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The use of PPP or MER in the construction of emission scenarios is more than a question of "metrics"

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FNs klimapanel (IPCC) publiserte i 2000 en rapport om utslippsscenarier frem til 2100 (Special Report on Emissions Scenarios, SRES, IPCC, 2000). Etter at Ian Castles og David Henderson for to år siden påsto at rapportens scenarier var basert på dårlig fagøkonomisk håndverk og av den grunn har gitt urimelig høy utslippsvekst, har rapporten vært gjenstand for debatt. Et sentralt punkt i kritikken fra Castles og Henderson var at nasjonale BNP-data ble konvertert til en felles valutaenhet ved bruk av markedsbaserte valutakurser (market exchange rates, MER). Kritikerne mente man i stedet burde korrigert for kjøpekraftspariteter (purchasing power parities, PPP). I responsen fra IPCC het det blant annet at valget mellom MER og PPP kun er et spørsmål om valg av måleskala og er like viktig som valget av Celsius eller Farenheit som måleenhet i temperaturmåling. I denne artikkelen adresseres både kritikken fra Castles og Henderson og responsen fra IPCC. Artikkelen bygger på vårt tidligere publiserte argument om at det er misvisende i noen henseender å ikke PPP-korrigere i den aktuelle kontekst. Men på den annen side mener vi at denne feilen ikke har gitt opphav til vesentlig overdrevne utslippsfremskrivninger. Likevel konkluderer vi med at valget av MER eller PPP som konverteringsmetode er langt viktigere enn valget av Celsius eller Farenheit i temperaturmåling. Avslutningsvis diskuteres hvorvidt SRES-scenariet med den laveste utslippsbanen representerer en rimelig nedre grense for fremtidige globale klimagassutslipp.

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Abstract:
The Intergovernmental Panel on Climate Change (IPCC)'s Special Report on Emissions Scenarios (SRES, IPCC, 2000) has been a matter of debate since Ian Castles and David Henderson claimed that the scenarios were based on unsound economics giving rise to improbably high emission growth. A main point in their critique was that the scenario-makers converted national GDP data to a common measure using market exchange rates (MER) rather than purchasing power parity rates (PPP). IPCC responded to the critique by claiming that the use of PPP or MER based measures is just a question of "metrics", as important as the "switch from degrees Celsius to Fahrenheit". This paper addresses both the critique from Castles and Henderson and the response from the IPCC. It builds on our earlier argument that the use of MER-based measures, although misleading in some respects, probably have not given rise to seriously exaggerated emission forecasts because comparing regional income levels by the use of MER has two types of implications that draw in different directions and effectively neutralize one another. Nevertheless, we argue that the choice between MER or PPP in the construction emission scenarios is far more than just a question of metrics. Finally, we discuss whether the SRES scenario with the lowest cumulative emissions is a reasonable lower limit with respect to global emission growth.

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1 Introduction

In a series of letters made public during 2002, Ian Castles and David Henderson, C&H in the following, criticized the Intergovernmental Panel on Climate Change (IPCC)'s Special Report on Emissions Scenarios (SRES).1 In this paper we will comment on three points of the critique put forward by C&H:

1. that emission growth was overestimated because national and regional GDP-levels in the majority of the scenarios were converted to a common currency by market exchange rates (MER) instead of purchasing power parity indexes (PPP-indexes2)
2. that the information on PPP-corrected measures actually included in SRES was "mislabelled"
3. and that the B1 scenario family, which has the lowest accumulated emissions of greenhouse gases (GHGs) in the SRES, may not really represent a lower limit with respect to GHG emissions.

The IPCC responded to the critique from C&H through a press statement 8 December 2003 (IPCC, 2003). This press statement is characterized by the attitude that the choice between PPP and MER is immaterial. It is for example maintained that the economy does not change by using a different metrics (PPP or MEX[3]), in the same way that the temperature does not change if you switch from degrees Celsius to Fahrenheit.

The overall aim of this paper is to argue against this oversimplification. The use of purchasing power parity correction is definitely essential in relation to long-term greenhouse gas (GHG) emission scenarios. In our view, it is a fortunate coincidence that the application of MER-based GDP data did not cause serious overestimation of future emissions in the SRES report. This point is addressed in section 2, which also provides some general arguments in relation to reasons why purchasing power parity correction is important in relation to long-term greenhouse gas (GHG) emission scenarios.

Sections 3-5 then address each of the points of critique raised by C&H above, respectively. Section 6 provides some conclusions.

2 Why are PPP - corrections more than just "metrics"?

Two contributions to the debate related to the SRES scenarios have revealed that the concept of PPP correction is not sufficiently understood and accepted. The IPCC press statement of 8 December 2003 (IPCC, 2003) is one example. The other example is the paper by Manne and Richels (2003), which confuse the so-called PPP doctrine, see below, with the methods for PPP corrections, cf. Heston (2004).4 It is therefore appropriate at the outset to present some basics related to the concept of purchasing power parities.

