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Letter to the Editor

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Statistical evidence shows that mortality tends to fall during recessions: a rebuttal to Catalano and Bruckner

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Catalano and Bruckner conclude in their letter[1] that there is no association between the Great Recession and life expectancy at birth (LEB) in the USA. What they are actually trying to do is to refute that recessions and expansions are associated with changes in mortality. That association has been shown by a number of authors in different ways, often employing the unemployment rate as economic indicator.

A standard approach to demonstrate a potentially causal link between two time series is to 'prewhiten' them and then to examine the cross-correlation function to look for significant crosscorrelations.[2] To prewhiten a series means to transform it so that the resulting series has negligible autocorrelation. This usually means removing low-frequency components of the series, and prewhitening is therefore closely related to detrending. To transform the series into first differences—i.e. annual variation if data are annual (Figure 1, panels A and D) is a common method to detrend a series that may also prewhiten it. For the period 1948–2013, the annual change in unemployment has an autocorrelation of 0.10, whereas that of LEB is 0.02. With autocorrelations as close to zero as these, most algorithms indicate that these two series in first differences are adequately prewhitened. Considering the sample, 1948–2013 unemployment and LEB in first differences cross-correlate 0.42 at lag 0 (Table 1), a highly significant correlation revealing that the annual changes of both variables are substantially synchronized in the 65-year sample (Figure 1, panels D and G). Note for instance how in the recessions of the mid-1970s and 2008–09, large annual increases in unemployment coincide with large annual gains in LEB (Figure 1, panel D).

Many procedures can be used to detrend a series. Common methods are subtracting a non-linear trend like the Hodrick-Prescott (HP) filter or a linear trend, i.e. a straight line (Figure 1, panels A to C). The autocorrelation of the transformed series indicates how good is the prewhitening. The series of LEB and unemployment rates linearly detrended have respective autocorrelations of 0.88 and 0.73, whereas the autocorrelations of the series detrended with the HP filter (using a smoothing parameter 6.25 which is recommended for annual data[3]) are, respectively, 0.01 and 0.22. Thus the prewhitening is poor with linear detrending and much better with the HP filter. The cross-correlations at lag 0 (Table 1) are 0.46 for the linearly detrended series and 0.45 for the HP-detrended series of LEB and unemployment, both highly significant. Scatterplots of annual variations or deviation from HP or linear trend (Figure 1, panels G to I) indicate that the statistically positive cross-correlations at lag 0 are not determined by outliers.

A more sophisticated method for prewhitening a series is obtaining the residuals from fitting an ARIMA (p,d,q) model. This requires choosing a value p for the autoregressive (AR) order, a value d for the integrating (I) order and a value q for the moving average (MA) order. Choosing an

