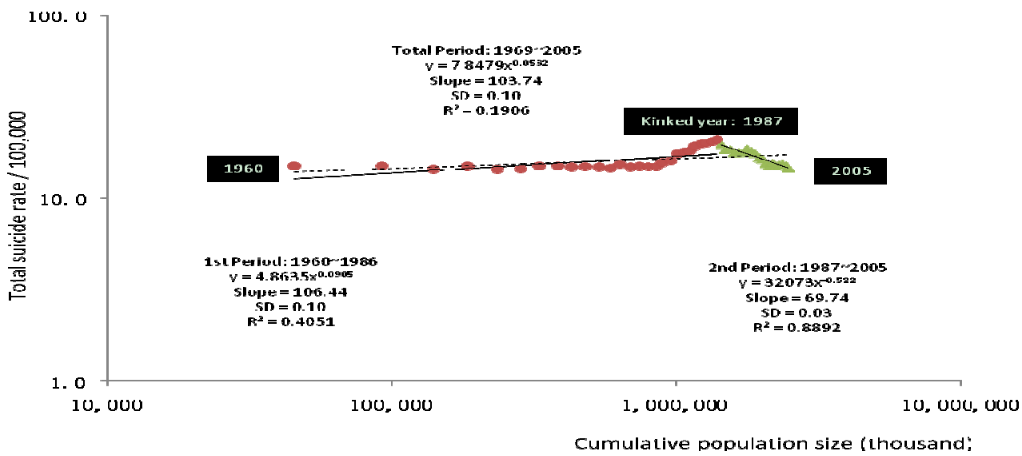

Figure 4. Historic experience curve of suicide rate for France

In Table 3, we summarize the results of both classical and kinked experience curve analyses for 15 OECD countries. As for the kinked years for our sample of 15 countries, the earliest year is 1980 for Switzerland and the latest year is 1998 for Australia. With the exception of two countries (1998 for Australia and 1992 for Finland), all the other 13 countries had their kinked years during the 1980s. As shown in Table 3, for each country, the first slope from the kinked experience curve analysis is similar to the slope from the classical experience curve analysis, but the second slope is significantly steeper than the slope from the classical experience curve. The average slope for the first and the second periods from the kinked experience curve is 103.09% and 61.20% respectively, whereas the average slope from the classical experience curve is 98.09%. Thus, while the classical experience curve analysis implies that there was little reduction in suicide rate, the kinked experience curve analysis suggests that, on average, there was no reduction in suicide rate before a kink, but the doubling of the cumulative population for our sample countries would generate a reduction of 39.80% in suicide rate for the second period. The Newey-West t-statistic shows that the difference in slope between the first and second periods in the kinked model is statistically significant for each of the 15 countries.

Table 3. Classical and Kinked Experience Curve Analyses for Selected 15 OECD Countries (1960-2005)

