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How on/off Switching in Deaths Creates Periods of Unexplained Higher Life Insurance Costs.

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How on/off switching in deaths creates periods of unexplained higher life insurance costs

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Abstract

Since 2011 ongoing improvements in life expectancy and the mortality rate have been interrupted leading to the failure of actuarial models and higher than expected life insurance pay-outs. This has occurred to varying degrees across all the developed countries. This study presents evidence that deaths follow a curious pattern of on/off switching which can be demonstrated to occur in the 126 countries where monthly deaths data is available for analysis. This on/off switching can be documented to occur from the 1980's to the present. At switch-on monthly deaths suddenly jump to a new and higher level, remain high for around 12-months, and then suddenly revert to the former baseline where they stay until the next switch-on event arrives. Switch-on can seemingly occur in any month of the year, i.e. factors such as season and temperature can be excluded as causes for the behaviour, with the magnitude of the increase diminishing as the spatial area increases. On average, switch-on occurs around once evert three years. At an international level switch-on appears to cluster in time. Attempts to investigate period and cohort effect using calendar year data will therefore be hindered since a calendar year can contain a mix of on/off behaviour. Artefactual outputs from the method were excluded by analysis of monthly temperature and sunspot numbers.

Key Words

On/off switching; deaths; actuarial models; period and cohort effects; life insurance costs

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1 Introduction

The development and refinement of actuarial models is an ongoing process as new developments are incorporated into the models [1]. However, after 2011 ongoing improvements in life expectancy and the mortality rate were seen to suddenly halt or slow across most of the developed world leading to the catastrophic failure of most actuarial models [2-7]. This has seemingly affected the UK more so than other countries [6,7]. No convincing explanation for this behaviour has been offered. Under such circumstances it is useful to go back and look to see if unusual behaviour was present in the past but may have been overlooked.

In this respect, this author has been researching curious periods of unexplained growth in hospital medical admissions, but not surgical admissions, which are seemingly associated with periods of unexplained higher deaths [reviewed in 8,9].

The relevant point is that these periods are characterized by unique on/off switching behaviour. In switch-on deaths and medical admissions suddenly jump to a new and higher level, stay high for around 12 to 18 months, and then suddenly switch-off and revert to the previous trajectory. Switch-on can seemingly occur at any point in time leading to a mix of high/low behaviour within the artificial boundary of a calendar or financial year. Indeed, this mix of high/low in a calendar year will act to blur the impact of higher deaths on life expectancy and the mortality rate [9].

These periods of unexplained higher deaths and medical admissions have been proposed to account for the health insurance underwriting cycle [8,9] in which insurance premiums periodically fail to cover costs leading to an insurance deficit [10].

On/off switching is most readily detected using a rolling 12-month total of deaths. A rolling total is highly useful in that the effects of seasonality are largely removed; the higher annual totals are retained and switch-on is easily discerned. In a rolling total there will be 12-months of the normal level of deaths, however, at the point of switch-on there will be 11-months of the usual (lower) level of deaths plus 1-month of the now higher level. Move forward another month and there are 10-months of the lower level plus 2-months of the higher level, etc. This creates a rising trend whose slope is equal to the magnitude of the step-like change in deaths. The full magnitude of the step-increase is revealed when there are 12-months of the new higher level of deaths. When deaths switch-off the reverse happens. This creates typical saw-tooth patterns in the rolling 12-month total. A spike-event such as an influenza outbreak does not create saw-tooth features in a rolling 12-month total.

Having established that there is a simple method to scan for on/off switching this study will investigate if on/off switching is a universal phenomenon by analysing data for monthly deaths in 125 countries between 1980 and 2017. Artefactual outputs from the method are excluded by analysing monthly temperature and solar flare numbers.

2 Methods and Data Sources

2.1 Data Sources

Monthly deaths data from 1980 to 2017 was obtained from the United Nations database [11]. Additional data to fill gaps in the UN data was kindly provided by the Registrar General for the Falkland Islands (South Atlantic). A 55-year time series of quarterly deaths (1963 to 2018) was kindly provided by the Statistics Office, Ministry of Finance and Economic Management, Cook Islands (South Pacific). Monthly data for regions, counties and local authorities in England and Wales (2001-2019) was obtained from the Office for National Statistics [12].

Monthly data for temperature in the North and South of New Zealand and sunspot numbers [13,14] were also analysed to exclude the possibility of artefactual outputs from the analysis.

2.2 Methods

All analysis was performed using Microsoft Excel. On some occasions data for single years are missing from a countries time-series, and on these instances monthly data were imputed as the average for the same month in the two years either side of the missing data. For the UK, this missing data was then adjusted to the actual total deaths in that year using calendar year deaths obtained from the Office for national Statistics [15]. In all other instances of missing data, no change was made to the time series. Countries with less than three years data were removed from the study leaving 126 countries for analysis.

The analysis commences at December 1981 which calculates the rolling difference (as a percentage) between the 12-months ending December 1981 versus the 12-months ending December 1980, move forward one-month and repeat the calculation which ends at the 12-months ending December 2017.

When analysing the increase in deaths in 2015 some countries only had enough data, i.e. up to Dec-14, to extrapolate the value of the step-increase. For example, if five months were available for switch-on, then linear regression was applied and extrapolated forward by seven months, etc.

The average number of annual deaths for each country was calculated as the average of all available month’s times 12.

The Poisson statistics 98% Confidence Interval (CI) was calculated as 2 times the square root of the average annual number of deaths divided by the average number of deaths [16]. All data was manipulated using Microsoft Excell.

3 Results

3.1 Summary statistics for each country

A summary of the data for each country (n = 126) is given in Table S1 in the online Supplementary material. As may be expected, data for many African, some South American and some Asian countries is absent. Some 38 years of continuous monthly data was available for 10 countries, ranging down to 3 years for 3 countries. At the time of the UN data extract (April 2019) around half of the countries were missing data for 2017. The median was 26 years and 17% of countries had less than 10 years of data. 55 years of quarterly data was available for the Cook Islands.

3.2 Robustness of the method

To exclude artefactual results arising from the analytical method monthly temperature from the North and South of New Zealand and monthly sunspot numbers were analysed using the method employed in this study. This analysis did not produce any evidence for on/off switching (data not shown).

3.3 On/off switching demonstrated

Figure 1 shows the rolling difference for the ten countries which had continuous data between 1980 and 2017. As can be seen the saw-tooth behaviour dominates the trend in which differences in timing and magnitude are evident. For example, using the data for Macao we see two maxima of 18.3% at April 1988 and 16.7% at January 2009. This implies that a switch-on leading to a step-increase in deaths of 18.3% started in May 1987, while another switch-on with a step-increase of 16.7% commenced in February 2008. Switch-off then commences in May 1988 and February 2009 respectively. See Figure S1 in the online supplementary material for the 55-year time series for Cook Islands.

