Reply to Holtsmark

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February 2, 2006*

*Updated April 2010 to take into account revisions to the paper since this exchange took place.

1 Introduction

Holtsmark's comment is ostensibly in reply to McKitrick (2005), but draws upon the context of technical material presented in McKitrick and Strazicich (2005). To rebut Holtsmark's comment it is not necessary to elaborate on or repeat that material, we merely need to explain the theoretical implications of stationarity and cointegration, and point out that Holtsmark has not made a proper empirical argument for his own position. Holtsmark erroneously equates "stationarity" with "stability," which he takes to mean the absence of a trend. By conflating these terms he bypasses the whole structure of our argument, and his counterargument does not actually address our findings. If the global per capita emissions level is stationary and trendless then the economic mechanism generating the data is poorly represented by the large majority of IPCC emission scenario models. Holtsmark appears to dispute the finding of stationarity, but instead of arguing the point he switches to discussion of "stability," relying for his counterargument on a tautological identity which has neither diagnostic nor predictive power.

2 Stationarity

The title of Holtsmark's 2nd Section poses a question about stationarity, but provides no evidence for, or even a definition of, nonstationarity. He is incorrect to say "one needs a theory in order to claim that the global per capita CO_2 emissions rate is a stationary variable." What one needs is a test statistic.

Stationarity has a mathematical definition (see, e.g., Hamilton 1994, Ch. 3) and economic theory does not enter into it. After all, the test statistics are the same regardless of whether the data are from economics, biology, engineering, meteorology, etc. Economic theory might be used to rationalize a finding of stationarity of an economic variable. In the updated version of our study (McKitrick, Strazicich and Lee 2010) we derive a Ramsay growth model with Hotelling price dynamics to show that constant or declining global per capita emissions is likely to be observed, which implies trend stationarity. But the immediate issue under dispute is empirical. Holtsmark apparently disagrees that emissions are stationary, but provides none of the conventional statistical tests in support of his view.

A time series is (covariance) stationary if its mean is not time-dependent, nor its variance, nor any of the covariances between observations separated by *j* intervals, for any integer *j*. In econometrics usage, the term "stationarity" is typically taken to mean covariance stationarity. In our work we are interested in *trend* stationarity, in which a series is stationary after removing a linear trend, or a linear trend with one or two break points. There are stronger forms of stationarity that also rule out time-dependence in higher moments. Economic time series data often depart from stationarity by exhibiting what are called *unit roots*, or random walks. This is a form of nonstationarity that economic theory predicts is typical in many price and output series drawn from competitive, forward-looking markets.

If a linear combination of nonstationary series is itself stationary, the data are said to be *cointegrated*. Cointegrating series may individually follow random walks, but cannot "wander" too far from each other and will tend to return to predictable neighbourhoods of each other. Cointegration of a group of nonstationary series implies that they are subject to a long-run equilibrating constraint. It is sufficient to establish cointegration to demonstrate that such a relationship is likely to exist among the series tested, even if the equations governing the constraint mechanism are unknown. An example is the price of gasoline in two nearby cities. While each price may appear to be a random walk over time, the market will prevent the price of gasoline in one city from departing too much from that in the other city, over the long run, hence the differences will tend to be stationary. Cointegration can be established strictly on statistical grounds, without having to specify and estimate a microeconometric model of the retail gasoline market.

Our discussion paper (McKitrick and Strazicich 2005) presents evidence of trends and substantial variability in national per capita CO_2 emissions, including possible nonstationarity in some national economies, whereas the global average is trend stationary and, as of 1980, trendless. This implies that per capita CO_2 emissions across countries are likely subject to an underlying equilibrating mechanism. In McKitrick, Strazicich and Lee (2010) we provide an explanation of what the underlying equilibrating mechanism might be.

In economics, a contrast between the properties of market-level and aggregated data often indicates a cointegrating relationship, and hence a cross-market equilibrating constraint. Our conclusions on this point are borne out in the available data and are plausible on grounds of economic theory. Holtsmark claims that our time series is too short to establish our conclusions. In a statistical sense, ceteris paribus, a shorter time series will have less power to reject the nonstationary null hypothesis. While we would certainly like to have had more data, the time series that we examine is long enough to reject the null and discriminate between the properties of the national and global data. As such, our data is long enough to provide support for our conclusions.