No	Country	Kinked year	Time Period	Experience equation	Experience Curve			Newey-West T statistic		
					Slope (%)	SD	R^2	$\beta_2 - \beta_1$	T-value	P-value
1	Hungary		1960 ~ 2005 (Total period)	$y = 25.84x^{0.017}$	101.19	0.20	0.01			
		1988	1960 ~ 1987 (1st period)	$y = 3.985x^{0.185}$	113.68	0.05	0.90	-1.43	-23.59	<0.001
			1988 ~ 2005 (2nd period)	$y = 300000000x^{-1.25}$	42.04	0.03	0.97			
2	Finland		1960 ~ 2005 (Total period)	$y = 20.23x^{0.009}$	100.63	0.11	0.01			
		1992	1960 ~ 1991 (1st period)	$y = 11.62x^{0.062}$	104.39	0.06	0.44	-1.12	-17.42	<0.001
			1992 ~ 2005 (2nd period)	$y = 30000000x^{-1.17}$	44.44	0.03	0.94			
3	France		1960 ~ 2005 (Total period)	$y = 7.847x^{0.053}$	103.74	0.10	0.19			
		1987	1960 ~ 1986 (1st period)	$y = 4.863x^{0.090}$	106.44	0.10	0.41	-0.60	-11.41	<0.001
			1987 ~ 2005 (2nd period)	$y = 32073x^{-0.52}$	69.74	0.03	0.89			
4	Switzerland		1960 ~ 2005 (Total period)	$y = 22.053x^{-0.015}$	98.97	0.14	0.01			
		1980	1960 ~ 1979 (1st period)	$y = 9.054x^{0.068}$	104.83	0.09	0.31	-0.68	-13.61	<0.001
			1980 ~ 2005 (2nd period)	$y = 31705x^{-0.60}$	65.98	0.04	0.94			
5	Austria		1960 ~ 2005 (Total period)	$y = 42.08x^{-0.06}$	95.93	0.15	0.13			
		1983	1960 ~ 1982 (1st period)	$y = 12.49x^{0.05}$	103.53	0.05	0.47	-0.91	-20.47	<0.001
			1983 ~ 2005 (2nd period)	$y = 92009x^{-0.86}$	55.10	0.04	0.96			
6	Denmark		1960 ~ 2005 (Total period)	$y = 49.58x^{-0.08}$	94.61	0.27	0.08			
		1981	1960 ~ 1980 (1st period)	$y = 5.958x^{0.117}$	108.45	0.11	0.48	-1.54	-14.31	<0.001
			1981 ~ 2005 (2nd period)	$y = 400000000x^{-1.41}$	37.63	0.08	0.95			
7	Sweden		1960 ~ 2005 (Total period)	$y = 67.22x^{-0.12}$	92.02	0.16	0.34			
		1982	1960 ~ 1981 (1st period)	$y = 11.64x^{0.038}$	102.67	0.07	0.19	-0.79	-12.89	<0.001
			1982 ~ 2005 (2nd period)	$y = 17346x^{-0.75}$	59.46	0.04	0.94			

8	Germany		1960 ~ 2005 (Total period)	$y = 145.0x^{-0.157}$	89.69	0.18	0.39			
		1981	1960 ~ 1980 (1st period)	$y = 9.869x^{0.049}$	103.45	0.03	0.62	-0.91	-34.49	<0.001
			1981 ~ 2005 (2nd period)	$y = 4000000x^{-0.85}$	55.48	0.03	0.98			
9	Australia		1960 ~ 2005 Total period	$y = 27.47x^{-0.06}$	95.93	0.10	0.28			
		1998	1960 1997 1st period	$y = 24.80x^{-0.05}$	96.59	0.10	0.21	-1.28	-13.66	<0.001
			1998 2005 2nd period	$y = 600000000x^{-1.33}$	39.78	0.03	0.94			
10	Canada		1960 ~ 2005 (Total period)	$y = 4.225x^{0.080}$	105.70	0.13	0.27			
		1986	1960 ~ 1985 (1st period)	$y = 1.167x^{0.188}$	113.92	0.08	0.84	-0.59	-13.44	<0.001
			1986 ~ 2005 (2nd period)	$y = 3227.8x^{-0.41}$	75.26	0.04	0.85			
11	USA		1960 ~ 2005 (Total period)	$y = 18.28x^{-0.03}$	97.94	0.07	0.17			
		1986	1960 ~ 1985 (1st period)	$y = 9.074x^{0.019}$	101.33	0.03	0.21	-0.39	-10.54	<0.001
			1986 ~ 2005 (2nd period)	$y = 3162.5x^{-0.356}$	78.13	0.03	0.89			
12	Netherland		1960 ~ 2005 (Total period)	$y = 3.307x^{0.078}$	105.56	0.12	0.29			
		1985	1960 ~ 1984 (1st period)	$y = 1.400x^{0.154}$	111.27	0.10	0.65	-0.56	-9.87	<0.001
			1985 ~ 2005 (2nd period)	$y = 1829.x^{-0.40}$	75.79	0.03	0.88			
13	UK		1960 ~ 2005 (Total period)	$y = 49.28x^{-0.13}$	91.38	0.08	0.72			
		1982	1960 ~ 1981 (1st period)	$y = 47.03x^{-0.13}$	91.38	0.09	0.63	-0.27	-7.12	<0.001
			1982 ~ 2005 (2nd period)	$y = 2485.x^{-0.40}$	75.79	0.03	0.89			
14	Italy		1960 ~ 2005 (Total period)	$y = 3.097x^{0.048}$	103.38	0.09	0.19			
		1985	1960 ~ 1984 (1st period)	$y = 3.156x^{0.046}$	103.24	0.09	0.18	-0.50	-6.40	<0.001
			1985 ~ 2005 (2nd period)	$y = 3883.x^{-0.44}$	73.71	0.05	0.76			
15	Greece		1960 ~ 2005 (Total period)	$y = 8.3808x^{-0.08}$	94.61	0.11	0.32			
		1985	1960 ~ 1984 (1st period)	$y = 10.79x^{-0.10}$	93.30	0.11	0.43	-0.43	-5.82	<0.001
			1985 ~ 2005 (2nd period)	$y = 2422.x^{-0.52}$	69.74	0.06	0.72			
	► **Average of Total Period**				98.09	0.13	0.23			
	► **Average of 1st Period**				103.90	0.08	0.46			
	► **Average of 2nd Period**				61.20	0.04	0.90			