3.4 Frequency of switch-on

From Figure 1 it is also possible to estimate the frequency of switch-on in each country. For the 10 countries in Figure 1, each with 38 years of data, clearly discernible switch-on occurred with a frequency of between 13 occasions (New Zealand, Israel and Bulgaria) to 19 occasions (Portugal). The median lay between 14 and 15 occasions. Hence, switch-on seemingly occurs at national level around once every three years.

For the 55 years of data for the Cook Islands there were 24 events which gives once every 2.3 years for this location in the South pacific. The frequency of the events appears higher in recent years and this may give a clue to rising mortality since 2011. There were only 6 events in the first 18 years up to 1980, i.e. once every three years. See Figure S1 in the online supplementary material.

3.5 Maximum increase in deaths due to switch-on

From Figure 1 it is evident that the value of the maximum switch-on varies significantly between countries and Figure 2 presents the magnitude of the maximum switch-on for each country versus size as determined by the average number of annual deaths for that country. The 98% Confidence Interval (CI) is given to demonstrate that the maximum step-increase generated by switch-on achieved statistical significance in all countries studied.

It is possible that the maximum step-increase observed for each country has been increased due to Poisson randomness. Hence, the value of each data point minus the 98% CI has been given for each country (step-increase adjusted). As can be seen this adjustment has very little impact on the maximum value for countries with more than 10,000 deaths.

3.6 Timing of switch-on

Figure 1 also identified issues relating to the timing of switch-on and Figure 3 demonstrates that the maximum step-increase generated by switch-on in each country occurs at different times between countries, however, there is a degree of clustering in time. This is especially true for 2015 where 16% of countries experienced maximum switch-on for the 12-month period ending May-2015 to December 2015. This implies that switch-on for 2015 commenced between June 2014 (1 country) to January 2015 (1 country). Some 5% of countries (n = 6) experienced maximum switch-on for the 12-month period ending at August 2015, implying that switch-on commenced in September 2014.

3.7 Switch-on and deaths in 2015

Figure 4 explores the magnitude of switch-on for countries were data was available for 2015. Of the 80 countries where data was available for 2015 some 22 (28%) experienced maximum switch-on, while the remaining 58 countries experienced a switch-on which was lower than the maximum possible for that country. The step-increase in deaths was higher than the 98% CI in all but 4 countries which were only just below the 98% CI line. While data was available for Ukraine this country was in switch-off during 2015. Ukraine remained in switch-off until July 2016 (data not shown).

3.8 Seasonal behaviour of switch-on

While Figure 3 demonstrates a degree of clustering in time Figure 5 investigates if the month at which switch-on commences has a strong seasonal component. As can be seen switch-on can commence at any time of the year. Switch-on occurs at slightly higher frequency in late winter to early spring for all events, however, the event culminating in 2015 seemingly preferred July to November. Hence season of the year is clearly not the dominant force for determining when switch-on will commence.

4 Discussion

4.1 General comments

Switch-on/off behaviour seemingly characterises both medical admissions and deaths [8,9]. These two seemingly unrelated events are linked by what is known as the nearness to death effect. In the nearness to death effect around half of a person’s lifetime hospital admissions and bed occupancy is compressed into the last year of life and especially into the last month of life [17-23]. As may be expected switch-on for medical admissions occurs slightly earlier than deaths, i.e. illness precedes death [24].

The importance of switch-on/off has not seemingly made its way into actuarial studies and its existence has profound implications as to why deaths and life insurance pay-outs are seemingly higher in some years than others.

This study has illustrated several key points, namely

1. Switch-on/off affects all countries

2. The magnitude of switch-on is variable within a country and between countries
3. Switch-on/off is not directly initiated by winter but can occur at any time
4. The use of calendar year totals in most actuarial studies will be clouded by the presence of variable amounts of switch-on/off

Regarding the third point it is highly likely that endeavours to attribute period and cohort effects may be hindered by this mix of behaviour in arbitrary calendar year data. In this respect, age-specific effects have been demonstrated to occur during the 1993, 2012 and 2014 switch-on events [4,25,26]. Period and cohort effects have been recently demonstrated to occur in hospital admissions [27]. Unfortunately, this study did not disentangle the nearness to death effect from the effect of age alone.

Since switch-on/off can occur at any time and is occurring in sub-national geographies [28,29] the shape of the rolling 12-month trends as in Figure 1 can be modified by the sub-national behaviour. This explains why the maximum value of switch-on diminishes with size as demonstrated in Figure 2 [28].

4.2 Power Law relationships with size

The Power law relationship seen in Figure 2 in countries with fewer than 1,000 to 10,000 deaths is consistent with the known abundance of Power law relationships observed in nature [30], which seemingly arise out of random processes. Countries with more than 1,000 to 10,000 deaths appear to follow a Power Law with a lower order. For example, the 95% CI line in Figure 2 is derived from Poisson statistics which decays with size to the power of -0.5, i.e. a square root relationship [16]. In this study, maximum step-increase arising from switch-on decays with size to the power -0.365 for countries with fewer than 10,000 deaths per annum and to the power -0.051 for those with over 10,000 deaths.

It is important to explain how the relationship with size could arise as a result of a type of infectious-like spread. It is known that infectious events usually progress within social networks where contact or proximity allows passage of the agent between members of the network [31,32]. Such networks are often local within a neighbourhood or town; however, national and international air travel will then act to spread the agent wider afield with airports becoming hubs for international transmission [33,34]. Hence, the international time-clusters observed in Figure 3. The variable magnitude of each event is partly an outcome of complex system behaviour [35] and the movement along social networks will show elements of fractal geometry [36], hence, the nuanced shape of the time trends revealed by a rolling 12-month total [28].

4.3 Increase in International Deaths in 2015

The event culminating in 2015 deserves some further comment. The year 2015 saw the largest year-on-year increase in deaths in the UK in 30 years [37], and in the

USA [3] (see Table S1). Some have claimed that higher deaths in the UK in 2015 were due to influenza [38], however the timing and magnitude of switch-on which occurred earlier during 2014 indicates that it was switch-on rather than influenza which dominated the trends. The possibility exists that influenza vaccination in late 2014 with a poorly matched vaccine interacted with whatever caused switch-on earlier in 2014 [39]. This possibility is reinforced by the observation that 29% of countries were in switch-off during 2014 and 2015 and hence did not experience a rise in deaths. The very large rise in deaths in 2015 compared to 2014 seen in the UK arose from the fact that 95% of local government areas were in switch-on (Figure S2) compared only 71% in an international context (Table S1).

Small area behaviour of both medical admissions and deaths suggests that we may be dealing with a kind of transmissible agent, and this requires further study [8,9,24]. A role for on/off switching in the financial risk associated with health and social care budgets has also been recently proposed [40].

4.4 Temperature and season are excluded as causes

As was demonstrated in Figures 3 and 5, temperature or season, especially winter and associated infectious outbreaks such as influenza, can be excluded as the cause for switch-on. The agent responsible can initiate switch-on at any time. In addition, any role for temperature was excluded as contributing to the large increase in deaths in the UK in 2015 compared to 2014 [37].

