IJCEAS

International Journal of Contemporary Economics and Administrative Sciences
ISSN:1925 – 4423
Volume :1, Issue:3, Year:2011, pp.208-221

Forecasting the Number of Occupational Accidents in Bulgaria through Exponential Smoothing

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Received: May - 2011, Accepted: August - 2011

Abstract

The statistical recording of occupational accidents in Bulgaria has a history of almost a century. The first annual statistical data were recorded in 1922 and the process of recording continued with almost no interruptions. All these allow quite a long time series to be built which has its own 'memory' and is considered to have reflected all possible external and internal influences. Such a time series also allows searching for and applying of a univariate method for forecasting of the occupational accidents in Bulgaria.

The present paper regards several major problems in the application of exponential smoothing methods for the purpose of the long-run forecasting of occupational accidents in Bulgaria, such as: (i) the problem of determining the time series pattern; or the so-called "forecast profile"; (ii) the selection of a suitable forecasting method; (iii) Calculating of short-run and long-run forecasts; and (iv) the comparison of the results of the forecast techniques on the basis of the errors in the forecasts. Some conclusions on the produced forecasts are also being presented together with interpretations on the meaning of the different values of the smoothing constant with reference to the problems of over-reporting, under-reporting of occupational accidents and deindustrialization of economy.

Keywords: *Occupational accidents, forecasting, under-reporting*

JEL Codes: *C22; J11; I15*

1. Introduction

The statistical recording of occupational accidents in Bulgaria has a history of almost a century. The first annual statistical data were recorded in 1922 and the annual statistical surveys were published in joint editions at every four or

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five years up to 1988. The only exception took place within the period 1948 – 1951 when there were no statistical records made due to the turbulent economic situation after the end of the World War II, the transition to a Soviet-style planned economy (the nationalization of the private industrial enterprises) and the aftermaths of the Paris Peace Treaty (stipulating the expropriation of all the German industrial property in Bulgaria in favour of the Soviet Union and the consequent having-it-back arrangements needed to be accepted by the Bulgarian government). Since 1989 till now, the annual statistic data have regularly been recorded in the statistical yearbooks of the Republic of Bulgaria.

The statistical records made within the time period of 1922 to 2010 allow quite a long time series to be built. The length of these time series (84 recorded periods) suggests the idea that the fluctuations of the times series have reflected the influence of all possible external factors and thus the time series have incurred an internal logics and memory. The revealing of the internal logics and memory, i.e. the "decoding" of the internal information signal inherent in the times series and its transferring in the future stands in the essence of the so-called univariate forecasting methods, such as the exponential smoothening methods. A comparatively correct and reliable forecasting of the occupational accidents in Bulgaria would be worth for planning and policing making purposes.

2. Explaining the forecasting methodology

The usage of a method in a foreign trade transaction depends upon the duration of relationship and trust between the buyer and seller. To succeed in today's global marketplace and win sales against international trade presents a spectrum of risk, which causes uncertainty over the timing of payments between the exporter (seller) and importer (foreign buyer). For exporters, any sale is a gift until payment is received. Therefore, exporters want to receive payment as soon as possible, preferably as soon as an order is placed or before the goods are sent to the importer. For importers, any payment is a donation until the goods are received. Therefore, importers want to receive the goods as soon as possible but to delay payment as long as possible, preferably until after the goods are resold to generate enough income to pay the exporter.

The task of applying of the exponential smoothening for forecasting of the short and long-run development of the number of occupational accidents in Bulgaria meets with the solving of several major problems:

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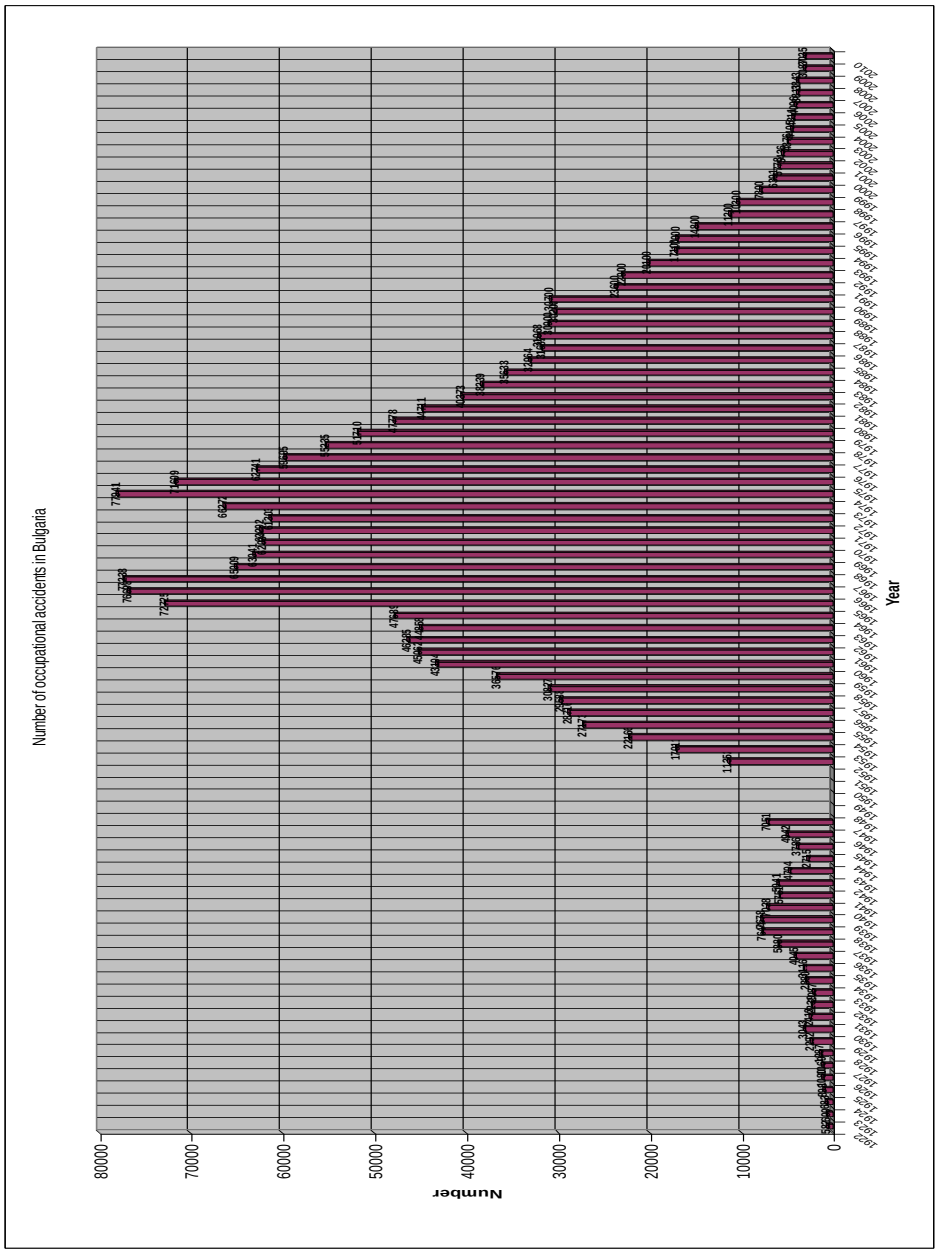
Chart 1. Times series of the number of occupational accidents in Bulgaria within the period 1922 – 2010



Source: Dimitrov, P. (2011), data by the NSI editions

(i)Determining the time series pattern, or the so-called "forecast profile" (Gardner, 1987:174-175) (Hyndman, Koehler, Ord and Snyder, 2008:11-23) and the quality of data in the pattern, on the basis of which to select the suitable forecasting exponential smoothing method;

(ii) Selecting a suitable forecasting method (technique);

(iii) Calculating of short-run and long-run forecasts for number of occupational accidents in Bulgaria (up to the year 2020);

(iv) Comparing the results of the forecast techniques (the forecast models) on the basis of the errors in the forecasts.

The problem of determining the times series pattern, or the so-called times series' "forecast profile" is usually solved by the comparing the times series in regard with a pre-set classification of exponential smoothing methods or the derived form them forecast profiles in terms of development curves. As Hyndman, Koehler, Ord and Snyder point out (Hyndman, Koehler, Ord and Snyder, 2008:11-12), this classification of smoothing methods originated with Pegles' taxonomy (Pegles, 1969:311-315). This was later extended by Gardner (Gardner, 1985:1-28) and modified by Hyndman et al. (2002, 2008) and extended by Taylor (Taylor, 2003:715-725) giving a classification set of fifteen models (Table 1). In the regarded time series, as it will become later clear, the Gardner's much simplified classification can also be successfully used for finding the best fit forecasting method or forecast profile (Chart 2).