Also, a kinked experience curve fits much better to the historical data than a classical experience curve for our sample of 15 OECD countries. The R^2's (0.46 for the first period and 0.90 for the second period) from kinked experience curve analysis are much higher than R^2 (0.23) from the classical analysis. The standard errors (0.08 for the first period and 0.04 for the second period) from kinked experience curve analysis are much smaller than standard error (0.13) from the classical analysis.

Overall, the kinked experience curve analysis provides much more accurate forecast of suicide rate in sample than the classical experience curve analysis. More importantly, while the slope from the classical experience curve analysis implies little reduction in suicide rate, the second slope from the kinked experience curve analysis suggests a declining pattern of suicide rate for the second period after a kink. Thus, we will use the estimation result from the kinked experience curve analysis in order to forecast future suicide rate for each of our sample countries.

4. Forecast of Suicide Rate and Number of Suicides

Next, we proceed to use the kinked slope for each country to forecast suicide rate as well as the number of suicides for years 2010, 2020 and 2030. The procedure of forecasting future suicide rates for years 2010, 2020 and 2030 is relatively easy to follow. First, we determine the cumulative population size through years 2010, 2020 and 2030. Then, we forecast suicide rate for these future years by using the kinked experience curve equation estimated earlier. The forecasted suicide rate is then multiplied by the projected annual population size for the years 2010, 2020 and 2030 in order to obtain the forecasted number of suicides for the same years. For the projected population size, we use the International Data Base (IDB) provided by the US Census Bureau. The IDB provides estimates of populations up to 2050 for more than 200 countries.

Again we use Hungary as an example to forecast future suicide rate and number of suicides in 2020 and 2030. We add the annual population from 1960 and obtain the cumulative population of 625,023,000 for 2020. Then, we add 10 more years of annual population sizes to the cumulative population size for 2020 in order to compute the cumulative population size of 720,945,000 for 2030.

The forecasts of suicide rates for 2020 and 2030 are estimated by applying these cumulative population sizes to Hungary's estimated kinked experience equation as follows:

$$\text{Suicide rate in 2020} = 300{,}000{,}000\ X\ (625{,}023)\text{-}1.25 = 17.1$$

$$\text{Suicide rate in 2030} = 300{,}000{,}000\ X\ (720{,}945)\text{-}1.25 = 14.3$$

As for the forecast of suicide numbers, we multiply suicide rates for 2020 and 2030 by respective annual population for these years as follows:

$$\#\ of\ suicides\ in\ 2020 = 17.1\ X\ \frac{9{,}772{,}000}{100{,}000} = 1{,}671$$

$$\#\ of\ suicides\ in\ 2030 = 14.3\ X\ \frac{9{,}426{,}000}{100{,}000} = 1{,}348$$

9,772,000 and 9,426,000 are the annual population size forecasted for 2020 and 2030 respectively by the IDB.