4.5 Poisson-chance and the maximum step-increase

Figure 2 presented the maximum value of the step-increase for each country minus the 98% CI from Poisson-based chance. This would only be expected to occur on 2% of occasions and Poisson-based chance could equally act to diminish the maximum step-increase. However, from Figure 1 and S1 we can see that in every country there are other peaks with values close to the maximum increase, hence, except for the smallest countries we can conclude that the maximum step-increase arising from switch-on is a reliable estimate of the maximum possible impact achievable in that country given its totality of social networks and their associated health behaviours (partly dependant on size).

4.6 How has on/off switching been missed?

Overall, most actuarial analysis uses calendar year data at whole country or regional level. As demonstrated in this study, switch-on can commence at any time of the year. Also, the effects of switch-on are attenuated using regional and national totals [28]. Both have combined to obscure the effects of on/off switching.

In many ways, it was widely assumed that excess winter mortality [41] arising from a mix of cold and winter infectious outbreaks was the sole source of the undulations in calendar year totals. However, this study (Figures 1 and 3 and Table S1) suggests that switch-on/off, occurring before the winter has commenced, seem to have a major role in determining the deaths in the ensuing winter. This possibility needs to be further explored. Indeed, if something is deemed not to exist then no one will go looking for its existence.

4.7 NHS deficits and the health insurance underwriting cycle

Following a large increase in deaths and associated medical admissions arising from switch-on in 2008 the NHS went into deficit due to an unexpected increase in costs [42]. It was widely assumed that this was due to acute hospitals reducing their threshold to admission [43]. This assumption was later proved to be incorrect and a casemix-adjusted study of emergency department thresholds to admission showed that thresholds to admission had increased rather than decreased [44].

However, based on the premise that the increase in emergency admissions was an acute hospital threshold problem NHS England introduced a 30% marginal rate tariff in 2010/11 whereby hospitals were only paid at 30% of cost for all emergency admissions higher than the 2008/09 outturn [45]. Similar events unfolded following another switch-on in late 2011 and early 2012 [46-48] led to further changes to the tariff in an attempt to reduce costs [49]. The rise in deaths since 2011 seen in the UK [2,4-7,50] has led to a huge £814 million deficit in the first quarter of 2018/19 [51]. No one had seemingly realised that the UK was undergoing a similar pattern to that seen in the Health Insurance Underwriting Cycle seen in the USA [8-10]. Government agencies run the perpetual risk of only seeing the evidence which is consistent with government policy [52]

4.8 Limitations of the study

While data for 126 countries has been analysed, that for most of the less developed countries in Africa and parts of Asia and South America is absent. The 17% of countries with less than 10 years of data are likely to suffer from bias in that the magnitude of the maximum step-increase arising from switch-on may be underestimated.

In some of the less developed countries natural disasters such as floods and earthquake could lead to spike increases in deaths. However, the death toll in such events for most of the countries studied would be small in comparison to the total deaths seen each year. The effect upon this study would depend if the natural disaster occurred during a period of switch-on. If the natural disaster occurred before switch-on then the magnitude of switch-on would be underestimated

5 Conclusions

In conclusion, international deaths are profoundly influenced by switch-on/off behaviour. Actuaries need to be aware that switch-on/off may act as a confounding factor in the attempts to attribute period and cohort effects. The agent for switch-on appears transmissible but its exact identity remains unknown. While a rolling 12-month method has been used in this study further studies using alternative methodologies will be required to fully elucidate exactly what is happening during switch-on/off. Actuaries from different countries need to start delving into sub-national data and especially explore gender differences. Whatever the cause(s) switch-on/off creates unexplained periods of higher insurance costs, the magnitude of which depend on the size and location of the insurance pool.

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Figure 1: Rolling year-on-year difference for 10 countries with a continuous time-series of monthly data

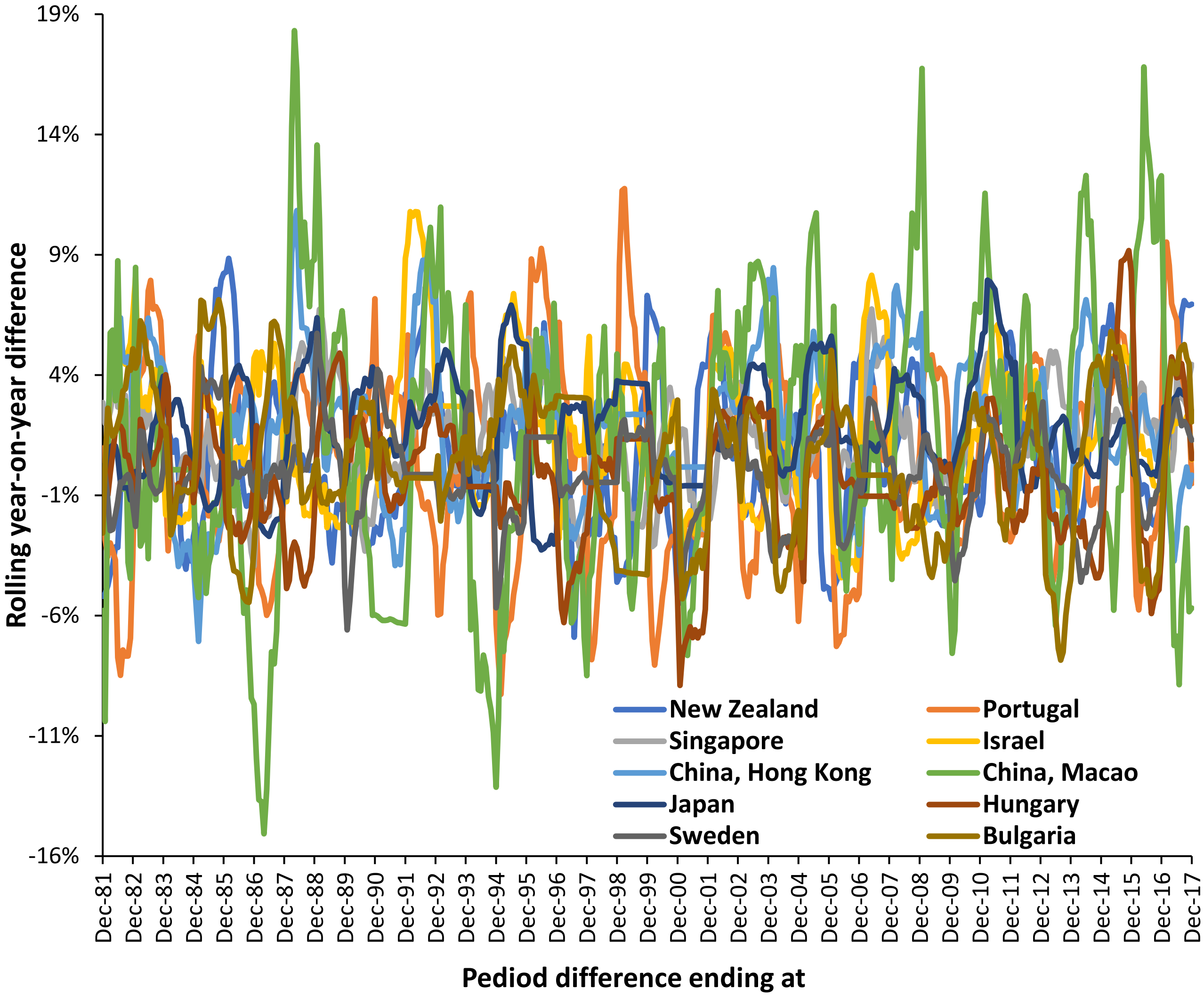


Figure 2: Value of the maximum step-increase in deaths for each country versus the size of that country measured as the average number of annual deaths