A simple visual comparison of the times series of the occupational accidents in Bulgaria for the period 1922-2010 with the Gardner's classification shows out that these particular time series comes into the "constant-level trend, non-seasonal" profile. Of course with the help of more sophisticated statistical analysis, such as the linear trend estimation by the use of the least squares method and etc., it can be also proved that these very same time series comes into the "N,N" variation of a Taylor's patterns of forecasting methods that requires the presence of no trend and seasonal components.

The finding that the time series of the occupational accidents in Bulgaria for the period 1922 – 2010 correspond to the "constant-level, non-seasonal" profile and require the "N,N" variation of exponential forecasting methods makes the problem of selecting and using of a suitable forecasting exponential smoothing method much more predetermined and easier to solve. As both Gardner and

Hyndman et al. point out this profile corresponds to the simple exponential smoothing forecasting method (SES) which has the following mathematical notation:

Table 1: Classification of forecasting methods

Trend component	**Seasonal component**		
	N (None)	**A** (Additive)	**M** (Multiplicative)
N (None)	**N,N**	**N,A**	**N,M**
A (Additive)	**A,N**	**A,A**	**A,M**
$\mathbf{A_d}$ (Additive damped)	$\mathbf{A_d}$**,N**	$\mathbf{A_d}$**,A**	$\mathbf{A_d}$**,M**
M (Multiplicative)	**M,N**	**M,A**	**M,M**
$\mathbf{M_d}$ (Multiplicative damped)	$\mathbf{M_d}$**,N**	$\mathbf{M_d}$**,A**	$\mathbf{M_d}$**,M**

Source: Hyndman et al. (2008), p.12

$$F_{T+1} = AY_T + (1-A)F_T\,, \tag{1}$$

Where:

F_{T+1} is the forecast for time period "T+1";

Y_T is the value of the Y variable in time period "T";

A is the smoothing constant with a value between 0 and 1;

F_T is the mean experience of the time series smooth to time period "T"; or the past forecast value for the time period "T".

Equation (1) imposes the combination of two values in preparing the forecast: the most recent value for the time series, Y_T, and the average experience of the time series smoothed to period $T - F_T$, also known as "old forecast". The forecast is a weighted average of these two values. The smoothing constant, A, is the weight attached to the most recent observation in the time series, i.e. to the most recent value of the forecasted variable. When A is close to 1, the new forecast will be greatly affected by the most recent observation. When A is close to 0, the new forecast will be very close to the old one (Hanke, J E., Reitsch, A., G., 1991).

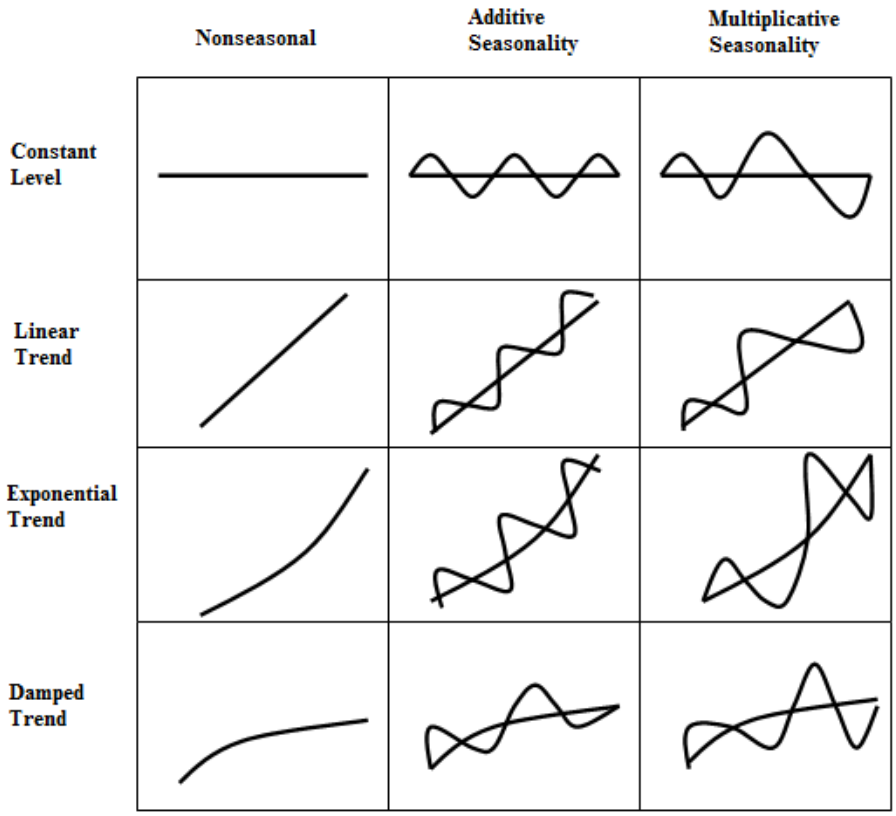
For long range forecast, it is assumed that the forecast function is flat (Hyndman et al., 2008:14), i.e. for all the future periods after the time period

