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**The choice of exchange rate in modelling the impact of climate change: A
response to the Castles-Henderson critique of the IPCC**

John Quiggin

**Australian Research Council Federation Fellow
School of Economics and School of Political Science and International Studies
University of Queensland**

EMAIL j.quiggin@uq.edu.au

PHONE + 61 7 3346 9646

FAX +61 7 3365 7299

<http://www.uq.edu.au/economics/johnquiggin>

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Introduction

Issues relating to climate change and possible mitigation options are highly controversial. In this context, a good deal of attention has been paid to claims that modelling undertaken by, or on behalf of, the International Panel on Climate Change is invalid because of the inappropriate use of market exchange rates to convert currency values for different countries.

In this paper, it is argued that these claims are unfounded, and that the effects on model outputs of the choice of exchange rate conversion procedure are likely to be small (provided the same procedure is used consistently). While the use of an inappropriate measure may bias results, effects on measures of income growth and on estimates of the income elasticity of demand for energy will offset each other, and the net effect cannot be predicted *a priori*.

Background

The problem of comparing bundles of goods, or dually, price vectors arises in a number of economic contexts, most notably the computation of price indexes for national economies, and comparisons of average living standards between national economies. There is no general solution to the ‘index number problem’, but there are a wide variety of partial solutions applicable in particular cases.

For comparisons between countries, a simple and readily applicable approach is to use market exchange rates to convert prices and values expressed in one currency into a second currency. This procedure is justified under the conditions of the ‘purchasing power parity hypothesis’. If trade in all goods and service is unrestricted and costless, arbitrage will ensure that relative prices are the same in all countries, and exchange rates will equalise purchasing power between countries.

In reality, the conditions of the purchasing power parity hypothesis are not satisfied, and two systematic violations of purchasing power parity are

commonly observed. These violations have led to the abandonment of market exchange rate conversions as a basis for comparisons of living standards.

First, exchange rates fluctuate widely over the short term and medium term, without any comparable change in output quantities, productivity or other real variables. Thus, attempts to measure relative changes in living standards between over periods of, say, five to ten years will be distorted by market exchange rate movements and the associated problem of choosing starting and ending dates for comparison.

Second, in a world where some goods (and services) are traded and others are not, the elimination of arbitrage (or near-arbitrage) opportunities tends to equalise purchasing power in relation to traded goods, rather than in relation to consumption bundles containing both traded and non-traded goods. Thus, exchange rate conversions will overstate relative living standards for countries where the ratio of non-traded to traded goods prices is relatively high. Since personal services are largely non-traded, and are relatively costly in wealthy countries, the effect is to overstate relative living standards for those countries, and therefore to overstate the inequality of living standards between countries.

In response to the problems of market exchange rate conversions, many attempts have been made to develop currency conversion procedures that would better reflect comparative living standards. The results of these procedures are commonly referred to as purchasing-power parity (PPP) exchange rates. It is important to bear in mind, however, that *this description is an aspiration, rather than a reality*. None of the competing methods for determining PPP exchange rates is entirely satisfactory.

The first stage in developing a PPP exchange rate is to derive comparable prices for individual items of consumption. All existing PPP exchange rates use the same dataset, prepared by the International Comparisons Project with contributions from individual statistical agencies. The quality of the data used at this stage varies widely, being very high for European countries at the core of the project, and much weaker for less developed countries.

The second stage is the computation of a multilateral price index. The

most commonly-used PPP index, prepared by the World Bank, uses the Geary-Khamis method. This method has significant practical advantages, but some important disadvantages in economic applications.

The most important of these disadvantages apply in relation to comparisons of growth rates between countries, or, more generally, comparisons of living standards expressed in ratio terms. Such comparisons are meaningful under the assumption that observed consumption data is generated by the choices of a common representative consumer with homothetic preferences (the Homothetic Axiom of Revealed Preferences).

Unfortunately, even when the data is consistent with the Homothetic Axiom of Revealed Preferences, PPP estimates derived using the Geary-Khamis method may not be consistent with any set of homothetic preferences (Dowrick and Quiggin 1997). Alternative methods, such as that can guarantee consistency but will not yield a result if the data set is inconsistent with the Homothetic Axiom of Revealed Preferences, and therefore have limited practical appeal.