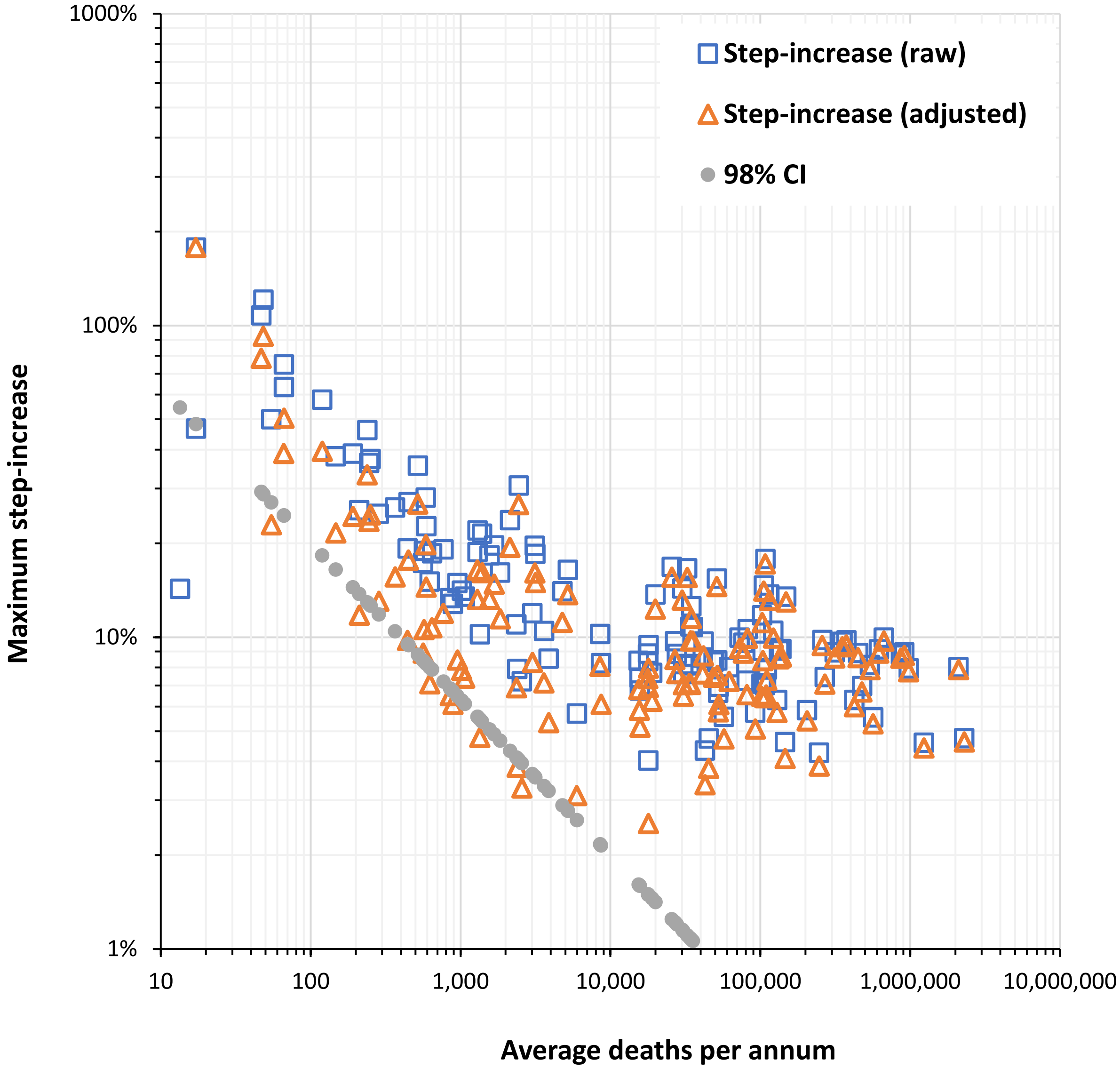


Figure 3: Time at which the maximum step-increase in deaths occurred for each country