In summary, for Hungary, the forecasted suicide rate and number of suicides in 2020 are 17.1 per 100,000 persons and 1,671 suicides. And the forecasted suicide rate and number of suicides in 2030 are 14.3 per 100,000 persons and 1,348 suicides.

We repeat the same steps in order to obtain forecasts of suicide rates and numbers of suicides for the remaining 14 countries. The results are summarized in Table 4. For example, suicide rate for Hungary, which had the highest suicide rate in 2005, is projected to decline from 21.0 in 2005 to 14.3 in 2030. Similarly, suicide rate for Australia, which had the suicide rate of 10.2 in 2005, is projected to decrease to 4.5 in 2030. Suicide rate for the U.S. is also estimated to decrease from 10.1 in 2005 to 8.1 in 2030. On average, suicide rate for our sample of 15 OECD countries is forecasted to decrease from 11.4 in 2005 to 7.72 in 2030

Table 4. Forecasts of Suicide Rates and Number of Suicides for 15 OECD Countries: Years 2010, 2020 and 2030

Country	1. Hungary			2. Finland			3. France			4. Switzerland			5. Austria		
Year	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide
2005	21.0	10,058	2,112	16.5	5,223	862	14.6	60,656	8,856	14.1	7,489	1,056	13.8	8,185	1,130
2010	21.2	9,992	2,118	14.5	5,255	762	13.8	64,768	8,925	13.5	7,623	1,029	13.1	8,214	1,076
2020	17.1	9,772	1,671	11.6	5,272	612	12.4	67,518	8,332	12.0	7,751	930	11.1	8,220	912
2030	14.3	9,426	1,348	9.6	5,201	499	11.2	69,249	7,756	10.8	7,756	838	9.7	8,120	788

Country	6. Denmark			7. Sweden			8. Germany			9. Australia			10. Canada		
Year	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide
2005	11.3	5,432	614	11.1	9,002	999	10.3	82,431	8,490	10.2	20,090	2,049	10.2	32,805	3,346
2010	9.2	5,516	507	9.8	9,074	889	8.9	82,283	7,323	8.3	21,516	1,786	9.9	33,760	3,342
2020	7.0	5,642	396	8.5	9,245	786	7.6	81,422	6,188	6.0	23,939	1,436	9.0	36,387	3,275
2030	5.6	5,730	321	7.5	9,324	699	6.6	79,573	5,252	4.5	26,056	1,173	8.3	38,565	3,201

Country	11. USA			12. Netherlands			13. UK			14. Italy			15. Greece		
Year	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide	Suicide Rate	Popul-ation	Number of Suicide
2005	10.1	295,734	29,869	7.9	16,407	1296	6.0	60,441	3,626	5.5	58,103	3,196	2.9	10,668	309
2010	9.4	310,233	29,192	8.2	16,783	1,376	6.4	62,348	3,990	5.6	58,091	3,262	2.5	10,750	269
2020	8.7	341,387	29,701	7.6	17,332	1,317	6.0	65,761	3,946	5.2	57,028	2,953	2.3	10,742	247
2030	8.1	373,504	30,254	7.1	17,673	1,255	5.6	68,451	3,833	4.8	55,360	2,681	2.1	10,583	222

* Suicide Rate in 100,000

** Projected Population in 1000 (sourse: US Cebsus Bureau, International Data Base)

As for the number of suicides, Hungary is expected to exhibit a very large reduction in the number of suicides from 2,112 in 2005 to 1,348 in 2030. Australia also shows a large reduction in the number of suicides from 2,049 in 2005 to 1,173 in 2030. However, the U.S. is forecasted to exhibit a slight increase in the number of suicides from 29,869 in 2005 to 30,254 in 2030. This is due to a projected increase in the U.S. population from 295.7 million in 2005 to 373.5 million in 2030. The forecasts of the number of suicides for the other sample countries are also reported in Table 4.