"T+1" the forecast values are equal to the forecast made for the time period *"T+1"*:

$$F_{T+m} = F_{T+1}, \qquad m = 2,3,... \qquad (2)$$

The flat function is applied as the simple exponential smoothing works best for time series that have no particular trend, seasonality, or other underlying characteristics.

Chart 2: Forecast profiles from Exponential Smoothing Models by Gardner (1987)



Source: Gardner (1987), p.175

Before calculating short-run and long-run forecasts by using the selected suitable forecast method, i.e. the simple exponential smoothing (SES) to forecast the number of the occupational accidents in Bulgaria, one can, of course, try some of the other variations of the exponential smoothing methods. However, most of these values either produce negative in value forecasts after the year 2020, or equal to zero, as it is in the case of Brown's linear (double) one parameter smoothing (Chart 3).

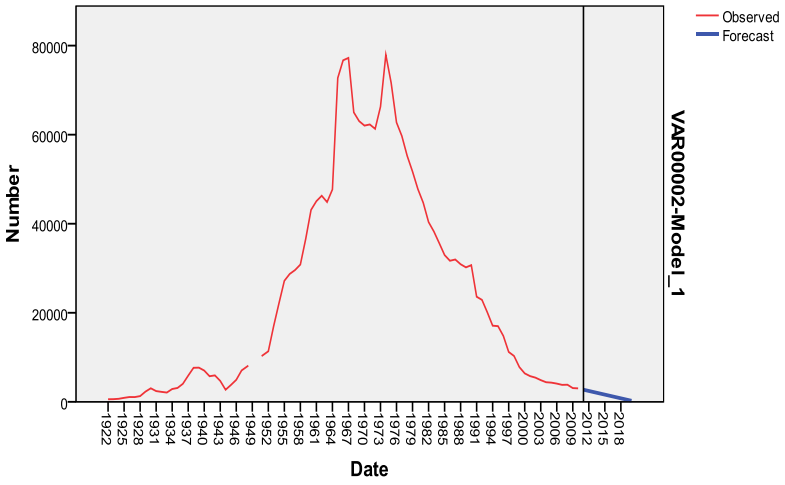
Chart 3 : Forecasting of the occupational accidents in Bulgaria up to 2020 by the use of Brown's one parameter adaptive method for double exponential smoothing and SPSS® software package

Model Description

			Model Type
Model ID	Numbe of occupational accidents	Model_1	Brown

Model Statistics

Model	Number of Predictors	Model Fit statistics		Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	MAPE	Statistics	DF	Sig.	
Numbe of occupational accidents-Model_1	0	,131	12,593	40,944	17	,001	0



Source: Dimitrov, P. (2011). The data for the calculations are provided by the Bulgarian National Statistic Institute.

Such types of predictions, though technically seeming correct, are groundless as they go beyond the limits of the common sense and the simple economic logics, just because the occupational accidents are unlikely to become extinguished.

