AGW Bombshell? A new paper shows statistical tests for global warming fails to find statistically significantly anthropogenic forcing

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From the journal Earth System Dynamics billed as "An Interactive Open Access Journal of the European Geosciences Union" comes this paper which suggests that the posited AGW forcing effects simply isn't statistically significant in the observations, but other natural forcings are.

> "…We show that although these anthropogenic forcings share a common stochastic trend, this trend is empirically independent of the stochastic trend in temperature and solar irradiance. Therefore, greenhouse gas forcing, aerosols, solar irradiance and global temperature are not polynomially cointegrated. This implies that recent global warming is not statistically significantly related to anthropogenic forcing. On the other hand, we find that greenhouse gas forcing might have had a temporary effect on global temperature."

This is a most interesting paper, and potentially a bombshell, because they have taken virtually all of the significant observational datasets (including GISS and BEST) along with solar irradiance from Lean and Rind, and CO2, CH4, N2O, aerosols, and even water vapor data and put them all to statistical tests (including Lucia's favorite, the unit root test) against forcing equations. Amazingly, it seems that they have almost entirely ruled out anthropogenic forcing in the observational data, but allowing for the possibility they could be wrong, say:

> "…our rejection of AGW is not absolute; it might be a false positive, and we cannot rule out the possibility that recent global warming has an anthropogenic footprint. However, this possibility is very small, and is not statistically significant at conventional levels."

I expect folks like Tamino (aka Grant Foster) and other hotheaded statistics wonks will begin an attack on why their premise and tests are no good, but at the same time I look for other less biased stats folks to weigh in and see how well it holds up. My sense of this is that the authors of Beenstock *et al* have done a pretty good job of ruling out ways they may have fooled themselves. My thanks to Andre Bijkerk and Joanna Ballard for bringing this paper to my attention on Facebook.

The abstract and excerpts from the paper, along with link to the full PDF follows.

Polynomial cointegration tests of anthropogenic impact on global warming

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Abstract.

We use statistical methods for nonstationary time series to test the anthropogenic interpretation of global warming (AGW), according to which an increase in atmospheric greenhouse gas concentrations raised global temperature in the 20th century. Specifically, the methodology of polynomial cointegration is used to test AGW since during the observation period (1880–2007) global temperature and solar irradiance are stationary in 1st differences whereas greenhouse gases and aerosol forcings are stationary in 2nd differences. We show that although these anthropogenic forcings share a common stochastic trend, this trend is empirically independent of the stochastic trend in temperature and solar irradiance. Therefore, greenhouse gas forcing, aerosols, solar irradiance and global temperature are not polynomially cointegrated. This implies that recent global warming is not statistically significantly

related to anthropogenic forcing. On the other hand, we find that greenhouse gas forcing might have had a temporary effect on global temperature.

Introduction

Considering the complexity and variety of the processes that affect Earth's climate, it is not surprising that a completely satisfactory and accepted account of all the changes that oc- curred in the last century (e.g. temperature changes in the vast area of the Tropics, the balance of CO2 input into the atmosphere, changes in aerosol concentration and size and changes in solar radiation) has yet to be reached (IPCC, AR4, 2007). Of particular interest to the present study are those processes involved in the greenhouse effect, whereby some of the longwave radiation emitted by Earth is re-absorbed by some of the molecules that make up the atmosphere, such as (in decreasing order of importance): water vapor, car- bon dioxide, methane and nitrous oxide (IPCC, 2007). Even though the most important greenhouse gas is water vapor, the dynamics of its flux in and out of the atmosphere by evaporation, condensation and subsequent precipitation are not understood well enough to be explicitly and exactly quantified. While much of the scientific research into the causes of global warming has been carried out using calibrated gen- eral circulation models (GCMs), since 1997 a new branch of scientific inquiry has developed in which observations of climate change are tested statistically by the method of cointegration (Kaufmann and Stern, 1997, 2002; Stern and Kauf- mann, 1999, 2000; Kaufmann et al., 2006a,b; Liu and Ro- driguez, 2005; Mills, 2009). The method of cointegration, developed in the closing decades of the 20th century, is intended to test for the spurious regression phenomena in non-stationary time series (Phillips, 1986; Engle and Granger, 1987). Non-stationarity arises when the sample moments of a time series (mean, variance, covariance) depend on time. Regression relationships are spurious[1] when unrelated non- stationary time series appear to be significantly correlated be- cause they happen to have time trends.