5. Conclusion

We have presented a model of forecasting long-term suicide rate by the kinked experience curve. In our model, future suicide rate is determined by the projected cumulative population size. As far as we are aware, this is the first application of the experience curve to forecasting suicide rate. As a matter of fact, our study is one of the very few attempts to systematically forecast suicide rate over a long-term period. One exception is the often quoted WHO's forecast of 1.53 million suicides that may account for 2.4% of all global deaths by 2020 (WHO, 1999). The reason why there are so few studies on forecasting suicide rate is that suicide rate is influenced by a large number of complex factors. These factors can be hardly predicted specially for the long-term future. Instead, we propose a simple forecasting model as alternate to multivariate models using on experience curve which is successfully used as a forecasting model in many other areas

The results of our analysis for the 15 OECD countries are remarkable in that every country shows kinked patterns without exception. In the kinked experience curve analysis, we have divided the whole sample period into two sub-periods for a country. Then, our sample countries show little reduction in suicide rate before a kink, but exhibit declining pattern of suicide rate in the later period.

In the use of experience curve as a forecasting tool, it is important to be able to answer the two important questions. First, will the experience slope remain valid throughout the forecasting period? Second, what is the appropriate measure for the independent variable of cumulative experience? The inability to answer these two questions adequately can become the limiting factors in long-term forecasting by the experience curve model. We believe that we have made a significant progress in answering these questions in our analysis. However, further future research on these question is recommended. Finally, we may use the experience model to forecast future suicide rate by sex and age groups as well. We also hope that this study will prompt others to undertake alternative methods of forecasting future suicide rates and other types of accidents and events which constitute major social issues.

Acknowledgements

We are grateful to the KDI School of Public Policy and Management for providing financial support.

References

Agerbo, E. et al. (2006). Psychiatric illness, socioeconomic status, and marital status in people committing suicide: a matched case-sibling-control study. *Journal of Epidemiology Community Health*, *60,* 776-781. http://dx.doi.org/10.1136/jech.2005.042903

Anderson, M., & Jenkins, R. et al.(2005). The Challenge of Suicide Prevention: An Overview of National Strategies. *Disease Management & Health Outcomes, 13*(4), 245-253.

Bertolote, J. M. (2004). Suicide prevention: at what level does it work? *World Psychiatry*, *3*(3), 147-151.

Begley, M., & Quayle, E. (2007). The Lived experience of adults bereaved by suicide: a phenomenological study. *Crisis*, 28 (1), 26-34.

Boston Consulting Group. (1968). Perspectives on experience, Boston Consulting Group.

Brahmi, S. (2008). Technological learning in energy–environment–economy modelling: A survey. *Energy Policy*, *36*(1), 138–162. http://dx.doi.org/10.1016/j.enpol.2007.09.001

Chambers, S., & Johnston, R. (2000). Experience curves in services: macro and micro level approaches. *International Journal of Operations & Production Management*, *20*(7), 842-859. http://dx.doi.org/10.1108/01443570010330757

Day, G. S. (1977). Diagnosing the product portfolio. *The Journal of Marketing*, *41*(2), 29-38.

Day, G. S., & Montgomery, D. B. (1983). Diagnosing the Experience Curve. *The Journal of Marketing*, *47*(2), 44-58.

Dutton, J. M., & Thomas, A. (1984). Treating progress functions as a managerial opportunity. *Academy of Management Review*, *9*(2), 235-247.

Elvik, R. (2010). The stability of long-term trends in the number of traffic fatalities in a sample of highly motorised Countries. *Accident Analysis and Prevention, 42*(1), 245–260.