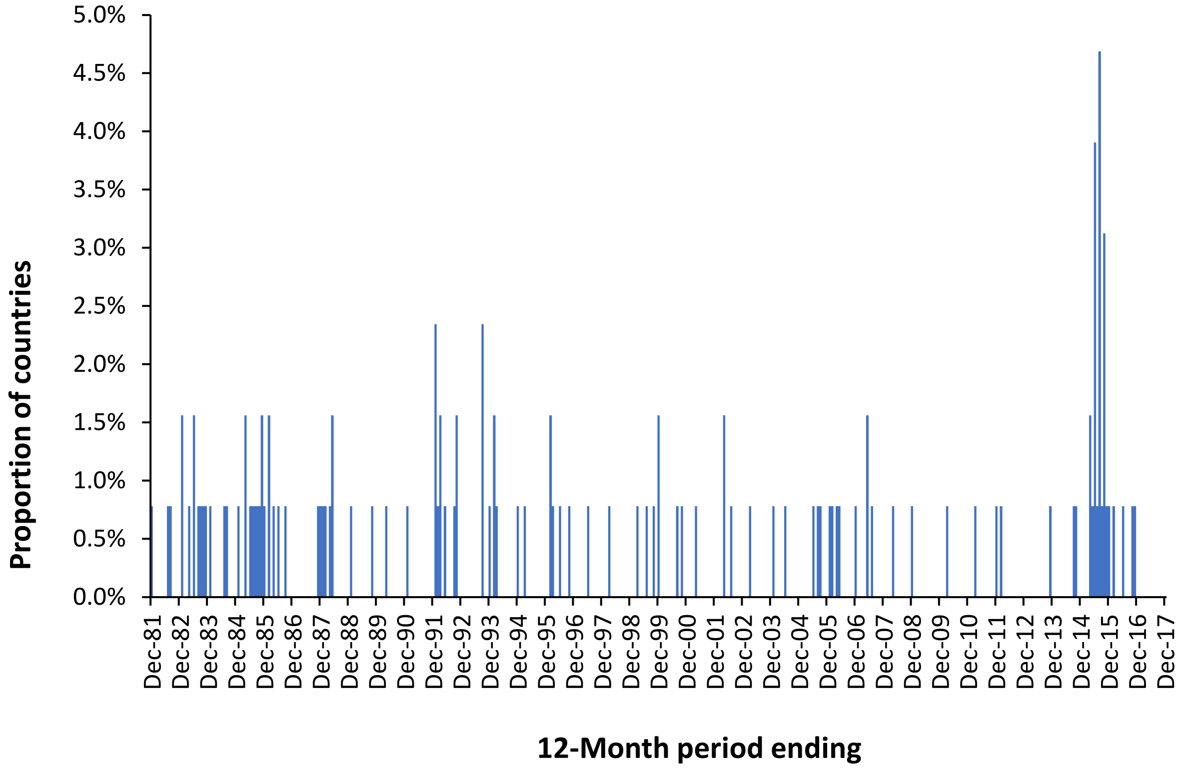


Figure 4: Magnitude of the step-increase in countries having a step-increase for the period ending during 2015 (n = 80). Note that switch-on will have commenced earlier in 2014.

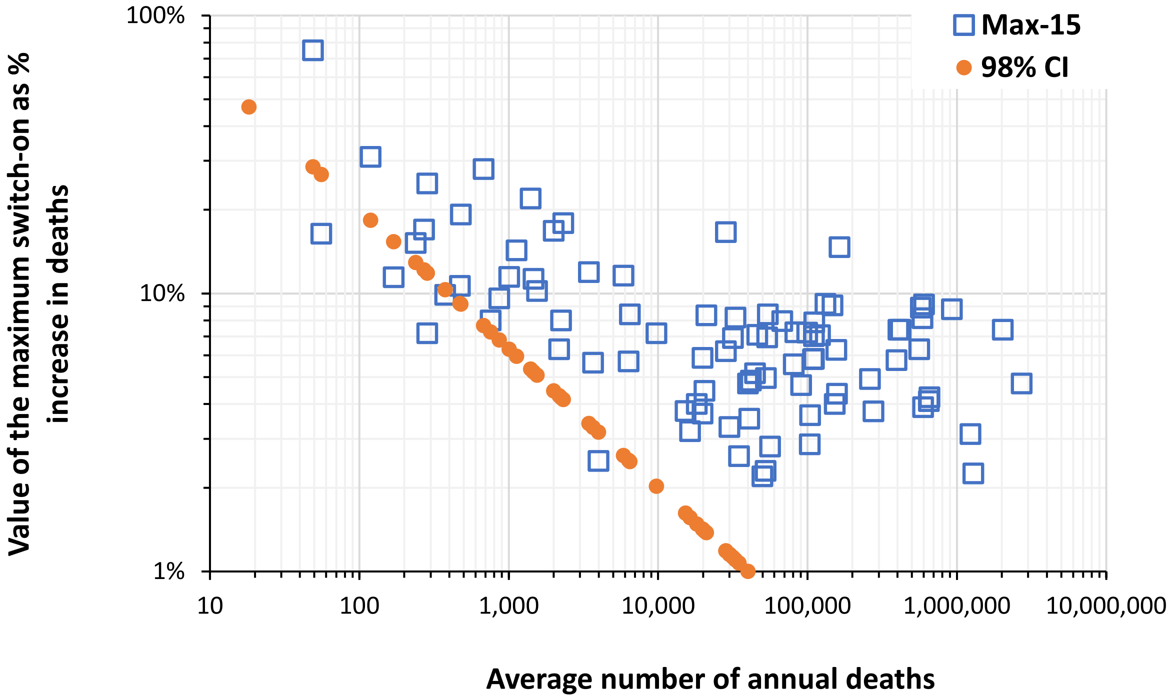
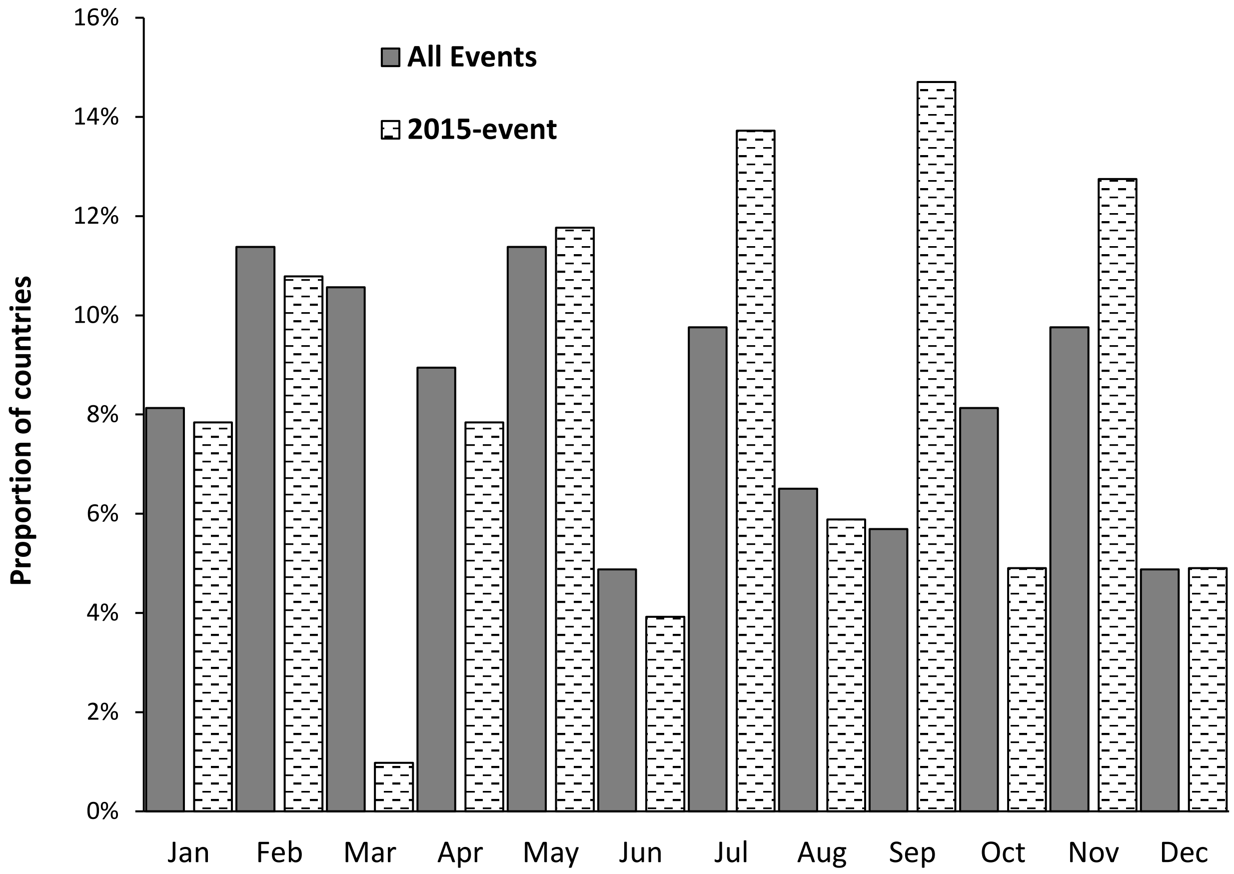


