GLOBAL, HEMISPHERIC, AND REGIONAL TEMPERATURE ANOMALIES - HOW DIFFERENT ARE THEY AND WHAT DOES IT MEAN?

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Overview

Concerted research efforts by climate scientists have been (and are still being) undertaken in order to enhance the understanding of the relationship between forcings from greenhouse gas emissions and increases in temperatures. Contributions to this discussion also come from the perspective of climate econometrics. The focus of that literature so far has been on two questions: first, the analysis of time series properties of global and hemispheric temperature anomalies and, second, modelling the relationship between those temperatures and radiative forcing from greenhouse gases. As the latter is often done using cointegration models, it is obvious that the former is not merely a statistical exercise.

Cointegration between two (or more) time series implies that the series share the same common trend and, thus, this trend has to be described appropriately in the first place. The conventional view is that there is a cointegration relationship between temperature anomalies and greenhouse gas emissions which is linear and not characterised by structural breaks.

This paper's contribution to the literature is twofold. First, methods such as refined structural break tests, fractional integration models, and tests for (temporary) explosiveness are used in order to improve the understanding of time series behavior of temperature anomalies. The existing literature mainly deals with the question whether temperatures are characterised by deterministic (Estrada et al., 2013; Nature Geoscience) or stochastic (Kaufmann et al., 2013; Climatic Change) trends. In particular the two latter methods used in this paper are more flexible in terms of the order of integration of time series. Moving away from unit root tests as in Kaufmann et al. (2013), allows one to quantify the deviation from a random walk. Second, this paper not only uses data on global as well as hemispheric temperature anomalies, but also regional data. This is motivated by recent papers such as Chang et al. (2020) and Holt and Terasvirta (2020; both Journal of Econometrics). While the former propose a refined testing procedure for unit roots, the latter focus on co-shifting between hemispheric temperature series. It is worth highlighting that both papers point to differences in the time series behaviour in the Northern and Southern hemispheres. One way to interpret these findings is that overly focussing on global anomalies bears the risk of overlooking important details. As Brock and Xepapadeas (2017, European Economic Review) illustrate, this can result in sub-optimal climate policies. What is more, Diebold and Rudebusch (2021, Journal of Econometrics) vividly illustrate that the analysis of regional climate time series can yield surprising findings: They find strong evidence that the amount of Arctic Sea Ice declines at an increasing rate. What is more, they also find that the probability to witness an effectively ice-free Arctic Ocean at some point during the 2030s to be considerably higher than projected by global climate models. Thus, this paper's focus on regional temperature anomalies is well justified. This paper uses data from regions such as California, Florida, Tasmania, and others.

Methods

This paper uses established time series methods such as fractional integration models, structural break tests as well as tests for (temporary) explosiveness.

Results

The key findings of this paper can be summarised as follows: first, there are enormous differences in timing and number of structural breaks in temperature anomalies. While in global and hemispheric data, there are two breaks around the years 1925 and 1990, for the case of Tasmania, the two identified breaks occur at later points in time. What is more, for Prince Edward Island, the number of structural breaks is found to be three rather than two.

Second, while there is little evidence of fractional integration in global and hemispheric data - d is found to be close to one in each case, there is considerable heterogeneity across regions. In many regions, d is found to be around 0.5;

this implies long memory. For Prince Edward Island and Irkutsk, however, this estimate is considerably lower. Finally, evidence of (temporary) explosiveness is found in global as well as hemispheric temperature anomalies. This last finding illustrates the extent temperature changes have already reached.

Conclusions

The literature this paper directly contributes to is dominated by the discussion whether stochastic or deterministic trends are present in temperature time series. The findings of this paper not only imply that the statistical behaviour of global temperature anomalies seems to change over time, but also that temperature in different latitude areas and regions exhibit different time series properties. These insights are relevant for a literature that analyses the relationship between temperatures and radiative forcings from greenhouse gases using cointegration methods. Studies such as Agliardi et al . (2019) and Eroglu et al (2021) epitomise these research efforts. The results obtained in this paper challenge the conventional view that there is a stable and linear cointegration relationship. Finally, the observed differences in temperature changes across areas of higher and lower latitude have been discussed in the literature under the term polar amplification. The findings of this paper suggest that it is not just that there are differences in the magnitude of the temperature change, the temperatures are characterised by different time series properties. While this as such makes a contribution to the so-called climate econometric literature, there is also a more general message that emerges from this paper. In a number of recent papers, authors such as Dietz and Venmans (2019) express the concern that climate economic models insufficiently take into account recent climate science insights. The more complex temperature dynamics identified in this paper indicate that these concerns are more than justified. To summarise this differently, climate econometric studies analyse climate dynamics from a very different perspective. This helps not only evaluate climate economic models in specific, but perhaps even climate models in general. This altogether is of relevance in the context of climate policy design. Given the urgency of the problem, it is important to get this right.

References

Agliardi, E., Alexopoulos, T., & Cech, C. (2019). On the Relationship Between GHGs and Global Temperature Anomalies: Multi-level Rolling Analysis and Copula Calibration. Environmental and Resource Economics, 72(1), 109–133. https://doi.org/10.1007/s10640-018-0259-3

Brock, W., & Xepapadeas, A. (2019). Regional Climate Change Policy Under Positive Feedbacks and Strategic Interactions. Environmental and Resource Economics, 72(1), 51–75. https://doi.org/10.1007/s10640-018-0254-8

Chang, Y., Kaufmann, R. K., Kim, C. S., Miller, J. I., Park, J. Y., & Park, S. (2020). Evaluating trends in time series of distributions: A spatial fingerprint of human effects on climate. Journal of Econometrics, 214(1), 274–294. https://doi.org/10.1016/j.jeconom.2019.05.014

Diebold, F. X., & Rudebusch, G. D. (2021). Probability assessments of an ice-free Arctic: Comparing statistical and climate model projections. Journal of Econometrics. https://doi.org/10.1016/j.jeconom.2020.12.007

Dietz, S., & Venmans, F. (2019). Cumulative carbon emissions and economic policy: In search of general principles. Journal of Environmental Economics and Management, 96, 108–129. https://doi.org/10.1016/j.jeem.2019.04.003

Eroglu, B. A., Miller, J. I., & Yigit, T. (2020). Time-varying cointegration and the Kalman filter. Econometric Reviews. https://doi.org/10.1080/07474938.2020.1861776

Estrada, F., Perron, P., & Martínez-López, B. (2013). Statistically derived contributions of diverse human influences to twentieth-century temperature changes. Nature Geoscience, 6(12), 1050–1055. https://doi.org/10.1038/ngeo1999

Holt, M. T., & Teräsvirta, T. (2020). Global hemispheric temperatures and co-shifting: A vector shifting-mean autoregressive analysis. Journal of Econometrics, 214(1), 198–215. https://doi.org/10.1016/j.jeconom.2019.05.011

Kaufmann, R. K., Kauppi, H., Mann, M. L., & Stock, J. H. (2013). Does temperature contain a stochastic trend: Linking statistical results to physical mechanisms. Climatic Change, 118(3–4), 729–743. https://doi.org/10.1007/s10584-012-0683-2