Stationarity also implies that the current distribution of global per capita emissions can be represented using a standard confidence interval. Holtsmark dismisses our estimation of uncertainties as being due to our "somewhat optimistic view." But the confidence interval is derived from the data, not from any optimism on our part. Holtsmark implies, implausibly, that we bear the burden of proving that the distribution will not change. Our position is that the burden of proof is on the IPCC to show why it will. To justify the SRES scenarios, the IPCC needs to account for the mechanisms that have hitherto constrained the distribution of per capita emissions, and then if they believe that the distribution will radically change in the next few years, they must explain why and show that the underlying mechanism will change in such a way as to generate a new emissions trajectory.

We do not rule out the possibility of future structural breaks. Indeed in our updated study (McKitrick, Strazicich and Lee 2010) we use both Monte Carlo simulation and Hierarchical Bayesian Modeling to evaluate probability distributions of future emission scenarios allowing for endogenous structural breaks. We show that the top half of IPCC emission scenarios remain highly improbable in all cases. In the absence of any evidence that the historical mechanisms governing emissions is undergoing a complete alteration, simply saying that such breaks might occur in the future does not amount to a counterargument to our findings. For one thing, the two breaks that occurred in the past both reduced the trend, first from positive and significant to positive and insignificant, then to negative and insignificant. This pattern suggests, if anything, the next break will cause the trend to become negative and significant. We do not assert this will be so, and nothing in our analysis makes this assumption, but we mention it to point out that merely invoking the possibility of future breaks may make the IPCC scenarios appear even more exaggerated than they already are, not less. In our paper we identify the worst-case scenario, from a historical perspective, but it still indicates a large fraction of the 40 SRES scenarios are too high.

3 Identities versus Models

Having failed to grasp the meaning interpretation of our empirical evidence, Holtsmark also criticizes us for not having developed a theory. We did so until a later version of the paper. What Holtsmark presents is not a model or a theory, it is merely an identity. His argument is a tautology and thus it cannot be used to explain historical changes or to predict the future.

The statement $E_1 + E_2 = E$ merely labels as "*E*" the sum of a quantity drawn from groups 1 and 2, as does the statement $N_1 + N_2 = N$. The manipulation

$$E = \frac{E_1}{N_1} N_1 + \frac{E_2}{N_2} N_2 \qquad [1]$$

adds nothing and is just a mathematical tautology. Dividing through by *N* still leaves us with an identity:

$$e = e_1 n_1 + e_2 n_2 , \qquad [2]$$

where lowercase *e* denotes 'divided by *N*' and n_i denotes N_i / N . The time derivative of [2]:

$$\dot{e} = \Sigma_i (e_i \dot{n}_i + \dot{e}_i n_i) \qquad [3]$$

also tells us nothing additional and is just a mechanical restatement of [2].

At this point, Holtsmark observes that nothing in [3] constrains $\dot{e}$, and, therefore, nothing constrains the behaviour of future global CO_2 emissions per capita. But [3] does not establish this. We have not even identified *E* with emissions and *N* with population. Equations [1—3] would be true regardless of the data we plug in: eggs and nails, elephants and newspapers, etc. Equations [1-3] are tautologies that must be true and have neither explanatory nor predictive power.

To turn [3] into an economic model of global CO_2 emissions would require developing a model of the mechanisms that govern emissions and population growth. This would, among other things, require expressions for derivatives like $\partial \dot{e}_1 / \partial \dot{n}_2$, which impose constraints on the way one variable changes in response to changes in another; in this case the way growth in the share of the population in region 2 affects emissions per capita in region 1. No such constraints are applied in Holtsmark's example, so developing country emissions are allowed to grow without impinging on developed country emissions. We argue that this is not only inconsistent with the historical data but theoretically implausible as well. Holtsmark presents a simulation where he assumes away this constraint, then concludes on the basis of the simulated data that the constraint does not exist. Unfortunately this simply begs the question.

In our empirical work we showed that any emissions scenario model, in order to be plausible, must account for the stationarity of global per capita emissions and the lack of a significant trend over the past 20 or more years. This is so even while national per capita emissions were subject to considerably larger variations, trends and drifts. Holtsmark's equation [3] is not such a model, it is a tautology and, as such, has neither explanatory power for the past nor predictive power for the future.

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