On a regular basis *The Economist* publishes prices of Big Mac hamburgers from a selected number of countries converted by market exchange rates to US dollars (the Big Mac Index).

[1] The letters were later published in *Energy & Environment* (Castles and Henderson, 2003a), see also Castles (2004).

[2] Cf. for example Gulde and Schulze-Ghattas (1993).

[3] MEX = Market exchange rate. We denote this by MER in this paper.

[4] Manne and Richels (2003) interpret conclusions related to the dismissal of the PPP doctrine, cf. among others Rogoff (1996), and thus, use them as arguments against PPP correction. However, the dismissal of the PPP doctrine is an argument in favour of PPP corrections, not the opposite.

Table 1 contains some numbers from the Big Mac Index of 23 April 2002. The table illustrates to what extent price levels vary substantially across countries, or, put differently, the large variations of the purchasing power of a US dollar across countries.

Table 1. The Big Mac Index. 23 April 2002.

		Big Mac prices	
	Local currency	In local currency	In USD using MER
Argentina	Peso	2.50	0.78
China	Yuan	10.50	1.27
Poland	Zloty	5.90	1.46
South Korea	Won	3100	2.36
United States	USD	2.49	2.49
Switzerland	SFr	6.30	3.81

Source: The Economist (2002)

The original purpose of publishing the Big Mac Index was to provide an informal and easily understood guide to likely future changes in market exchange rates. This is based on the so-called Purchasing Power Parity Doctrine, put forward by the Swedish economist Gustav Cassel, which claimed that "As long as anything like free movement of merchandise and a somewhat comprehensive trade between two countries takes place, the actual rate of exchange cannot deviate much from this purchasing power parity" (Cassel, 1918, p. 413). To put it simply: in the long term, a US dollar should be able to buy the same bundle of goods and services everywhere, at least if there is comprehensive trade between countries. Hence, according to Cassel's theory, the Big Mac Index could give some indications about future movements in exchange rates.

Unfortunately, Cassel was wrong. Currently, 86 years later, the price-level differences are of the same order of magnitude as they were in Cassel's time. Theories related to this paradox make up the topic of a considerable body of literature; cf. for example Rogoff (1996). One important implication is that conversion by market exchange rates is, and probably will continue to be, a misleading method if the purpose is to measure and compare output and income levels, or emission intensities in production, across countries and regions.

Table 1 is also useful for the illustration of the term PPP correction. The first column of the table shows local-currency prices of a Big Mac. The second converts them into US dollars, using MER. The average price of a Big Mac in USA was 2.49 USD in April 2002. The cheapest was in Argentina (0.78 USD), while the most expensive were in Switzerland (3.81 USD). Hence, almost identical products are priced very differently in different parts of the world if we use market exchange rates as the basis for price comparisons. The Big Mac index does of course not represent any serious research. However, investigations have revealed that on a broad basis almost identical products are priced very differently across countries and regions.

The implication of this is that national accounts, which apply prices as weights when national production and income levels are calculated, provide significantly misleading indicators of for example relative income levels, if GDP levels are converted to a common currency using market exchange rates.

Table 2. Income level and emission intensity in three regions. Measured by MER and PPP. Percentage of the OECD level in 1990.

	GDP/cap		CO_2/GDP	
	MER	**PPP**	**MER**	**PPP**
Soviet Union and Eastern Europe (REF)	14.0 %	38.4 %	685 %	249 %
Asia	2.8 %	11.5 %	444 %	108 %
Middle East, Africa and Latin America (ALM)	8.3 %	19.4 %	220 %	94 %

Source: IPCC (2000).

Table 2 illustrates further the importance of PPP corrections. The first two columns show per capita GDP in three world regions as percentage of per capita GDP in OECD as of 1990, measured by using MER and PPP respectively. Because the PPP-corrected GDP levels represent the best available estimates of real income differences between the regions, these two columns illustrate to what extent the income gap between rich and poor countries is overstated by the use of MER.

In relation to emission scenarios, however, the two last columns are of even greater interest, as they show to what extent the emission intensity gaps are overstated by the use of MER. In fact the significant emission intensity gap between the OECD and the developing countries in 1990, which appears when MER are applied, is considerably reduced as PPP data are applied. Thus, the potential for technological catch-up in the less developed regions may not be as large as the emission intensity estimates based on MER converted GDP numbers would suggest.

In the SRES scenarios, the most important driving force is the income gap between OECD and the rest of the world. The importance of an accurate representation of that income gap, not least at the starting point of the scenarios, is then rather obvious. From table 2 it is apparent that the choice between PPP and MER is essential in the determination of both the income gap and the emission intensity gap. It is therefore our view that the statement from IPCC that "the economy does not change by using a different metrics (PPP or MEX)" is both confusing and misleading.