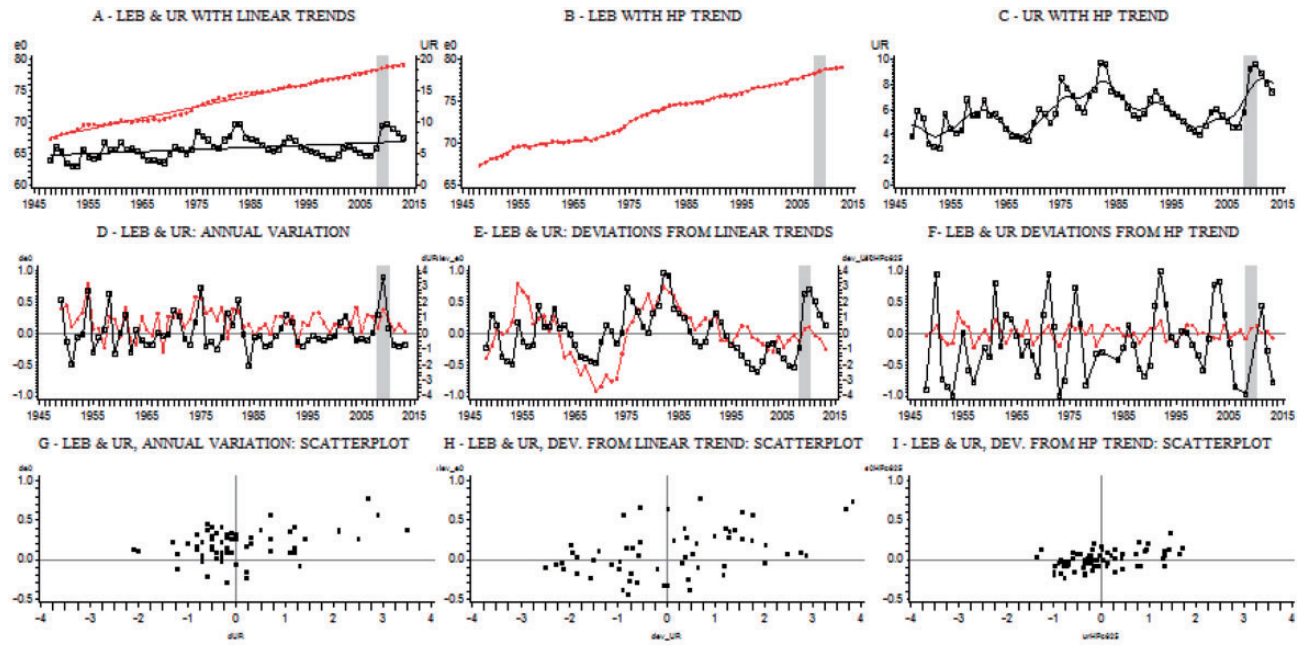

Figure 1. Life expectancy at birth (LE, dots) and unemployment rate (UR, hollow squares), USA 1948–2013. Panel A includes linear trends, panels B and C include Hodrick–Prescott (HP) trends computed with $\gamma = 6.25$. The trend in panel B is hard to see as it follows closely the data. Panels D, E and F present the annual variation (first differences) of the two series, and the deviations from linear trends or from an HP trend. Panels G, H and I are the scatterplots corresponding to the panels D, E and F. The Great Recession is marked with a vertical grey bar in panels A to F

Sources: LEB from Human Mortality Database (www.mortality.org), unemployment rates from Bureau of Labor Statistics (www.bls.gov/data/). Data downloaded in 2015.

Table 1. Correlations between the annual series of life expectancy at birth and the unemployment rate of the USA for 1948–2013 and subsamples of this period. Series detrended by three different procedures

Sample	Series in first differences	Series detrended using the HP filter ($\gamma = 6.25$)	Series linearly detrended
1948–2013	0.42***	0.45***	0.46***
1948–80	0.44*	0.52**	0.41*
1981–2013	0.36*	0.36*	0.65***
1948–59	0.53†	0.59*	0.14
1950–69	0.46*	0.59**	0.48*
1960–79	0.50*	0.45*	0.68***
1970–89	0.42†	0.54*	0.58**
1980–99	0.26	0.45*	0.82***
1990–2009	0.22	0.16	0.38
2000–13	0.32	0.32	0.50†

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; †$P < 0.1$, assuming negligible autocorrelation.

ARIMA (4,0,1) which is the ARIMA (p,d,q) recommended by the ESACF algorithm of the statistical program SAS, the lag-0 cross-correlation of the prewhitened series of LEB and unemployment is 0.39, which is statistically very significant ($P < 0.001$).

The analysis with two series can be refined in different ways (see: http://ionides.github.io/USA_cyclical_mortality/report.html). Another possibility is to analyse series of unemployment rates and LEB (or mortality) for the 50 states, rather than for the nation.[4] All methods show however the same conclusion, that there is a positive and significant correlation between the properly transformed series of LEB and unemployment. This must be taken as strongly suggestive of causality between the two series, or a third variable causing both.