Ethan, H., & Clara, L. (2002). Is Volume Related to Outcome in Health Care? A Systematic Review and Methodological Critique of the Literature. *Annals of Internal Medicine*, *137*(6), 511-520.

Grantcharov, T. P. et al. (2003). Learning curves and impact of previous operative experience on performance on a virtual reality simulator to test laparoscopic surgical skills. *The American Journal of Surgery*, *185*(2), 146–149. http://dx.doi.org/10.1016/S0002-9610(02)01213-8

Gunnel, D., & Frankel, S. (1994). Prevention of suicide: aspirations and evidence. *British Medical Journal*, 308, 1227-1233. http://dx.doi.org/10.1136/bmj.308.6938.1227

Hawton, K. (1998). A national Target for reducing suicide. *British Medical Journal*, *317*,156-157. http://dx.doi.org/10.1136/bmj.318.7177.191a

Horowitz, M., & Salzhauer, E. (2006). The 'Learning Curve' In Hypospadias Surgery. *BJU International*, *97*(3), 593-596.

Hopper, A. N. et al. (2007). Learning curves in surgical practice. *Postgraduate Medical Journal*, 83, 777-779. http://dx.doi.org/10.1136/pgmj.2007.057190

Kouvaritakis, B., & Rossiter, J.A. (2001). Modelling and implicit modelling for predictive control. *International Journal of Control*, *74*(11), 1085-1095. http://dx.doi.org/10.1080/00207170110054129

Kung, H. C. et al. (2003). Risk factors for male and female suicide decedents aged 15-64 in the United States-results from the 1993 National Mortality Followback Survey. *Social psychiatry and psychiatric epidemiology*, *38*(8), 419-426.

Knox , K. L. et al. (2004). If suicide is a Public Health Problem, What are we doing to prevent it? *American Journal of Public Health*, *94*(1), 37-45.

Lee, H. C. et al. (2006). Suicide rates and the association with climate: a population-based study. *Journal of Affective Disorders*, *92*(2-3), 221-226. http://dx.doi.org/10.1016/j.jad.2006.01.026

Lieberman, M. B. (1984). The learning curve and pricing in the chemical processing industries. *The RAND Journal of Economics*, *15*(2), 213-228.

Lin, Herng-Ching et al. (2008). Seasonality and Climatic Associations with Violent and Nonviolent Suicide: A Population-Based Study. *Neuropsychobiology*, *57*(1-2), 32-37. http://dx.doi.org/10.1159/000129664

Lorant, V. et al. (2005). The EU Working Group: A European comparative study of marital status and socio-economic inequalities in suicide. *Soc Sci Med*, *60*(11), 2431-2441. http://dx.doi.org/10.1192/bjp.187.1.49

Mann, J. et al. (2005). Suicide Prevention Strategies: A systematic Review. *The Journal of the American Medical Association*, *294*(16), 2064-2074. http://dx.doi.org/10.1001/jama.294.16.2064

McDonald, A., & Schrattenholzer, L. (2001). Learning rates for energy technologies. *Energy Policy*, *29*(4), 255-261. http://dx.doi.org/10.1016/S0301-4215(00)00122-1

Minter, A. L. (1987). Road casualties-improvement by learning process. *Traffic Engineering & Control*, 28 (2), 74-79.