It should be clear that both MER- and PPP-based measures should play important roles in economic models used for generating long-term emissions scenarios. In general, these models contain endogenous variables determined during the simulations, a set of exogenous assumptions determined outside the models, and a set of parameters determining the behaviour of the economic agents in the models. The parameter values are usually established by estimations or calibrations of the model equations to historical data and these are, where relevant, expressed in MER. For consistency, the model simulations will therefore often have to be carried out using MER to convert to a common unit where necessary.

However, in *designing* the scenarios, i.e. in determining the exogenous variables, one is not always free to choose between MER or PPP. In the case of SRES, where an important design criterion for the scenarios is the income gap closure between the rich (OECD) and poor (non-OECD) regions, it is intuitively clear, as C&H point out, that interregional comparisons of income levels are best done by using PPP.

However, in reporting the actual output of the models, one is once again free to choose either MER or PPP in converting e.g. GDP values to a common unit.

It is crucial for the debate that the uses of MER and PPP as conversion factors in these steps are distinguished. There is no doubt that it is far more than a question of "metrics".

3 Two "wrongs" may make a "right"

C&H argue that using MER-based GDP-measures makes developing countries generally appear to be poorer than they actually are. This is essential in the SRES context because the size of the income gap between rich and poor countries is a key driving force in the scenarios. A basic premise has been that the income gap has to be considerably reduced by the end of the century. Although C&H claim that the assumed degree of gap closure might be too rapid, they agree that such a convergence is a reasonable premise for the scenarios. Their main objection is that an overstated income gap in 1990/2000 gives rise to exaggerated projected economic growth in the poor countries in order to reduce the gap "with corresponding implications, other things being equal, for energy use and for CO2 emissions." (Castles and Henderson, 2003a, p. 169).

In Holtsmark and Alfsen (2005) our concern was that, even if it is accepted that the SRES scenarios overstate the GDP growth in the poor countries, it is far from obvious that this implies overstated emissions growth in SRES. As concluded in McKibbin et al. (2004a,b), whether the use of MER in the SRES scenarios has caused overestimation of future emissions depends on the other assumptions made in the scenario construction, not least to what extent the technological change is made endogenous by other assumptions and driving forces. C&H do not really analyze that question. They just maintain that the SRES scenarios overstate emissions growth because "the partial derivative of emissions with respect to output is positive, since it is the output – the real GDP and final expenditure – that gives rise to the emissions" (Castles and Henderson, 2003b, p. 428).

In Holtsmark and Alfsen (2005) we argued that there are not one, but *two* gaps to be closed in the scenarios. The first one is the income gap. The second one is the technology or emission-intensity gap. Using MER implies an overestimation of the economic growth necessary to close or narrow the income gap. On the other hand, it also represents a corresponding overestimation of the *potential* for energy efficiency improvements in the developing countries. In other words, the use of MER overvalues the energy efficiency improvements that will take place in the developing countries in a process where the emission-intensity gap is narrowed. Hence, comparing regional income levels by the use of MER has two types of implications that draw in different directions with respect to expected emission levels; in fact, they neutralize one another. Holtsmark and Alfsen (2005) thus argue that if gap closure is accepted as the driving force behind both economic growth and reduction of emission intensities in the non-OECD countries, the use of MER when converting national GDP levels to a common currency does not necessarily imply an overestimation of future emissions. Although we accept that the use of MER-based data in SRES could be criticized, we do not believe that this has led to an overestimated emission growth in the poor countries. The reason is that the MER-based data also overstate the emission intensities in the poor regions, and consequently also the potential for emission reductions in those regions. Below, this argument is illustrated by a numerical example.

The numerical example relates to the B1 IMAGE scenario, cf. IPCC (2000). We use this scenario as a point of departure because C&H (2003a), p. 169, also use this scenario (see also Castles and Henderson, 2003b). The numerical example is set out in tables 3 and 4. We have added a foot script in order to clarify whether we refer to GDP measures based on MER or PPP.

There were two noticeable gaps between rich and poor regions in 1990. First, there was an income gap as the ratios of per capita GDP in the OECD region to that of the non-OECD countries were 20.7 and 8.1 when we apply the MER- and PPP-based GDP measures, respectively. Second, there was an emission-intensity gap as the ratios of per GDP unit CO_2

emissions (tC/10^3 USD) in the non-OECD region to that of the OECD countries were 4.1 and 1.6 when we apply the MER- and PPP-based GDP measures, respectively. [5]

The following four key assumptions are important driving forces in the B1 IMAGE scenario:

1. GDP_{MER} per capita of OECD increases by a factor of 3.9 between 1990 and 2100.
2. The ratio of per capita GDP_{MER} in the OECD countries to that of the non-OECD countries drops from 20.7 to 1.9 over the same period.
3. The emission intensity in the OECD region drops from 171.5 tC/10^3 USD_{MER} in 1990 to 13.4 tC/10^3 USD_{MER} in 2100.
4. The MER-based emission intensity gap drops from 4.1 to 1.2 by the end of the century.

Table 3. The B1 IMAGE as set out in IPCC (2000) using market exchange rates (MER). B1 IMAGE adjusted using purchasing power parity (PPP).