Figure 5: Month in which switch-on commences for the maximum value of switch-on at any time or for the switch-on which concludes during 2015



Supplementary material

Table S1: Data for all countries including count of number of months data, annual average deaths, maximum step-increase and the point at which the maximum step-increase ended (all years and for the event ending near 2015)

Country	Months of data	All years					2014 to 2016 (centred on 2015)				
		Average Deaths	Step-increase (raw)	Step-increase (adjusted)	Maximum Increase ends at	98% CI	Average deaths 2015	Maximum (2015, else 2014, 2016)	98% CI	On/Off	12-months ending
Cook Islands	660	119	57.8%	39.5%	Nov-87	18.3%	119	31.0%	18.3%	OFF	Jun-14
Japan	456	976,669	7.9%	7.7%	Mar-11	0.2%	1,290,444	2.3%	0.2%	ON	Oct-15
United Kingdom	456	617,307	9.1%	8.9%	Jun-15	0.3%	601,272	9.1%	0.3%	ON	Jun-15
France	456	539,687	8.1%	7.9%	Dec-15	0.3%	587,000	8.1%	0.3%	ON	Dec-15
Hungary	456	138,263	9.2%	8.6%	Nov-15	0.5%	131,575	9.2%	0.6%	ON	Nov-15
Bulgaria	456	109,177	7.1%	6.5%	Oct-85	0.6%	110,117	5.8%	0.6%	ON	Apr-15
Portugal	456	102,847	11.8%	11.1%	Mar-99	0.6%	108,539	5.8%	0.6%	ON	Jul-15
Sweden	456	92,432	5.7%	5.1%	Jan-89	0.7%	90,816	4.7%	0.7%	ON	Apr-15
Israel	456	35,397	10.8%	9.7%	Feb-92	1.1%	44,507	5.2%	0.9%	ON	Sep-15
China, Hong Kong SAR	456	34,254	10.8%	9.8%	May-88	1.1%	46,108	7.1%	0.9%	OFF	Jun-14
New Zealand	456	27,742	8.8%	7.6%	Feb-86	1.2%	31,608	6.9%	1.1%	ON	Apr-15
Singapore	456	15,712	6.7%	5.1%	May-07	1.6%	19,862	3.7%	1.4%	OFF	Apr-16
China, Macao SAR	456	1,561	18.3%	13.3%	Apr-88	5.1%	2,002	16.8%	4.5%	OFF	May-16
Mexico	444	477,025	7.0%	6.7%	Mar-10	0.3%	654,231	4.2%	0.2%	ON	Oct-15
Poland	444	375,008	9.8%	9.4%	Apr-85	0.3%	394,921	5.8%	0.3%	ON	Oct-15
Australia	444	129,363	6.3%	5.7%	Aug-85	0.6%	157,162	4.4%	0.5%	ON	Apr-15
Austria	444	81,271	7.3%	6.6%	Oct-15	0.7%	83,073	7.3%	0.7%	ON	Oct-15
Cuba	444	77,027	9.6%	8.9%	Nov-85	0.7%	99,691	7.2%	0.6%	ON	Oct-15
Denmark	444	57,131	5.6%	4.7%	Feb-96	0.8%	52,555	5.0%	0.9%	ON	Jun-15
Ireland	444	30,654	7.6%	6.5%	Feb-94	1.1%	30,064	3.3%	1.2%	ON	Oct-15

Country	Months of data	All years					2014 to 2016 (centred on 2015)				
		Average Deaths	Step-increase (raw)	Step-increase (adjusted)	Maximum Increase ends at	98% CI	Average deaths 2015	Maximum (2015, else 2014, 2016)	98% CI	On/Off	12-months ending
Cyprus	444	5,195	16.5%	13.7%	May-92	2.8%	5,859	11.6%	2.6%	ON	Dec-15
Malta	444	3,014	11.9%	8.3%	May-15	3.6%	3,442	11.9%	3.4%	ON	Apr-15
Iceland	444	1,840	16.1%	11.5%	May-88	4.7%	2,178	6.3%	4.3%	ON	Dec-15
Maldives	444	1,296	18.8%	13.2%	Sep-05	5.6%	1,130	14.3%	5.9%	OFF	Aug-16
Republic of Korea	432	313,757	8.9%	8.6%	Nov-83	0.4%	275,895	3.8%	0.4%	ON	Nov-15
Netherlands	432	133,189	9.1%	8.5%	Jun-15	0.5%	147,134	9.1%	0.5%	ON	Jun-15
Chile	432	82,270	10.6%	9.9%	Jul-07	0.7%	103,327	2.9%	0.6%	ON	Mar-15
Switzerland	432	61,906	8.0%	7.2%	Apr-90	0.8%	67,606	8.0%	0.8%	ON	Sep-15
Belarus	422	122,002	10.5%	9.9%	Sep-93	0.6%	120,025	0.3%	0.6%	ON	Apr-15
Italy	420	565,595	5.5%	5.3%	Apr-02	0.3%	647,571	4.1%	0.2%	OFF	Nov-14
Spain	420	353,092	9.7%	9.3%	Jun-83	0.3%	420,408	7.4%	0.3%	ON	Aug-15
Egypt	408	449,257	8.9%	8.6%	Aug-15	0.3%	573,879	8.9%	0.3%	ON	Aug-15
Ukraine	396	667,592	10.0%	9.7%	Jan-92	0.2%	594,795	3.9%	0.3%	OFF	May-17
Kuwait	396	4,784	14.0%	11.2%	Jun-04	2.9%	6,481	8.4%	2.5%	ON	Mar-15
Finland	384	48,802	8.4%	7.5%	Jul-85	0.9%	52,492	2.3%	0.9%	OFF	Mar-16
Norway	384	42,771	4.3%	3.4%	Dec-85	1.0%	40,676	3.5%	1.0%	ON	Mar-15
El Salvador	384	30,121	14.3%	13.2%	Mar-94	1.2%	30,121	103.9%	1.2%	OFF	Feb-14
Qatar	384	1,392	21.5%	16.1%	Jul-82	5.4%	2,317	17.9%	4.2%	OFF	Jun-14
Belgium	372	107,033	7.0%	6.4%	Oct-15	0.6%	110,541	7.0%	0.6%	ON	Oct-15
Kyrgyzstan	372	34,240	8.1%	7.1%	Mar-03	1.1%	34,805	2.6%	1.1%	ON	Oct-14
Luxembourg	372	3,876	8.5%	5.3%	Jan-04	3.2%	3,983	2.5%	3.2%	ON	Feb-15
United States of America	360	2,292,477	4.7%	4.6%	Aug-15	0.1%	2,712,630	4.7%	0.1%	ON	Aug-15
Romania	360	258,897	9.8%	9.4%	Mar-96	0.4%	261,294	4.9%	0.4%	ON	Apr-15
Puerto Rico	360	26,935	9.7%	8.5%	Sep-85	1.2%	28,409	6.2%	1.2%	ON	Mar-15
Croatia	348	51,624	8.4%	7.5%	Aug-15	0.9%	54,205	8.4%	0.9%	ON	Aug-15

