Cointegration modelling of climatic time series

Submitted by

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I certify that all material in this thesis which is not my own work has been identified and that no material is included for which a degree has previously been conferred upon me.

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Abstract

This thesis has used bivariate time series models to investigate the long-run causal relationships between climatic variables. The cointegration approach, widely used in econometrics, has been shown to provide more reliable estimates for detection and attribution of trends in global mean temperature.

The traditional ordinary least squares (OLS) and total least squares (TLS) estimates from a static regression model are critically compared with the maximum likelihood (ML) estimates from a cointegrating vector autoregressive (VAR) model. Using synthetic data, generated by a simple stochastic model of the climate-carbon system, the estimates are compared against a known true value and evaluated in terms of key desirable statistical properties. Results show that the OLS estimates are strongly negatively biased, TLS estimates are less biased than OLS and positively biased compared to the VAR-ML estimates. TLS estimates are much more uncertain than those from the other approaches. VAR-ML estimates are less biased and more efficient compared to estimates from the traditional approaches.

Comparison has also been made using real historic global mean temperature data and climate model simulations from Coupled Model Intercomparison Project 5 (CMIP5) archive, and similar conclusions were found. All CMIP5 model runs were

found to have cointegrating relationship with historical observed temperature.

Another issue addressed in this thesis is the Granger causality between paleoclimate temperature and CO_2. Different extensions of the VAR model were used to assess Granger causality between the two variables. This research has shown that two-way causality (feedback) is occurring between temperature and CO_2, particularly during the glacial epochs. Impulse-response analysis was also carried out to quantify dynamic interactions between the variables. This showed that each variable reacted positively to a shock in another. For example, a 100ppmv increase in CO_2 can induce an increase of up to 4°C in temperature and a 1°C increase in temperature induces up to 2.3ppmv increase in CO_2 during glacial periods in particular. A shock to CO_2 during the warmer interglacial periods was seen to induce an explosive increase in both temperature and CO_2.

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Finally, I would like to dedicate this thesis to my late father, Abate Turasie. He shaped my childhood life into the way I am today, in a very remote rural village of Ethiopia. Dad, I will always miss you.

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