	PPP-correction	Population	GDP (MER)	GDP (PPP)	GDP/Cap. (MER)	GDP/Cap. (PPP)	CO_2	CO_2/GDP (MER)	CO_2/GDP (PPP)
		10^6	10^{12} USD		10^3 USD/capita		10^9 tC	tC/10^3 USD	
1990									
OECD	1.00	799	16.5	16.5	20.6	20.6	2.83	171.5	171.5
Non-OECD	2.55	4 480	4.5	11.4	1.0	2.5	3.2	706.2	276.7
World	1.33	5279	21.0	27.9	4.0	5.3	6.0	285.6	214.6
Income gap between OECD and non-OECD					20.7	8.1			
Emission intensity gap between OECD and non-OECD								4.1	1.6
2100 SRES B1 IMAGE (MER-based)									
OECD	1.00	1032	82.3	82.3	79.7	79.7	1.1	13.4	13.4
Non-OECD	2.55	6016	246.1	628.0	40.9	104.4	4.1	16.7	6.5
World	2.16	7048	328.4	710.3	46.6	100.8	5.2	15.8	7.3
Income gap between OECD and non-OECD					1.9	0.8			
Emission intensity gap between OECD and non-OECD								1.2	2.0
Mean annual growth rates for OECD and Non-OECD regions 1990-2100. Percentage									
OECD	0.0	0.2	1.5	1.5	1.2	1.2	-0.9	-2.3	-2.3
Non-OECD	0.0	0.3	3.7	3.7	3.4	3.4	0.2	-3.3	-3.3
World	0.4	0.3	2.5	3.0	2.3	2.7	-0.1	-2.6	-3.0

OECD refers to OECD as of 1990. Non-OECD includes REF as the reforming economies, i.e. the former Soviet Union and Eastern Europe. ALM as Africa, Latin America and the Middle East and ASIA as Asia excluding OECD countries.

[5] There is no significant emission intensity gap between OECD and the developing countries if PPP-corrected GDP measures are applied. However, there is a significant emission intensity gap between the reforming economies encompassing former Soviet Union and the rest of the world, cf. figure 1.

Table 4. An alternative B1 scenario of 2100 using SRES gap closures and purchasing power parity (PPP).

	PPP-correction	Population	GDP (MER)	GDP (PPP)	GDP/Cap. (MER)	GDP/Cap. (PPP)	CO_2	CO_2/GDP (MER)	CO_2/GDP (PPP)
		10^6	10^{12} USD		10^3 USD/capita		10^9 tC	tC/10^3 USD	
OECD	1.00	1032	82.3	82.3	79.7	79.7	1.1	13.4	13.4
Non-OECD	2.55	6016	96.4	246.1	16.0	40.9	4.1	42.5	16.7
World	1.84	7048	178.7	328.4	25.4	46.6	5.2	29.1	15.8
Income gap between OECD and non-OECD					1.3	**1.9**			
Emission intensity gap between OECD and non-OECD								3.2	**1.2**
Mean annual growth rates for OECD and Non-OECD regions 1990-2100. Percentage									
OECD	0.0	0.2	1.5	1.5	1.2	1.2	-0.9	-2.3	-2.3
Non-OECD	0.0	0.3	2.8	2.8	2.6	2.6	0.2	-2.5	-2.5
World	0.3	0.3	2.0	2.3	1.7	2.0	-0.1	-2.1	-2.3

IPCC (2000) does not provide information on the development of the exchange rates in the B1 IMAGE scenario. We have therefore in this numerical example assumed that the PPP-correction factors are constant from 1990 to 2100.[6] In table 3 we have calculated income levels and emission intensities measured in GDP_{PPP} terms based on the SRES scenario growth rates.

Suppose now that we instead follow the thinking behind the numerical example set out in Castles and Hendersen (2003a, p. 169), and assume that the income gap in 2100 (the 1.9 ratio) is applied, but to the PPP-based GDP measures. The economic growth factor (the 3.9 ratio) of the OECD region is kept unchanged. The emission intensity gap (the 1.2 ratio) is applied, but to the PPP-based intensity measures. This numerical example is set out in table 4. For simplicity we report on only the aggregate regions OECD and non-OECD. The result is, in accordance with the criticism put forward by C&H, that the world's GDP in 2100 is reduced by almost 50%.

However, as claimed above, the CO_2 emissions are unaffected by the change from MER- to PPP-based assumptions. The important point is that the use of MER-based income comparisons in 1990 implies that *both* the income gap and the emission intensity gap are overstated. The use of MER-based income comparisons leads to overstated economic growth in the poor regions as well as the energy efficiency improvements in these regions. Thus, these two inaccuracies cancel each other out.

For an analytical discussion of this argument, see Holtsmark and Alfsen (2005).

[6] This is obviously a simplification, as structural changes in the different economies will alter this relationship. Furthermore, as the next two sections demonstrate, a reasonable interpretation of the SRES scenarios is that they assume that the currencies of the poor regions appreciate against the currencies of the OECD regions. Our argument nevertheless holds, cf. Holtsmark and Alfsen (2004).