After these additional proofs that the simple exponential smoothing is the best fit exponential smoothing forecasting model, it can be in fact applied for calculating the short-run and long-run forecasts for number of occupational accidents in Bulgaria up to the year 2020. And here comes the issue of selecting the proper value of the smoothing constant A.

Though in scientific literature there are numerous proposals either for the way of calculating of A (DeLurgio, 1997:156-157) (Gardner, 1985:179-180), or for direct attributing of values to A (Brown, 1959 and 1963) (Gardner, 1985:180) (Hanke, Reitsch, 1991) , the present paper shall regard and test a set of several values of A (0.10; 0.30, 0.70, 0.90, 0.95 and 0.99 respectfully, as well as the A=2/N +1 way for calculating) in order to minimize the forecast error. This will also provide a hint, as it will be seen later, for some plausible interpretations of the achieved forecasts values for the number of the occupational accidents in Bulgaria.

One of the criteria for the suggested minimizing could be the mean absolute percentage of error (MAPE). For the purpose of visualization and comparing of the results from the different forecast methods for past and future periods, as well as the extent of achieved error (in comparison of the forecast values with the actually observed ones for the past periods of time), these results are presented in table and graphic form in Table 2 and Chart 4.

Based on the results in Table 2 and Chart 4, one can outline seven major types of forecasts (two optimistic and three pessimistic ones) for the number of occupational accidents in Bulgaria up to the year 2020, as follows:

- *The most optimistic forecast* (the forecast with the lowest value) – calculated by the use of a smoothing constant A=0.99, the red column in Table 2 and the red doted line in Chart 4:

  Some 3230 occupational accidents in Bulgaria in year 2020;

- *The second most favourable forecast calculated by the use* a smoothing constant A=0.90, the dark green column in Table 2 and the dark green line in Chart 4:

  Some 4122 occupational accidents in Bulgaria in year 2020;

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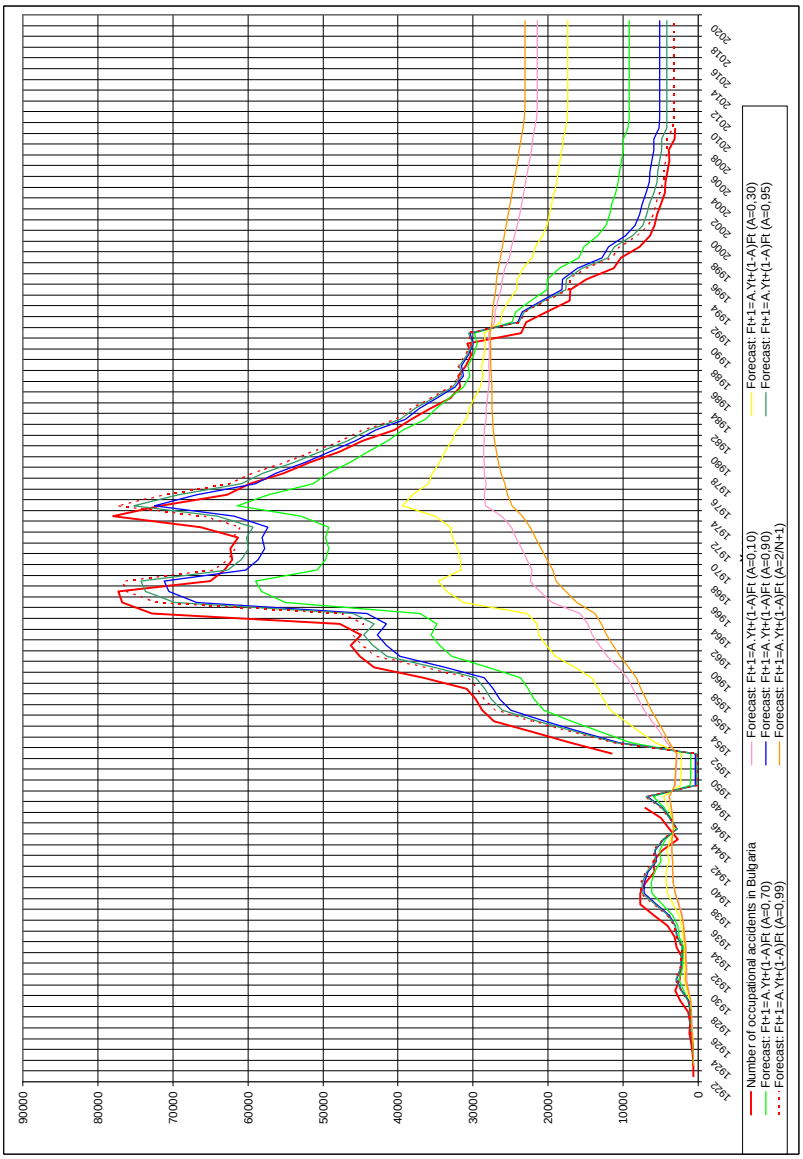
Chart 4. Forecasting of the number of occupational accidents in Bulgaria up to 2020 by the use of simple exponential smoothing with different values of the smoothing constant