Table 1 shows how robust to sample variation are the correlations correspondent to the series detrended by different methods. For all methods, the correlations in split samples (i.e. 1948–80 and 1981–2013) are positive and significant and they are also positive and significant in many 20-year samples. Of course, the smaller the sample, the harder it is to achieve statistical significance. But the correlation is positive in all cases, which would not be likely under the hypothesis that the actual correlation is zero, in which case we would expect negative correlations at least in some samples. The correlation between the annual variation of LEB and unemployment is 0.22 in the 20-year sample 1990–2009 and 0.32 in the 14-year sample 2000–13. It has been suggested indeed that the procyclical oscillation of mortality (i.e. its oscillation rising in expansions and decreasing in recessions) may have dampened in

recent decades.[5,6] These are issues which are still in discussion,[7] but Catalano and Bruckner ignore them. At any rate, all this evidence suggests that periods of economic recession have some beneficial effect on population mortality.

In their letter, Catalano and Bruckner[1] use LEB data for 1958–2007 to estimate an ARIMA model in which LEB in first differences, that they call ∇EX_t, is modelled as follows:

$$\begin{aligned}\nabla EX_t &= 0.1778 + (1 - 0.3618B^{11})\ a_t \\ &= 0.1778 + a_t\ - 0.3618\ a_{t-11}\ .\end{aligned}$$

Next, they apply this model—an ARIMA (p,d,q) in which $p = 0$, $d = 1$ and $q = 11$—to the data 1958–2013, and look at the residuals. Since all the residuals for 2008–13 are inside the 95% confidence interval, they conclude that these values are expected: therefore, they conclude, there is no evidence of association between the Great Recession and LEB. Their analysis is flawed for several reasons.

To start with, it is usually inappropriate to fit an ARIMA model that depends on one high lag while excluding all shorter lags. This is essentially the same as the regression analysis principle that, if interaction terms are included in the model, the main effects should be included too.[8] A model including lag 11 should include lags 1–10 as well, unless compelling theoretical reasons suggest otherwise. Considering all MA models with lags from 0 to 11 (as Catalano and Bruckner appear to do) involves comparing $2^{12} = 4096$ models if you allow yourself to cherry-pick specific lags. This exponential explosion of possible models requires a careful consideration of the problems posed by a high-dimensional model selection, an issue which Bruckner and Catalano completely ignore. They do not say why this particular ARIMA (0,1,11) is appropriate versus, say, an ARIMA (0,1,10) or any other specification.

Catalano and Bruckner mistakenly state that the Box–Jenkins approach 'uses an iterative model-building process by which the researcher infers the filter that imposed the observed pattern'. In the Box–Jenkins or ARIMA approach, the outcome is a model which is consistent with the observed pattern. There may be others, indeed fitting ARIMA models 'is as much an art as it is a science'.[9] Scientifically, one should acknowledge that there is not a unique defensible model and check that the conclusions are robust to model variation.

Catalano and Bruckner's reasoning is that if the Great Recession were linked to a change in mortality, at least one of their residuals for 2008–13 would be out of the 95% confidence interval. That implies a statement about the power of their test, but they don't determine the statistical power. It would be very low, since they are testing an association on only 5 years. To see why this is inappropriate, an analogy can be apposite: imagine seeking to test the theory that men are on average taller than women, based on how often, in a random sample of five people, the men and women happen to have heights incompatible with a model fitted to a much larger sample under the assumption that there is no relationship between sex and height. A relationship that is evident over 25 years of data might indeed be statistically insignificant when tested on a sample of 5 years. An experiment that fails to find a result might simply be a weak experiment. Formally, the absence of an effect cannot be shown by this route; all that can be shown is that if there is an effect, this method is not able to find it.

The statistical exercise in Catalano and Bruckner's letter is poorly targeted, as the intention of the original commentary[10] was not to demonstrate an association between the Great Recession and mortality. What many authors since the 1920s[11] have investigated is whether there is a relationship between changes in mortality and changes in macroeconomic conditions. We,[4,12–17] as many others,[7,11,18–21] have concluded that in general recessions are associated with lower mortality, i.e. higher LEB, once long-term trends are accounted for. In the first part of this letter we have shown this with a straightforward method. More complicated methods obtain the same conclusion.

Catalano and Bruckner reach different conclusions in their letter,[1] as in their previous analysis,[22] because they use Box–Jenkins methods inappropriately to construct weak statistical arguments.

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