4 The use of PPP in SRES: Are the PPP – based series in SRES "mislabelled"?

In their restated and extended critique of SRES (Castles and Henderson, 2003b), C&H responded to the fact that SRES presented a set of PPP-corrected emission scenarios, as pointed out by Nakićenović *et al.* (2003). However, C&H claim that the presented PPP-corrected emission scenarios have characteristics that are in conflict with what would be reasonable properties of soundly based PPP scenarios. We argue that the PPP-based scenarios have some reasonable characteristics but that they reveal that the MER-based scenarios are based on changing exchange rates. That implies that the MER-based GDP-series in SRES do not represent real economic growth because the changing market exchange rates influence them strongly.

Before we discuss the PPP-based series in SRES, a short overview of the different SRES scenarios is appropriate. Altogether there are four so-called marker scenarios in SRES. These four qualitative storylines – labelled A1, A2, B1, and B2 – illustrate possible futures with varying emphasis on material welfare (the A-scenarios) versus concern for cultural and environmental values (the B-scenarios), a high degree of globalization (the 1-scenarios) versus a more fragmented and regionally self-sufficient kind of future (the 2-scenarios), respectively. Within each family of scenarios the simulations share common or "harmonized" assumptions on key issues like global population, gross world product, and final energy use. Six modelling teams developed a total of 40 SRES scenarios. Only the MESSAGE model, developed and operated by IIASA, provides information on assumptions related to PPP-corrections. It is definitely somewhat surprising that the other five models ignore information related to PPP-corrections. However, because the MESSAGE model is applied to each of the four scenario families, it is possible for the interested readers of the SRES report to get an impression of how PPP-corrections would have changed the four story lines.

Nakićenović et al. (2003) and Grübler et al. (2004) emphasize that all the MESSAGE scenarios provide GDP data based on both PPP and MER. However, C&H (2003b) did not accept the PPP corrections of the MESSAGE scenarios and maintained that "the MESSAGE GDP series expressed in PPP terms is not such a measure – it is mislabelled". (Castles and Henderson, 2003b, p. 423, second paragraph). A further investigation of the PPP series will, from our point of view, reveal that the scenarios are better founded than claimed by C&H. In our view some "unsound economics" might, however, be related to the MER-based GDP-series.

C&H put forward two arguments for why the PPP corrections of GDP in MESSAGE are unsound. First, they claim that the "proportionate changes shown in this series for the OECD 90 group of countries are identical with those for the MER-based series, which they would not be if they were genuine measures of GDP" (p 422). If "proportionate changes" is interpreted as growth rates, however, the two series are different. Nevertheless, the differences might be too small in relation to what is reasonable, cf. Ryten (2004). However, this is probably an inaccuracy related to the level of aggregation and, in our view, does not reveal a very serious weakness of the PPP scenarios.

The second reason C&H claim that the PPP corrections of GDP in MESSAGE are unsound is because with respect to GDP measures for the developed and "for the developing regions, the divergences between the two series are impossibly great". (p 423, first paragraph.) This is related to the assertion from C&H that "any difference between them can only arise from the use of different weighting systems." (p 422).

As far as we can see, this claim by C&H is misleading because there is another source of divergence that may explain the large difference between the two series – namely price levels. The important point is that the scenario makers obviously have assumed that the price levels

in the developing countries, measured by MER, converge towards the price levels of the OECD region. In other words, the conversion factors using MER and PPP converge. In that process, the exchange rates of the local currencies of the developing countries appreciate relative to USD. It is also important to note that the GDP series of the developing countries are measured in USD at *current* or nominal MER.[7] Due to the large differences in price levels in different regions in the base year (1990), that process should imply that the PPP-corrected GDP growth in the developing regions is considerably higher than the MER-based growth-measures in these regions.

The case can be illustrated by some numerical examples set out by C&H. They point to the fact that the GDP_{MER} of the developing countries in B1 IMAGE is projected to increase by a factor of 65 between 1990 and 2100. The effect of this is to reduce the ratio of projected GDP_{MER} per capita in the industrialized countries to that in the developing countries from 16.7 to 1.8. (The corresponding numbers for the B1 MESSAGE scenario are 16.1 and 1.7.)

However, C&H point to the fact that the MER-based ratios are misleading and that the PPP-based GDP-ratio of 1990 would have been around 6.2. If this PPP-based ratio has to be reduced to the postulated level of 1.8 in 2100, the factor-increase in GDP_{PPP} of the developing countries would be 25 rather than 65. If, however, C&H had taken the PPP-corrected GDP-series as the starting point of their discussion, they would have discovered that 25 is exactly the factor by which GDP_{PPP} of the developing countries is increased in B1 MESSAGE. In other words, the real GDP of the developing countries is increased by a factor of 25 in the B1-scenarios, not 65 as claimed by C&H. Hence, in a sense C&H fight against a non-existent enemy.