The method of cointegration has been successful in detecting spurious relationships in economic time series data.

Indeed, cointegration has become the standard econometric tool for testing hypotheses with nonstationary data (Maddala, 2001; Greene, 2012). As noted, climatologists too have used cointegration to analyse nonstationary climate data (Kauf- mann and Stern, 1997). Cointegration theory is based on the simple notion that time series might be highly correlated even though there is no causal relation between them. For the relation to be genuine, the residuals from a regression between these time series must be stationary, in which case the time series are "cointegrated". Since stationary residuals mean- revert to zero, there must be a genuine long-term relationship between the series, which move together over time because they share a common trend. If on the other hand, the resid- uals are nonstationary, the residuals do not mean-revert to zero, the time series do not share a common trend, and the relationship between them is spurious because the time series are not cointegrated. Indeed, the $R2$ from a regression between nonstationary time series may be as high as 0.99, yet the relation may nonetheless be spurious.

The method of cointegration originally developed by En- gle and Granger (1987) assumes that the nonstationary data are stationary in changes, or first-differences. For example, temperature might be increasing over time, and is there- fore nonstationary, but the change in temperature is station- ary. In the 1990s cointegration theory was extended to the case in which some of the variables have to be differenced twice (i.e. the time series of the change in the change) be- fore they become stationary. This extension is commonly known as polynomial cointegration. Previous analyses of the non-stationarity of climatic time series (e.g. Kaufmann and Stern, 2002; Kaufmann et al., 2006a; Stern and Kaufmann, 1999) have demonstrated that global temperature and solar irradiance are stationary in first differences, whereas green- house gases (GHG, hereafter) are stationary in second differ- ences. In the present study we apply the method of polyno- mial cointegration to test the hypothesis that global warming since

1850 was caused by various anthropogenic phenom- ena. Our results show that GHG forcings and other anthropogenic phenomena do not polynomially cointegrate with global temperature and solar irradiance. Therefore, despite the high correlation between anthropogenic forcings, solar irradiance and global temperature, AGW is not statistically significant. The perceived statistical relation between temperature and anthropogenic forcings is therefore a spurious regression phenomenon.

Data and methods

We use annual data (1850–2007) on greenhouse gas (CO_2, CH_4 and N_2O) concentrations and forcings, as well as on forcings for aerosols (black carbon, reflective tropospheric aerosols). We also use annual data (1880–2007) on solar irradiance, water vapor (1880–2003) and global mean tem- perature (sea and land combined 1880–2007). These widely used secondary data are obtained from NASA-GISS (Hansen et al., 1999, 2001). Details of these data may be found in the Data Appendix.

We carry out robustness checks using new reconstructions for solar irradiance from Lean and Rind (2009), for globally averaged temperature from Mann et al. (2008) and for global land surface temperature (1850–2007) from the Berkeley Earth Surface Temperature Study.

Key time series are shown in Fig. 1 where panels a and b show the radiative forcings for three major GHGs, while panel c shows solar irradiance and global temperature. All these variables display positive time trends. However, the time trends in panels a and b appear more nonlinear than their counterparts in panel c. Indeed, statistical tests reported be- low reveal that the trends in panel c are linear, whereas the trends in panels a and b are quadratic. The trend in solar irradiance weakened since 1970, while the trend in temperature weakened temporarily in the 1950s and 1960s.