Nakicenovic, N. et al. (1999). Dynamic of energy technologies and global change. *Energy Policy*, *27*(5), 247-280. http://dx.doi.org/10.1016/S0301-4215(98)00067-6

Nemet, G. F. (2006). Beyond the learning curve: factors influencing cost reductions in photovoltaics. *Energy Policy*, *34*(17), 3218-3232. http://dx.doi.org/10.1016/j.enpol.2005.06.020

OECD. (2009). Society at a Glance 2009 - OECD Social Indicators. Retrieved from http://www.oecd.org/els/social/indicators/SAG

Oppe, S. (1989), Macroscopic Models for Traffic and Traffic Safety, *Accident and Analysis and Prevention*, *21*(3). 225-232. http://dx.doi.org/10.1016/0001-4575(89)90013-4

Qin, P. et al. (2003). Suicide risk in relation to socioeconomic, demographic, psychiatric, and familial factors: a national register-based study of all suicides in Denmark, 1981-1997. *American Journal of Psychiatry*, *160*, 765-772. http://dx.doi.org/10.1176/appi.ajp.160.4.765

Smith, J. C. et al. (1988). Marital status and the risk of suicide. *American Journal of Public Health*, *78*(1), 78-80.

Stern, C. W., & Deimler, M. S. (2006). *The Boston Consulting Group on Strategy.* Wiley and Sons Inc., New Jersey.

UK Department of Health. (1992). *The Health of the Nation - a strategy for health in England.* London, HMSO.

UK Secretary of State for Health. (1998). Our Healthier Nation: a contact for health. London, Stationery Office.

United Nations/World Health Organization. (1996). Prevention of suicide guidelines for the formulation and implementation of national strategies(ST/ESA/245). Geneva.

Upanne, M. et al. (1999). Can Suicide Be Prevented? The Suicide Project in Finland 1992-1996: Goals, Implementation and Evaluation. STAKES National Research and Development Centre for Welfare and Health, Helsinki, Finland.

US Census Bureau, International Data Base (IDB). Retrieved from: http://www.census.gov/ipc/www/idb/count ry.php

Van Sark, W. (2008). Introducing errors in progress ratios determined from experience curves. *Technological Forecasting and Social Change*, *75* (3), 405-415. http://dx.doi.org/10.1016/j.techfore.2007.03.006

Viren, M. (1999). Testing the 'natural rate of suicide' hypothesis. *International Journal of Social Economics*, *26*(12), 1428-1440. http://dx.doi.org/10.1108/03068299910370535

Weiss, M. et al. (2010). A review of experience curve analyses for energy demand technologies. *Technology Forecasting & Social Change*, *77*, 411-428. http://dx.doi.org/10.1016/j.techfore.2009.10.009

WHO & UN. (1996). Prevention of suicide guidelines for the formulation and implementation of national strategies (ST/ESA/245). Geneva.

WHO. (1999). Figures and facts about suicide. Geneva.

WHO. (2002). Suicide Prevention in Europe: The WHO European monitoring survey on national suicide prevention programmes and strategies. Copenhagen.

Wright, T. P. (1936). Factors Affecting the Cost of Airplanes. *Journal of Aeronautical Sciences*, *3*(4), 122–128.

Yang, B. (1992). The Economy and Suicide: A Time-Series Study of the U.S.A. *American Journal of Economics and Sociology*, *51* (1), 87-99.

Yang, B., & Lester, M. (2009). Is there a natural suicide rate? *Applied Economics Letters*, *16(*2), 137-140. http://dx.doi.org/10.1080/13504850601018189

Yeh, S. et al. (2005). Technology Innovations and Experience Curve for Nitrogen Oxides Control Technologies. *Journal of the Air & Waste Management Association*, *55*(12), 1827-1838.

Notes

Note 1. There is a few exceptions. The U.K. targeted a reduction of 15% in suicide rate in 1992 (UK Department of Health (1992)) and set a further reduction of 17% by 2010 from a base line in 1996 (UK Secretary of State for Health (1998)). According to Hawton (1998), "The overall suicide rate has declined since the original target was set." In case of Finland, the Finish Suicide Prevention Project (1986-1996) had its aim to reduce suicide rate by 20% by 1995. The evaluation study (Upanne, Hakanen and Rautave (1999)) showed a reduction of 8.7% between 1987 and 1996 in Finland.

Note 2. Hawton (1998). 156

Note 3. Elvik (2010). 245

Note 4. Elvik (2010). 251