In line with the above numerical examples, C&H (2003b, pp. 424–427) present a set of figures from the SRES-scenarios in order to strengthen their view that the scenarios overstate likely economic growth in the developing countries. The argumentation is consequently based on MER-based GDP series, while the PPP-corrected GDP series are accordingly ignored. If we accept that the MER-based GDP series are based on changing market exchange rates, the entire argumentation is unfortunately senseless. The point is that real economic growth in the scenarios, which appears only from the MESSAGE scenarios, is considerably smaller than the MER-based GDP growth.

Thus, it is our view that there are reasons to believe that the PPP-series from the MESSAGE scenarios are basically well founded, although these series, like all model simulations, have their weaknesses and are affected by a series of simplifying assumptions.

However, if the PPP-series are reasonable, the MER-based series of the non-OECD countries have been reported in USD at current or nominal market exchange rates. It is important to underline that this mode of reporting can be quite misleading because it means that the reported GDP_{MER} series do not represent real income/production changes, but rather nominal income/production changes. What is important here is that this concerns all the scenarios in SRES, which therefore provides a highly misleading picture and is worthy of criticism.[8]

[7] If the conversions instead had been based on a constant exchange rate, C&H would be right.

[8] A comparison of the MESSAGE GDP_{MER}-series will show that they are quite similar to the corresponding GDP_{MER}-series from the other models. Hence, if the MESSAGE GDP_{MER}-series do not represent real economic growth, neither do the other GDP_{MER}-series.

5 Does the B1 scenario represent a lower limit?

This section provides a short discussion related to the question raised by C&H on whether the B1 scenario, which is the SRES scenario with the lowest cumulative emissions, represents a lower limit with respect to future emissions of GHGs. It is our view that this has to be approached through a look at the development of some basic variables, such as population growth, average real economic growth, energy intensities and the share of fossil fuels in global energy supply. In this section we go beyond the discussion related to conversion factors and provide a short overview and discussion of a number of some basic assumptions in the B1 scenario.

In this regard it can be useful to draw attention to some relevant key variables related to this discussion, cf. figure 1. This figure shows, first, the considerable degree of emission intensity improvements that are assumed to take place in all regions in the B1 scenario during the coming century. It is difficult to judge whether this represents a lower limit or not. Although there is a considerable degree of convergence of emission intensities between regions (both in absolute and relative terms), the low emission intensities in Middle East, Africa and Latin America (the ALM-region) and in Asia compared to OECD in 2100 are perhaps somewhat surprising.

Figure 1 shows how fossil fuels from the middle of the century gradually are replaced by mainly biomass and other renewables in addition to nuclear energy. However, even by the end of the century the global fossil fuel consumption is only slightly below current levels. It might be reasonable to question whether the B1 scenario really represents a lower limit in this regard. We find it somewhat surprising that fossil fuels, almost 100 years from now, still play a crucial role in global energy supply in a scenario that should represent a lower limit with respect to CO_2 emissions. Obviously, nuclear energy could play a much more prominent role if it were found to be socially acceptable. There are other similar model studies where fossil fuels have a considerably smaller share of total energy supply by the end of the century, see e.g. Nakićenović *et al.* (1998).

Figure 1 also shows how income levels develop within the century. There is definitely a catching up, although the absolute income differences are enhanced. Again we find it difficult to judge whether this is a reasonable lower limit or not. However, for the period 1990–2100 there is an annual average per capita GDP_{PPP}-growth of 2.7 percent in Asia, 2.5 per cent in the ALM region, and 2.0 on a global basis. These are relatively high growth rates. In comparison, the corresponding average growth rate of for example the United States in the period 1913–2001 was 1.9 per cent, according to Maddison (2003).[9]

Finally, Figure 1 shows the large differences as regards CO_2 emissions in the different scenario families. However, although the emissions in the B1 scenario are relatively low compared to especially A2, it might be argued that the lower limit could have been even lower. Not least the large share of fossil fuels in world energy supply in 2100 could be questioned. Moreover, the economic growth rates of the developing countries are relatively high. However, as argued by Holtsmark and Alfsen (2005) and Grübler et al. (2004), exaggerated economic growth rates do not necessarily imply overstated emission growth.

[9] According to Mitchell (1998) the pr cap GNP growth rate in the US for the period 1910-1990 was 1.8 per cent.