Country	Months of data	All years					2014 to 2016 (centred on 2015)				
		Average Deaths	Step-increase (raw)	Step-increase (adjusted)	Maximum Increase ends at	98% CI	Average deaths 2015	Maximum (2015, else 2014, 2016)	98% CI	On/Off	12-months ending
Lithuania	348	41,243	8.6%	7.6%	Feb-06	1.0%	41,776	4.9%	1.0%	ON	Jun-15
Bahamas	348	1,677	19.7%	14.8%	Mar-98	4.9%	2,243	8.0%	4.2%	OFF	Mar-14
American Samoa	348	239	46.2%	33.2%	Jan-91	12.9%	239	15.2%	12.9%	OFF	Jul-12
Liechtenstein	348	211	25.5%	11.8%	Jun-05	13.8%	271	17.0%	12.1%	ON	May-15
Estonia	336	17,767	8.9%	7.4%	Sep-93	1.5%	15,243	3.8%	1.6%	ON	Mar-15
Costa Rica	336	15,428	8.4%	6.8%	Jan-83	1.6%	21,039	8.4%	1.4%	ON	Aug-15
Suriname	336	3,161	18.5%	15.0%	Sep-93	3.6%	3,663	5.6%	3.3%	ON	Jan-15
Latvia	334	32,531	16.6%	15.5%	Apr-15	1.1%	28,478	16.6%	1.2%	ON	Apr-15
Canada	324	205,022	5.8%	5.4%	Feb-94	0.4%					
Czechia	324	110,476	7.9%	7.3%	Aug-15	0.6%	111,173	7.9%	0.6%	ON	Aug-15
Slovakia	324	52,801	6.9%	6.1%	Aug-15	0.9%	53,826	6.9%	0.9%	ON	Aug-15
Slovenia	324	18,967	7.7%	6.2%	Mar-92	1.5%	19,834	5.9%	1.4%	ON	Aug-15
TFYR of Macedonia	324	17,935	9.4%	8.0%	Oct-92	1.5%	20,461	4.5%	1.4%	ON	Apr-15
Mauritius	324	8,519	10.2%	8.1%	Jun-97	2.2%	9,747	7.2%	2.0%	OFF	Oct-16
New Caledonia	324	1,068	13.5%	7.4%	Oct-99	6.1%	1,465	11.3%	5.2%	ON	May-15
Cayman Islands	324	147	38.1%	21.6%	Jun-86	16.5%	170	11.4%	15.3%	ON	May-15
Montserrat	324	66	75.0%	50.5%	Oct-15	24.5%	49	75.0%	28.6%	ON	Oct-15
San Marino	315	192	38.9%	24.4%	May-06	14.5%					
Germany	312	866,191	8.8%	8.6%	Aug-15	0.2%	925,200	8.8%	0.2%	ON	Aug-15
Malaysia	312	115,095	13.7%	13.1%	Dec-99	0.6%	155,786	6.3%	0.5%	ON	Jan-15
Greece	312	102,015	7.1%	6.5%	Sep-15	0.6%	121,212	7.1%	0.6%	ON	Sep-15
Greenland	312	449	27.1%	17.7%	Aug-82	9.4%	472	10.6%	9.2%	ON	Sep-15
Republic of Moldova	300	41,801	9.7%	8.7%	Jan-92	1.0%	39,883	4.7%	1.0%	ON	Apr-15
Armenia	288	25,690	16.8%	15.6%	Apr-08	1.2%	27,970				
Saint Vincent & Grenadines	276	769	19.1%	11.9%	Mar-95	7.2%	866	9.6%	6.8%	OFF	Dec-14

Country	Months of data	All years					2014 to 2016 (centred on 2015)				
		Average Deaths	Step-increase (raw)	Step-increase (adjusted)	Maximum Increase ends at	98% CI	Average deaths 2015	Maximum (2015, else 2014, 2016)	98% CI	On/Off	12-months ending
Saint Helena ex. dep.	274	47	107.7%	78.4%	May-99	29.2%	56	16.4%	26.8%	OFF	Sep-14
Kazakhstan	264	148,620	13.5%	13.0%	Dec-93	0.5%					
Sri Lanka	264	103,898	9.0%	8.4%	Jul-84	0.6%					
Trinidad and Tobago	264	8,665	8.2%	6.1%	Feb-88	2.1%					
Martinique	264	2,359	11.0%	6.9%	May-07	4.1%					
Azerbaijan	252	52,325	6.6%	5.8%	Aug-05	0.9%	56,148	2.8%	0.8%	ON	Jul-15
Philippines	240	423,761	6.3%	6.0%	Sep-14	0.3%	560,605	6.3%	0.3%	OFF	Aug-14
Venezuela (Bolivarian Republic)	240	105,476	14.7%	14.1%	Jul-15	0.6%	163,712	14.7%	0.5%	ON	Jul-15
Uruguay	240	30,651	8.2%	7.1%	Dec-15	1.1%	32,967	8.2%	1.1%	OFF	Jun-16
United States Virgin Islands	240	571	18.9%	10.6%	Jan-88	8.4%					
Guernsey	236	623	15.1%	7.1%	Jun-96	8.0%					
Falkland Islands (Malvinas)	235	17	177.8%	129.5%	Dec-92	48.3%	18	115.0%	46.8%	OFF	Jan-16
Reunion	228	3,603	10.5%	7.1%	Apr-06	3.3%					
Bermuda	228	444	19.3%	9.8%	Apr-15	9.5%	478	19.3%	9.1%	ON	Apr-15
Guatemala	216	72,768	10.0%	9.2%	Apr-86	0.7%	80,876	5.6%	0.7%	ON	Sep-15
Faeroe Islands	216	366	26.1%	15.6%	Jun-83	10.5%	376	9.9%	10.3%	ON	Jan-15
Russian Federation	204	2,102,108	8.0%	7.9%	Dec-94	0.1%	2,023,667	7.4%	0.1%	OFF	Sep-14
Mongolia	204	15,639	7.4%	5.8%	Apr-02	1.6%	16,374	3.2%	1.6%	OFF	Sep-14
Guam	204	644	18.6%	10.7%	Jan-92	7.9%	1,009	11.5%	6.3%	ON	Jun-15
French Guiana	204	591	22.7%	14.5%	Apr-83	8.2%					
Gibraltar	204	245	36.3%	23.5%	Oct-83	12.8%					
Pakistan	192	914,071	8.9%	8.7%	Oct-92	0.2%					
Turkey	192	269,520	7.5%	7.1%	Feb-96	0.4%	406,128	7.4%	0.3%	OFF	Sep-14
Georgia	168	45,294	4.7%	3.8%	Dec-08	0.9%	49,929	2.2%	0.9%	OFF	Aug-14
Albania	168	17,924	8.4%	6.9%	Oct-89	1.5%					