Source: Dimitrov, P. (2011). The data for the calculations are provided by the Bulgarian National Statistic Institute.

Table 2. Calculating of short and long-run forecasts for the number of the occupational accidents in Bulgaria by the use of different smoothing constants

Year	Number of periods (N)	Number of occupational accidents in Bulgaria	Forecast: Ft+1=A.Yt+(1-A)Ft (A=0,10)	Forecast: Ft+1=A.Yt+(1-A)Ft (A=0,30)	Forecast: Ft+1=A.Yt+(1-A)Ft (A=0,70)	Forecast: Ft+1=A.Yt+(1-A)Ft (A=0,90)	Forecast: Ft+1=A.Yt+(1-A)Ft (A=0,95)	Forecast: Ft+1=A.Yt+(1-A)Ft (A=0,99)	Forecast: Ft+1=A.Yt+(1-A)Ft (A=2/N+1)
1922	1	582							
1923	2	600	582	582	582	582	582	582	582
1924	3	683	592	594	597	599	600	600	597
1925	4	898	628	640	665	677	680	682	652
1926	5	1080	711	753	836	877	888	896	774
1927	6	1069	800	862	987	1049	1064	1077	872
1928	7	1287	844	894	994	1048	1056	1066	890
1929	8	2292	926	1006	1167	1247	1267	1283	986
1930	9	3043	1184	1431	1923	2169	2230	2280	1335
1931	10	2413	1458	1810	2515	2867	2955	3025	1634
1932	11	2239	1497	1700	2108	2311	2362	2403	1580
1933	12	2087	1548	1702	2009	2162	2201	2231	1599
1934	13	2880	1579	1692	1918	2031	2059	2081	1610
1935	14	3116	1752	2003	2504	2755	2817	2867	1806
1936	15	4045	1872	2148	2701	2976	3047	3102	1918
1937	16	5880	2103	2535	3338	3820	3937	4023	2157
1938	17	7644	2511	3260	4757	5566	5693	5843	2577
1939	18	7678	2979	4016	6089	7126	7385	7592	3037
1940	19	7028	3244	4229	6200	7185	7432	7629	3270
1941	20	5751	3381	4192	5812	6823	6825	6987	3381
1942	21	5941	3378	3906	4960	5487	5619	5725	3366
1943	22	4704	3519	4057	5134	5672	5806	5914	3494
1944	23	2715	3454	3732	4287	4565	4635	4690	3436
1945	24	3786	3232	3117	2887	2772	2744	2721	3241
1946	25	4942	3358	3453	3643	3728	3762	3781	3348
1947	26	7051	3532	3845	4472	4788	4864	4926	3496
1948	27		3870	4577	5991	6698	6874	7016	3778
1949	28		3048	2371	1016	339	169	34	3145
1950	29		2939	2286	980	327	163	33	3040
1951	30		2838	2207	946	315	158	32	2943
1952	31	11352	2743	2133	914	305	152	30	2851
1953	32	17011	4119	5727	8941	10548	10950	11272	3818
1954	33	22166	5070	7724	13031	15583	16348	16878	4548
1955	34	27173	6088	9661	16807	20380	21273	21987	5353
1956	35	28716	7194	11634	20513	24953	26063	26951	6243
1957	36	29588	7959	12572	21797	26410	27563	28485	6934
1958	37	30827	8645	13299	22607	27261	28424	29355	7576
1959	38	36576	9365	14134	23673	28442	29635	30589	8235
1960	39	43104	10641	16404	27931	33694	35135	36288	9237
1961	40	45062	12109	18997	32772	39680	41382	42760	10387
1962	41	46285	13124	20221	34416	41513	43288	44707	11306
1963	42	44858	14052	21215	35541	42704	44494	45927	12176
1964	43	47689	14646	21360	34787	41501	43180	44522	12851
1965	44	72725	15691	22802	37023	44134	45911	47333	13752
1966	45	76698	19434	31277	54961	68804	69764	72133	16145
1967	46	77238	21095	33451	58164	70520	73609	76080	17603
1968	47	65009	22368	34562	58948	71141	74190	76628	18866