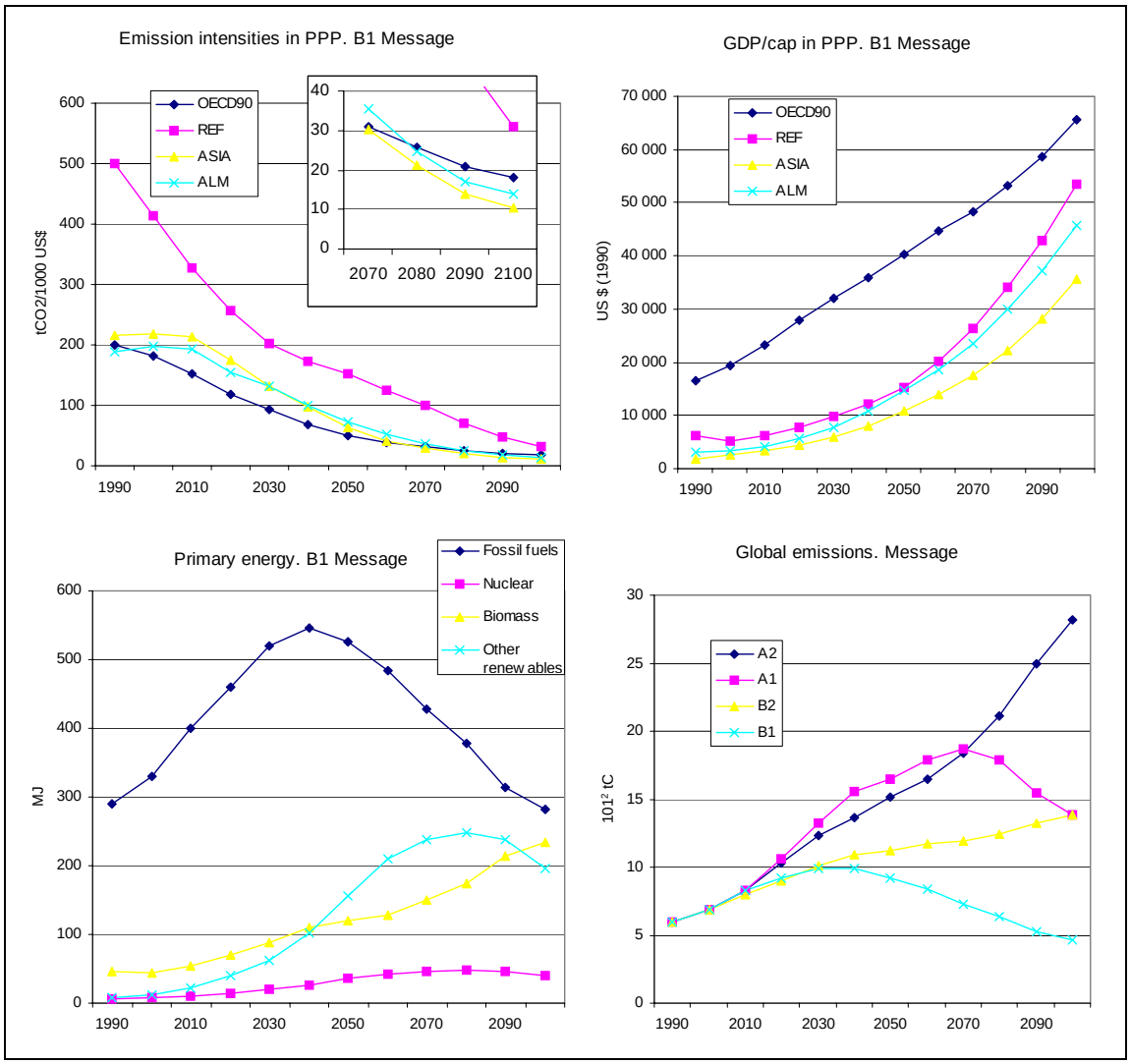

Figure 1. The development of some variables in the MESSAGE scenarios. OECD90 is OECD as of 1990, REF is the reforming economies, i.e. the former Soviet Union and Eastern Europe, ALM is Africa, Latin America and the Middle East, and ASIA as Asia excluding OECD countries.

6 Conclusions

Our conclusion is that we agree with C&H when they argue that PPP correction should be included in the type of scenario work carried out in SRES. Because relative income and emission intensity levels play crucial roles in the scenario design, these levels have to be correctly pictured. That can only be done by the use of PPP corrected measures. The choice between PPP or MER is far more than a question of "metrics", as claimed by the IPCC.

On the other hand, we reiterate our view that the lack of PPP corrections has not necessarily caused exaggerated estimates of emission growth in the SRES. In our view it seems obvious that the scenario makers have had two types of gap closure in mind as important driving forces. The degree of convergence of the income levels between rich and poor countries, and the degree of convergence of the emission intensities are apparently set exogenously. While

the use of MER-based measures means overstated income gaps, it also means overstated emission intensity gaps. Hence, the scenario makers have probably overestimated the economic growth necessary in the process of catching up. Moreover, they have exaggerated the potential for emission intensity reductions in the poor parts of the world. These two overstatements effectively neutralize each other as far as global emission growth is concerned.