Country	Months of data	All years					2014 to 2016 (centred on 2015)				
		Average Deaths	Step-increase (raw)	Step-increase (adjusted)	Maximum Increase ends at	98% CI	Average deaths 2015	Maximum (2015, else 2014, 2016)	98% CI	On/Off	12-months ending
Guadeloupe	168	2,388	7.9%	3.8%	Nov-85	4.1%					
Barbados	168	2,137	23.7%	19.4%	Feb-86	4.3%					
Serbia	156	107,974	17.8%	17.2%	Dec-06	0.6%	104,265	3.7%	0.6%	ON	Jul-15
Saint Lucia	156	889	12.8%	6.1%	Jul-02	6.7%					
Aruba	156	587	28.0%	19.8%	Jun-15	8.3%	679	28.0%	7.7%	ON	Jun-15
Andorra	156	251	37.3%	24.7%	Feb-12	12.6%					
Niue	156	17	46.7%	-1.6%	Jun-85	48.3%					
Lebanon	144	19,954	13.7%	12.3%	Dec-11	1.4%					
Jersey	144	853	13.3%	6.5%	Jan-84	6.8%	756	8.0%	7.3%	ON	Dec-15
Isle of Man	132	954	14.9%	8.4%	Apr-85	6.5%					
Montenegro	120	5,968	5.7%	3.1%	Oct-15	2.6%	6,329	5.7%	2.5%	ON	Oct-15
Bosnia and Herzegovina	108	33,571	8.2%	7.1%	Jan-06	1.1%					
Seychelles	108	563	17.3%	8.9%	Jan-85	8.4%					
Uzbekistan	96	146,098	4.6%	4.1%	Oct-96	0.5%	152,035	4.0%	0.5%	OFF	Jun-14
Tajikistan	96	34,671	12.6%	11.5%	Sep-92	1.1%					
Curacao	96	1,298	22.0%	16.4%	Jun-15	5.6%	1,398	22.0%	5.3%	ON	Jun-15
French Polynesia	96	1,020	14.1%	7.8%	Mar-92	6.3%					
Cabo Verde	84	2,446	30.7%	26.6%	Sep-83	4.0%					
Tonga	84	519	35.5%	26.8%	Dec-99	8.8%					
British Virgin Islands	84	66	63.5%	38.9%	Sep-86	24.6%					
Brunei Darussalam	72	1,345	10.2%	4.8%	Feb-16	5.5%	1,547	10.2%	5.1%	OFF	Feb-16
Norfolk Island	72	13	14.3%	-40.3%	Dec-81	54.6%					
Turks and Caicos Islands	68	48	121.1%	92.3%	Apr-00	28.8%					
Bahrain	60	2,567	7.2%	3.3%	Oct-14	3.9%	285	7.2%	11.8%	OFF	Oct-14
Ãland Islands	60	285	24.9%	13.1%	Jun-15	11.8%	285	24.9%	11.8%	ON	Jun-15

Country	Months of data	All years					2014 to 2016 (centred on 2015)				
		Average Deaths	Step-increase (raw)	Step-increase (adjusted)	Maximum Increase ends at	98% CI	Average deaths 2015	Maximum (2015, else 2014, 2016)	98% CI	On/Off	12-months ending
Thailand	48	246,847	4.3%	3.9%	Aug-83	0.4%					
Syrian Arab Republic	48	51,278	15.4%	14.5%	Jan-83	0.9%					
Fiji	48	3,128	19.7%	16.1%	Dec-87	3.6%					
Panama	36	17,914	4.0%	2.5%	Nov-16	1.5%	18,182	4.0%	1.5%	OFF	Jul-16
Brazil	36	1,233,398	4.6%	4.4%	Oct-16	0.2%	1,231,400	4.4%	0.2%	OFF	Oct-16
Anguilla	36	55	50.0%	22.9%	Nov-13	27.1%					

Figure S1: Rolling year-on-year difference for Cook Islands, quarterly deaths

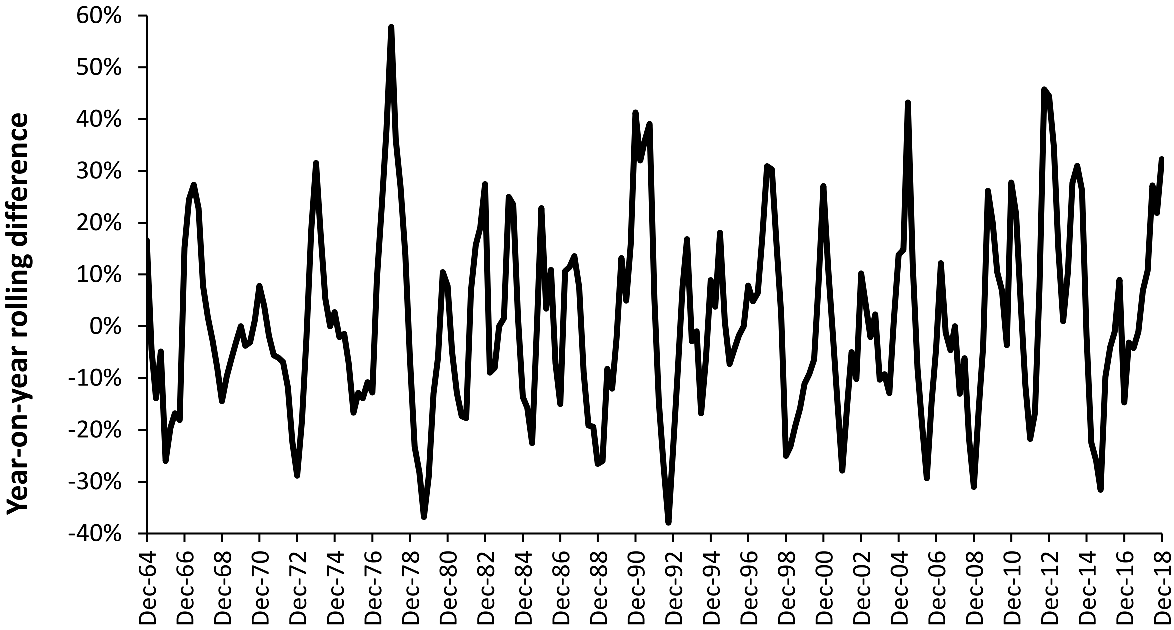


Figure S2: Point at which 12-month year-on-year rolling difference reaches a maximum in the interval 2014 to 2016 for 398 regions, counties and local authorities in England and Wales – 12% of which were in switch-off at the time of the January 2015 influenza outbreak