1969	48	63041	22079	31619	50699	60239	62624	64532	19296
1970	49	62034	22739	31695	49607	58568	60802	62593	20089
1971	50	62292	23443	32019	49170	57746	59890	61605	20870
1972	51	61303	24245	32700	49610	58066	60178	61869	21675
1973	52	66272	24875	32970	49160	57255	59279	60898	22384
1974	53	77941	26158	35072	52901	61815	64043	65826	23383
1975	54	71609	28280	39316	61387	72423	75182	77389	24806
1976	55	62741	28461	38049	57226	68815	69212	71130	25410
1977	56	59695	28214	35886	51232	59905	60823	62357	25747
1978	57	55235	28477	35414	49289	56228	57961	59348	26225
1979	58	51710	28508	34447	46328	52263	53750	54938	26562
1980	59	47778	28561	33706	43994	49138	50424	51453	26861
1981	60	44711	28501	32784	41352	45636	46707	47564	27073
1982	61	40373	28469	32078	39297	42906	43809	44531	27256
1983	62	38239	28238	30934	36328	39025	39699	40238	27324
1984	63	35633	28189	30422	34889	37122	37681	38127	27427
1985	64	32964	28051	29736	33106	34791	35212	35549	27471
1986	65	31682	27865	28998	31264	32397	32681	32907	27472
1987	66	31968	27797	28661	30387	31250	31466	31639	27496
1988	67	30900	27889	28795	30608	31515	31741	31923	27571
1989	68	30200	27828	28511	29876	30559	30729	30866	27587
1990	69	30700	27794	28329	29398	29933	30066	30173	27604
1991	70	23600	27886	28511	29762	30387	30544	30669	27662
1992	71	22900	27125	26341	24775	23992	23796	23639	27406
1993	72	20100	26996	26086	24265	23355	23128	22946	27325
1994	73	17100	26624	25174	22275	20825	20462	20172	27150
1995	74	17000	26198	24176	20133	18011	17605	17201	26935
1996	75	14800	26064	24049	20021	17907	17504	17101	26802
1997	76	11200	25696	23275	18432	16011	15405	14921	26588
1998	77	10300	25150	22050	15850	12750	11975	11355	26298
1999	78	7800	24869	21631	15156	11919	11109	10462	26072
2000	79	6391	24403	20713	13334	9645	8722	7984	25781
2001	80	5778	24036	20115	12273	8382	7371	6587	25506
2002	81	5436	23747	19754	11768	7775	6776	5978	25251
2003	82	4876	23487	19476	11453	7442	6439	5637	25004
2004	83	4405	23205	19132	10986	6913	5894	5080	24751
2005	84	4311	22932	18815	10581	6466	5434	4611	24500
2006	85	4096	22701	18614	10441	6354	5333	4515	24264
2007	86	3811	22461	18380	10218	6137	5116	4300	24027
2008	87	3843	22216	18126	9946	5856	4833	4015	23791
2009	88	3087	22008	17971	9898	5861	4852	4045	23567
2010	89	3025	21718	17578	9297	5197	4122	3294	23323
2011			21502	17396	9144	5078	4122	3230	23099
2012			21431	17341	9144	5078	4122	3230	23021
2013			21431	17341	9144	5078	4122	3230	23021
2014			21431	17341	9144	5078	4122	3230	23021
2015			21431	17341	9144	5078	4122	3230	23021
2016			21431	17341	9144	5078	4122	3230	23021
2017			21431	17341	9144	5078	4122	3230	23021
2018			21431	17341	9144	5078	4122	3230	23021
2019			21431	17341	9144	5078	4122	3230	23021
2020			21431	17341	9144	5078	4122	3230	23021

Source: Dimitrov, P. (2011). The data for the calculations are provided by the Bulgarian National Statistic Institute.