In this article we have also discussed another point in the critique raised by C&H. They claimed in their second contribution to the debate (Castles and Henderson, 2003b) that the PPP-based series in the MESSAGE-based scenarios in SRES were mislabelled because divergence between the GDP measures for the developed and the developing regions "are impossibly great". (p 423, first paragraph.) This is related to the claim from C&H that "any difference between them can only arise from the use of different weighting systems." (p 422, third paragraph). In fact, however, there might be another important source of difference between the two types of series in question: how the MER series are defined. The MER series could either be based on constant exchange rates taken from one specific base year, or on current (changing) exchange rates. This division is common in statistics; cf. for example OECD (2004), which sets out both types of MER-based series. It is not specified in IPCC (2000) whether the MER series are based on current or constant exchange rates. However, the high degree of convergence between the MER-based and the PPP-based series makes it reasonable to believe the MER-based series are based on changing (current or nominal) exchange rates. If that is the case, the divergences are not "impossibly great." Hence, we conclude that the PPP-series as presented in SRES (IPCC, 2000) are plausible.

On the other hand, this means that the MER-based series do no represent real economic growth, but are influenced by changing exchange rates. If this really is the case, it should have been made clear in presentations of the scenarios. As it now stands, the MER-based series represent nominal economic growth and are, consequently, quite misleading.

Our final point is related to the question of whether it is reasonable to consider the B1 scenarios to represent a lower limit with respect to emissions. We have definitely no basis for any firm conclusions at this point. However, we note that this discussion has to go beyond the question of whether to use PPP or MER. We have pointed out some key variables that should be analysed with regard to this question. We especially think that the share of fossil fuels in the global energy supply in the B1 scenarios might be questioned. On the other hand, the considerable drop in energy intensities might be too optimistic.

References

Cassel, G. (1918): Abnormal deviations in international exchanges, *Economic Journal* 28, pp. 413-414.

Castles, I. (2004): The role of the IPCC is to assess climate change not advocate Kyoto. *Energy & Environment 15* 3, pp 369-373.

Castles I., and D. Henderson (2003a): The IPCC Emission Scenarios: An Economic-Statistical Critique, *Energy & Environment* 14 2-3, pp. 159-185.

Castles I., and D. Henderson (2003b): Economics, Emissions Scenarios and the Work of the IPCC, *Energy & Environment* 14 4, pp. 415-435.

Grübler, A., N. Nakićenović, J. Alcamo, G. Davis, J. Fenhann, B. Hare, S. Mori, B. Pepper, H. Pitcher, K. Riahi, H. Rogner, E. L. La Rovere, A. Sankovski, M. Schlesinger, R.P. Shukla, R. Swart, Na. Victor and T. Y. Jung (2004): Emission scenarios: A final response, *Energy & Environment* 15 1, pp 11-24.

Gulde, A. M., and M. Schulze-Ghattas (1993): Purchasing Power Parity Based Weights for the World Economic Outlook, *World Economic Outlook* 1993, pp. 106-123.

Heston, A. (2004): The Flaw of One Price: Some Implications for the MER-PPP Discussions. Paper presented to the PPP vs MER Workshop, Hartley Conference Center, Stanford University, February 19-20, 2004

Holtsmark, Bjart and Knut H. Alfsen (2005): PPP Correction of the IPCC Emission Scenarios: Does It Matter? Forthcoming in *Climatic Change* 68 1.

IPCC (2000): *Special Report on Emissions Scenarios*, Working Group III, Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, 595 pp. http://www.grida.no/climate/ipcc/emission/index.htm

IPCC (2003): IPCC press information on AR4 and emissions scenarios, Press release, 8. December, 2003, http://www.ipcc.ch/press/pr08122003.htm

Maddison, Angus (2003): The World Economy. Historical statistics. OECD.

Manne, A., and R. Richels, (2003): Market Exchange Rates or Purchasing Power Parity: Does the Choice Make a Difference to the Climate Debate? Unpublished paper.

McKibbin, W. J., D. Pearce, and A. Stegman (2004a): Can the IPCC SRES be improved?, *Energy & Environment* 15 3, pp. 351-362.

McKibbin, W. J., D. Pearce, and A. Stegman (2004b): Long Run Projections for Climate Change Scenarios. Working Papers in International Economics no 1.04. Lowy Institute for International Policy.

Mitchell, B. R. (1998): *International Historical Statistics. The Americas 1750-1993.* MacMillan, London.

Nakicenovic, N., A. Grübler and A. McDonald (1998): *Global energy perspectives,* Cambridge University Press, Cambridge.

Nakićenović, N., A. Grübler, S. Gaffin, T. T. Jung, T. Kram, T. Morita,H. Pitcher, K. Riahi, M. Schlesinger, P. R. Shukla, D. van Vuuren, G. Davis, L. Michaelis, R. Swart and N. Victor (2003): IPCC SRES revisited: a response, *Energy & Environment* 14 2-3, pp. 187-214.

OECD (2004): *National Accounts of OECD Countries.* Main aggregates. Volume I 1991-2002.

Rogoff, K. (1996): The Purchasing Power Parity Puzzle, *Journal of Economic Literature* XXXIV pp. 647-668.

Ryten, J. (2004): MERs PPPs and IPCC: Illusions and reality. Energy & Environment 15 3, pp. 364-367.

The Economist (2002): BigMacCurrencies, 25 April 2002.