The problems with the Geary-Khamis method, and with the choice of PPP index more generally have significant practical implications. The World Bank PPP indexes exhibit violations of the type described above. Compared to an index based on the homothetic approach, the World Bank PPP appears to over-correct the bias associated with market exchange rates, leading to an underestimate of global inequality. Moreover, in assessing such questions as whether the worldwide distribution of income became more or less unequal over the 1990s, different PPP indexes yield different answers (Achmal and Dowrick ...).

Despite these limitations, it is generally agreed that the use of PPP conversions is the best procedure for undertaking comparisons of living standards, and no competitor for the World Bank series has gained widespread acceptance.

The IPCC SRES scenarios

As part of the analysis supporting its Third Assessment Report – Climate Change 2001 , the IPCC produced a Special Report on Emissions Scenarios,

consisting of a variety of scenarios used to derive projections of emissions under 'business as usual' assumptions and under a variety of possible interventions. The scenarios incorporated various alternative parameter values and different assumptions about the path of economic development and the pace of technological change.

A feature common to all of the scenarios was that domestic product for different regions was expressed in \$US converted using market exchange rates. Further, the standard procedure in the scenarios was to postulate a growth scenario for the leading countries including the US, and to assume that income in other regions would gradually catch up to the levels prevailing in developed countries over the period 2000-2100.

Although the assumption of convergence appears plausible, it is obviously possible that the pattern of divergence observed for much of the 19th and 20th centuries will reassert itself, and that less-developed countries will fail to grow. However, most of the policy discussion surrounding international action on climate change (including much criticism of the Kyoto protocol) is premised on the assumption that output and energy demand in less-developed countries will grow to levels more comparable with those in rich countries. It seems reasonable that supporting modelling should embody the same assumption.

Although the scenarios commonly extended to 2100, as did other , most showed a decline in emissions after 2050, and most of the important implications for climate change could be summed up in terms of cumulative emissions to 2050. This is relevant because some of the features of the scenarios that have been the subject of vigorous dispute, such as the question of whether rapid rates of growth can be sustained for a century or more (as opposed to the several decades of rapid growth observed in a range of Asian countries in the second half of the 20th century), are of little practical significance in terms of the uses to which the scenarios are put.

The Castles-Henderson critique

The SRES simulations have been criticised by Ian Castles, a former

Australian statistician, working with David Henderson, former chief economist of the Organization for Economic Co-operation and Development (OECD). The critique emerged in a somewhat confused fashion, including letters from Castles and Henderson to the IPCC Chairman, Dr Rajendra Pachauri in 2002, an opinion piece by Castles published in the *Canberra Times* newspaper and a presentation to an IPCC Working Group in 2003. All of these documents were supplied to and published by the Lavoisier Institute <http://lavoisier.com.au/>

The various elements of the critique were collected in an article published in the journal *Energy and Environment*, but by this time the critique had already been widely publicised, for example in the *Economist* magazine in February 2003.

As a result of this history, it is not easy to summarise the critique. It is clear, however, that the central issue is the decision by the IPCC SRES groups to use market exchange rates in conversions for their scenarios. Castles played an important role in the development of the International Comparisons Project and had previously made highly effective criticisms of the United Nations Development Project for the use of exchange rate conversions in comparisons of living standards. Hence, his contributions on this issue must be taken seriously.

As regards exchange rates, the main points of the Castles-Henderson critique may be summarised as follows

- * the use of market exchange rates in the SRES scenarios is inappropriate and PPP exchange rates should always be used

- * the effect of using market exchange rates is to overstate the income gap between poor and rich countries and therefore the rate of growth required to achieve convergence over any given time period

- * the result is to inflate the likely level of emissions

- * these effects are so substantial as to invalidate the SRES exercise

The fourth point is crucial in considering public discussion of the Castles-Henderson critique. There are many debatable assumptions in any modelling procedure, but most make only a modest difference to the results. In his initial critique, Castles referred to “fantastic assumptions”, “astronomical” projections

of growth rates and “extraordinary results”. These characterisations have been widely publicised.