- *The third, moderately optimistic forecast* (the forecast with the lowest value) – calculated by the use of a smoothing constant A=0.90, the blue column in Table 2 and the blue line in Chart 4:

  Some 5070 occupational accidents in Bulgaria in year 2020;

- *The next moderate forecast* calculated by the use a smoothing constant A=0.70, the light green column in Table 2 and the light green line in Chart 4:

  Some 9160 occupational accidents in Bulgaria in year 2020;

- *The first comparatively pessimistic forecast calculated by the use* a smoothing constant A=0.30, the yellow column in Table 2 and the yellow line in Chart 4:

  Some 17341 occupational accidents in Bulgaria in year 2020;

- *The second comparatively pessimistic forecast calculated by the use* a smoothing constant A=0.10, the rose column in Table 2 and the rose line in Chart 4:

  Some 21431 occupational accidents in Bulgaria in year 2020;

- *The most pessimistic forecast calculated by the use* a smoothing constant achieved by the rule A=2/N+1 (where N is the number of the observed value), the orange column in Table 2 and the orange line in Chart 4:

  Some 23021 occupational accidents in Bulgaria in year 2020.

3. Forecasts' interpretations and conclusions

The above-presented seven forecasts can have different interpretations. The first interpretation, which comes from the most optimistic forecast achieved with A=0.99, is that taking into the account the whole time series from 1922 to 2010, the number of occupational accidents in Bulgaria by 2020 will most probably not have to be less than 3230 accidents. This means that even in a forecast which almost entirely takes into the account the most recent values in the time series (and which takes them as true ones), the number of the occupational accidents in Bulgaria by 2020 will stay quite closely to the last reported figures for the years 2008, 2009 and 2010, but will not diminish any further. One can easily conclude from the slight discrepancy between the forecast for 2020 and the reported values for 2008, 2009 and 2010 (actually in favour of the forecast for 2020) that expectations by the Bulgarian OSH

authorities (the General Labour Inspectorate Executive Agency and the National Social Security Institute) for an even further decline in the number of the occupational accidents in Bulgaria are quite unlikely to happen.

The second interpretation, which comes from the second most optimistic forecast achieved with A=0.90, is that taking into the account the whole time series from 1922 to 2010, the number of occupational accidents in Bulgaria by 2020 will most probably not have to be less than 5070 accidents. This means that even in a forecast which predominantly takes into the account the most recent values in the time series (and which takes them as true ones), the number of the occupational accidents in Bulgaria by 2020 will stay much higher than the last reported figures for the years 2008, 2009 and 2010. One can easily conclude from the discrepancy between the forecast for 2020 and the reported values for 2008, 2009 and 2010 that in the recent years there has been a serious underreporting in the number of the occupational accidents in Bulgaria. And if the recorded values in 2020 are again much lower than 5070 accidents, it will also mean that underreporting continues and is persistent.

Another follow-up interpretation of the achieved five forecasts is that each forecast achieved with a different value of the smoothing constant A may correspond to a different presumable level of underreporting. This interpretation could be accepted to some extent under the assumption that the high levels of the number of occupational accidents reported in the 1960s, 1970s and 1980s have not changed abruptly in the next twenty years. However, this assumption is quite unlikely as the Bulgarian economy did changed in structure in the 1990s and in the first decade of the 21st century. All this opens room for a fourth possible interpretation.

The fourth interpretation of the achieved five forecasts is that each forecast achieved with a different value of the smoothing constant A corresponds not only to a different presumable level of underreporting, but also to a different level of deindustrialization of the Bulgarian economy, a process which goes on for the past twenty years (Iliev, 2008:30-113). This will also mean, for example, that the most optimistic forecasts of 5070 occupational accidents per year from 2011 to 2020, achieved with a value of the smoothing constant of 0.90 correspond to a staggering 90% percent value of deindustrialization of the Bulgarian economy in regards to the levels achieved in the 1980s. This assumption, though perhaps exaggerated, is unfortunately supported by both statistical data and independent economic researches (Vladimirova, Iliev et al.,

2008) especially in some particular industrial sectors of the Bulgarian economy.

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