The statistical analysis of nonstationary time series, such as those in Fig. 1, has two natural stages. The first consists of unit root tests in which the data are classified by their order and type of nonstationarity. If the data are nonstationary, sample moments such as means, variances and co- variances depend upon when the data are sampled, in which event least squares and maximum likelihood estimates of parameters may be spurious. In the second stage, these nonstationary data are used to test hypotheses using the method of cointegration, which is designed to distinguish between genuine and spurious relationships between time series. Since these methods may be unfamiliar to readers of *Earth System Dynamics*, we provide an overview of key concepts and tests.

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Fig. 1. Time series of the changes that occurred in several variables that affect or represent climate changes during the 20th century. a) Radiative forcings (rf, in units of $W\ m^{-2}$) during 1880 to 2007 of CH_4 (methane) and CO_2 (carbon dioxide); (b) same period as in panel a but for Nitrous-Oxide (N_2O); (c) solar irradiance (left ordinate, units of $W\ m^{-2}$) and annual global temperature (right ordinate, units of $^\circ C$) during 1880–2003.

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3 Results

3.1 Time series properties of the data

Informal inspection of Fig. 1 suggests that the time series properties of greenhouse gas forcings (panels a and b) are visibly different to those for temperature and solar irradiance (panel c). In panels a and b there is evidence of acceleration, whereas in panel c the two time series appear more stable. In Fig. 2 we plot $rfCO_2$ in first differences, which confirms by eye that $rfCO_2$ is not $I(1)$, particularly since 1940. Similar figures are available for other greenhouse gas forcings. In this section we establish the important result that whereas the first differences of temperature and solar irradiance are trend free, the first differences of the greenhouse gas forcings are not. This is consistent with our central claim that anthropogenic forcings are $I(2)$, whereas temperature and solar irradiance are $I(1)$.

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Fig. 2. Time series of the first differences of rfCO2.

What we see informally is born out by the formal statistical tests for the variables in Table 1.

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Although the KPSS and DF-type statistics (ADF, PP and DF-GLS) test different null hypotheses, we successively increase d until they concur. If they concur when $d = 1$, we classify the variable as *I (*1*)*, or difference stationary. For the anthropogenic variables concurrence occurs when $d = 2$. Since the DF-type tests and the KPSS tests reject that these variables are *I (*1*)* but do not reject that they are *I (*2*)*, there is no dilemma here. Matters might have been different if according to the DF-type tests these anthropogenic variables are *I (*1*)* but according to KPSS they are *I (*2*)*.

The required number of augmentations for ADF is moot. The frequently used Schwert criterion uses a standard formula based solely on the number of observations, which is inefficient because it may waste degrees of freedom. As mentioned, we prefer instead to augment the ADF test until its residuals become serially independent according to a la- grange multiplier (LM) test. In most cases 4 augmentations are needed, however, in the cases of rfCO2, rfN2O and stratospheric H2O 8 augmentations are needed. In any case, the classification is robust with respect to augmentations in the range of 2–10. Therefore, we do not think that the number of augmentations affects our classifications. The KPSS and Phillips–Perron statistics use the standard nonparametric Newey-West criteria for calculating robust standard errors. In practice we find that these statistics use about 4 autocorrelations, which is similar to our LM procedure for determining the number of augmentations for ADF.

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Discussion

We have shown that anthropogenic forcings do not polynomially cointegrate with global temperature and solar irradiance. Therefore, data for 1880–2007 do not support the anthropogenic interpretation of global warming during this period. This key result is shown graphically in Fig. 3 where the vertical axis measures the component of global temperature that is unexplained by solar irradiance according to our estimates. In panel a the horizontal axis measures the anomaly in the anthropogenic trend when the latter is derived from forcings of carbon dioxide, methane and nitrous oxide. In panel b the horizontal axis measures this anthropogenic anomaly when apart from these greenhouse gas forcings, it includes tropospheric aerosols and black carbon. Panels a and b both show that there is no relationship between temperature and the anthropogenic anomaly, once the warming effect of solar irradiance is taken into consideration.

However, we find that greenhouse gas forcings might have a temporary effect on global temperature. This result is illustrated in panel c of Fig. 3 in which the horizontal axis measures the change in the estimated anthropogenic trend. Panel c clearly shows that there is a positive relationship between temperature and the change in the anthropogenic anomaly once the warming effect of solar irradiance is taken into consideration.