Response to the Castles-Henderson critique

In this submission, it is argued, contrary to the claims of Castles and Henderson that

* In a fully-disaggregated multi-sector general equilibrium model, aggregate index numbers play no role and the choice between PPP and MER conversion of income levels does not arise

* In an aggregate model with consistent specification, the effects of the choice of conversion measure on energy demand should approximately cancel out, and the sign of the net effect is unpredictable.

* Available evidence suggests that the effects of projected emissions arising from the choice between PPP and ME exchange rates are small in comparison to the uncertainties represented by the range of scenarios and to the likely impacts of other debatable modelling choices.

The case of a disaggregated multi-sector general equilibrium model.

Consider an general equilibrium model in which commodities are fully disaggregated (say, to the level of disaggregation feasible with the data in the International Comparisons Project). Consumption decisions for a representative individual consumer depend on a vector of resource endowments and competitively determined prices, and similarly for production decisions. In a model of this kind, there is no necessary role for an ‘income’ variable. The budget constraint is specified in a disaggregated fashion, and welfare can be inferred directly from preferences, with no need for an income aggregate.

It is clear, in a multi-country model of this kind, that it does not matter whether all prices are expressed in home country prices, or whether some conversion procedure is used to express them in terms of a common currency such as \$US. Any change in the price unit, consistently applied, will be neutral, assuming that the usual property of homogeneity of degree zero for demand as a

function of prices is maintained (that is, there is no money illusions).

In practice, no real-world model achieves this degree of disaggregation and nearly all use an income variable as an argument in demand functions. But the fact that the choice between MER and PPP measures arises only as an artifact of aggregation suggests that the impact of this choice is likely to be small, provided aggregation is undertaken in a logically consistent fashion.

The case of an aggregate model

Now consider the opposite extreme, a model in which there are only two variables for each country: income, and energy consumption (assumed proportional to emissions). The relationship between energy consumption and income is estimated on the basis of cross-section or historical panel data, and growth in energy consumption is simulated on the basis of projections of income growth, incorporating the assumption that poor countries will catch up to rich ones.

As observed by Castles and Henderson, the use of market exchange rates in converting currencies will lead to an overstatement of the initial gap between rich and poor countries, relative to World Bank or other PPP conversions. This in turn increases the measured rate of growth required for the poor countries to catch up. Castles and Henderson infer that 'total projected world GDP is pushed up; and this in turn is reflected in higher projected emissions'.

The problem with this claim is that the choice of conversion measure also affects the estimated relationship between income and energy consumption. Since measurements of energy consumption are made in physical terms and are not affected by the choice of income unit, the larger the measured gap in income between poor and rich countries, the lower must be the estimated elasticity of energy consumption relative to income.

The two effects will work in opposite directions, and with approximately offsetting impacts. Since different data transformations imply different estimation procedures it is unlikely that they will cancel exactly, but there is no presumption as to which effect will dominate when simulation is undertaken

outside the range on which parameters were originally estimated.

Empirical evidence

A number of studies have examined the effect of the choice of exchange rate on projected emissions. Some, such as Manne and Richels (2003) have found negligible effects, while others such as McKibbin, Pearce and Stegman (2004) have found that the use of MER estimates yields an increase in estimated emissions of 22 per cent relative to PPP by 2050. Nordhaus, quoted in the House of Lords Economics Committee Report, concludes that “The jury is out on how much using PPP as compared to MER will affect aggregate emissions”.

These differences are modest relative to the differences between scenarios and the difference between emissions under ‘business as usual’ and under intervention, and to the typical differences in solution values arising in different runs of long-term simulation models using alternative functional forms or closure assumptions. It is quite possible that alternative modelling procedures would yield instances where the choice of MER conversions yielded lower projected emissions, for example because the elasticity of demand for energy might be modelled to decline with income.

Concluding comments

PPP measures are undoubtedly a superior method of converting national income statistics for the purposes of international welfare comparisons. However, there is no reason to suppose that the choice between PPP and market exchange rate conversions makes a substantial difference to projections of emissions in scenario-based analysis such as that of SRES.

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