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Fig. 3. Statistical association between (scatter plot of) anthropogenic anomaly (abscissa), and net temperature effect (i.e. temperature minus the estimated solar irradiance effect; ordinates). Panels (a)–(c) display the results of the models presented in models 1 and 2 in Table 3 and Eq. (13), respectively. The anthropogenic trend anomaly sums the weighted radiative forcings of the greenhouse gases (CO2, CH4 and N2O). The calculation of the net temperature effect (as defined above) change is calculated by subtracting from the observed temperature in a specific year the product of the solar irradiance in that year times the coefficient obtained from the regression of the particular model equation: 1.763 in the case of model 1 (a); 1.806 in the case of model 2 (b); and 1.508 in the case of Eq. (13) (c).

Currently, most of the evidence supporting AGW theory is obtained by calibration methods and the simulation of GCMs. Calibration shows, e.g. Crowley (2000), that to explain the increase in temperature in the 20th century, and especially since 1970, it is necessary to specify a sufficiently strong anthropogenic effect. However, calibrators do not re- port tests for the statistical significance of this effect, nor do they check whether the effect is spurious. The implication of our results is that the permanent effect is not statistically significant. Nevertheless, there seems to be a temporary anthropogenic effect. If the effect is temporary rather than permanent, a doubling, say, of carbon emissions would have no long-run effect on Earth's temperature, but it would in- crease it temporarily for some decades. Indeed, the increase in temperature during 1975–1995 and its subsequent stability are in our view related in this way to the acceleration in carbon emissions during the second half of the 20th century (Fig. 2). The policy implications of this result are major since an effect which is temporary is less serious than one that is permanent.

The fact that since the mid 19th century Earth's temperature is unrelated to anthropogenic forcings does not contravene the laws of thermodynamics, greenhouse theory, or any other physical theory. Given the complexity of Earth's climate, and our incomplete understanding of it, it is difficult to attribute to carbon emissions and other anthropogenic phenomena the main cause for global warming in the 20th century. This is not an argument about physics, but an argument about data interpretation. Do climate developments during the relatively recent past justify the interpretation that global warming was induced by anthropogenics during this period? Had Earth's temperature not increased in the 20th century despite the increase in anthropogenic forcings (as was the case during the second half of the 19th century), this would not have constituted evidence against greenhouse theory. However, our results challenge the data interpretation that since 1880 global warming was caused by anthropogenic phenomena.

Nor does the fact that during this period anthropogenic forcings are $I(2)$, i.e. stationary in second differences, whereas Earth's temperature and solar irradiance are $I(1)$, i.e. stationary in first differences, contravene any physical theory. For physical reasons it might be expected that over the millennia these variables should share the same order of integration; they should all be $I(1)$ or all $I(2)$, otherwise there would be persistent energy imbalance. However, during the last 150 yr there is no physical reason why these variables should share the same order of integration. However, the fact that they do not share the same order of integration over this period means that scientists who make strong interpretations about the anthropogenic causes of recent global warming should be cautious. Our polynomial cointegration tests challenge their interpretation of the data.

Finally, all statistical tests are probabilistic and depend on the specification of the model. Type 1 error refers to the probability of rejecting a hypothesis when it is true (false positive) and type 2 error refers to the probability of not rejecting a hypothesis when it is false (false negative). In our case the type 1 error is very small because anthropogenic forcing is $I(1)$ with very low probability, and temperature is polynomially cointegrated with very low probability. Also we have experimented with a variety of model specifications and estimation methodologies. This means, however, that as with all hypotheses, our rejection of AGW is not absolute; it might be a false positive, and we cannot rule out the possibility that recent global warming has an anthropogenic footprint. However, this possibility is very small, and is not statistically significant at conventional levels.

Full paper: http://www.earth-syst-dynam.net/3/173/2012/esd-3-173-2012.pdf

Data Appendix.

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