CICERO Policy Note 2004:01

On the question of PPP corrections to the SRES scenarios

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January 2004

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Tittel: On the question of PPP corrections to the SRES scenarios

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CICERO Policy Note 2001:04
8 sider

Finansieringskilde:
Prosjekt:
Prosjektleder:
Kvalitetsansvarlig:

Nøkkelord: SRES scenarier, IPCC

Sammendrag: Ian Castles og David Henderson har kritisert IPCCs spesialrapport om utslippsfremskrivninger. Kritikkens hovedpunkt er at det i scenariefremskrivningene ikke er foretatt korreksjoner for kjøpekraftspariteter når man har sammenlignet regionale inntektsnivåer. Konsekvensen er at fattige land fremstår som fattigere enn de faktisk er. En slik overdrivelse av inntektsgapet mellom fattige og rike land i basisåret fører til fremskrivninger med for høy økonomisk vekst i de fattige landene, ettersom scenariene er konstruert med sikte på at inntektsgapet mellom fattige og rike land reduseres. Castles og Henderson hevder at overdrevet inntektsvekst innebærer at også utslippsveksten blir overdrevet. Det Castles og Henderson overser imidlertid en annen sentral drivkraft i IPCC-scenariene. Det er i dag en betydelig forskjell i energieffektivitet mellom fattige og rike land. Vi fremhever at ved å unnlate å foreta korreksjoner for kjøpekraftspariteter, overdriver IPCC ikke bare inntektsforskjellene mellom fattige og rike land. De overdriver også forskjellene i utslipp pr. produsert enhet og dermed potensialet for å øke energieffektiviteten i de fattige landene. En annen sentral drivkraft i IPCC-scenariene er at forskjellen forskjellen i energieffektivitet også blir redusert over tid. Vi viser i dette notatet at disse to feilene nøytraliserer hverandre. Vi mener derfor at Castles og Henderson ikke har rett i sin kritikk når de konkluderer med at manglende korreksjoner for kjøpekraftspariteter har medført en overdrevet utslippsvekst i IPCC-scenariene..

Språk: Engelsk

Rapporten kan bestilles fra:
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P.B. 1129 Blindern
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Eller lastes ned fra:
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Title: On the question of PPP corrections to the SRES scenarios

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CICERO CICERO Policy Note 2001:04
8 pages

Financed by:
Project:
Project manager:
Quality manager:

Keywords: SRES scenarios, IPCC

Abstract: Ian Castles and David Henderson have criticized IPCC's Special Report on Emissions Scenarios (SRES) (IPCC, 2000) for using market exchange rates (MER) instead of purchasing power parities (PPP) when converting regional GDP into a common denominator. The consequence is that poor countries generally appear to be poorer than they actually are. An overstated income gap between rich and poor countries in the base year gives rise to projections of too high economic growth in the poor countries because the scenarios are constructed with the aim of reducing the income gap. Castles and Henderson claim that overstated economic growth means that greenhouse gas emissions are overstated as well. However, because closure of the emission intensity gap between the rich and the poor parts of the world is another important driving force in the scenarios, we argue that the use of MER in the SRES scenarios has not caused an overestimation of the global emission growth because the two types of errors effectively neutralize one another.

Language of report: Engelsk

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Acknowledgements

We would like to thank Bård Romstad and Kristin Rypdal for valuable discussions and suggestions. We would also like to thank Torstein Bye, Mads Greaker, Tom Kram and an anonymous referee for valuable comments to different drafts.

This paper is currently under review at *Climatic Change.*

1 Introduction and background

Ian Castles of the National Centre for Development Studies at Australian National University, formerly the head of Australia's national office of statistics, and David Henderson of the Westminster Business School, formerly the chief economist of the OECD, have put together a critique of the IPCC's Special Report on Emissions Scenarios (SRES) (Castles and Henderson, 2003a). This was picked up and commented upon by *The Economist* (13 February 2003: Hot Potato: The Intergovernmental Panel on Climate Change had better check its calculations.) The main thrust of the criticism is that the GDPs for the four world regions[1] covered in the SRES were derived using market exchange rates (MER) that were not corrected with respect to purchasing power parities (PPP). The consequence is that non-OECD countries generally appear to be poorer than they actually are. This is important 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 between rich and poor countries has to be considerably reduced by the end of the century. Castles and Henderson agree that such a convergence is a reasonable premise for the scenarios, but point to the fact 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 CO_2 emissions." (Castles and Henderson, 2003a, p. 169).

Nakićenović and colleagues, a group of authors connected with the SRES report, responded to the critique (see Nakićenović et al., 2003). First, they point out that some of the SRES scenarios in fact were based on PPP-based exchange rates. Second, they dispute that their use of MER instead of PPP measures in other scenarios was inappropriate. Furthermore, they claim that it is incorrect "both theoretically and practically" (p. 208) that lowering the GDP growth rate assumptions would mean lower emissions than reported in SRES. The theoretical argument made by Nakićenović et al. is in short that "technological change is *ceteris paribus* closely linked with income growth, or more precisely with the aggregate rate of macroeconomic productivity growth, usually represented by the growth of per capita GDP." (page 208)

In a follow-up paper, the critique of the use of MER-based GDP measures in the SRES scenarios was repeated and specified further (Castles and Henderson, 2003b). Among other things, it was pointed out that the use of MER-based GDP measures in the SRES scenarios was somewhat sloppy, as, for example, in figure 3-13 on page 125 in IPCC (2000), which clearly overstates the energy intensities of the poorer regions.

An unpublished paper by Manne and Richels (2003) applies the simulation model MERGE to analyze the extent to which the use of MER gave rise to overstated emission growth. The authors conclude that the use of MER instead of PPP affects the projected future emission growth only slightly – in part because while the use of MER means that the GDP growth in overstated, it also means that the potential for improved energy intensities in the developing countries is overstated as well.

In approaching this debate we first of all note that it should be possible to agree upon the fact that market actors are affected by market exchange rates, and thus in principle these rates should be employed in the models used to illustrate market economic behavior. On the other hand, to the extent that the economic growth in the scenarios are motivated by a wish to close the income gap between poor and rich countries, a PPP-based conversion should be applied as

[1] The four regions are as follows: (1) OECD: OECD as of 1990; (2) REF: Reforming economies encompassing former Soviet Union and Eastern Europe; (3) ASIA: Non-OECD Asia including Oceania; and (4) ALM: the Middle East, Africa and Latin America. The GDP is given in 1990 US$.

the basis for certain parts of the scenario's design criteria. It is the use of GDP measures in this part of the scenario design that we discuss in the following.

The purpose of this paper is to prove that there is a surprisingly straightforward and serious weakness of the critique put forward by Castles and Henderson. If it is accepted that the SRES-scenarios overstate the GDP growth in the poor countries, the key question is whether this implies overstated emissions growth in SRES. Castles and Henderson 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. 20). We want to show that this argument represents an oversimplification.

Although we agree that it might be reasonable to use PPP-based conversion factors in this particular context, Castles and Henderson have by no means proved that the MER-based SRES scenarios overestimate the emissions growth. The point is 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 constitutes 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, the SRES scenarios are based on two mistakes that draw in different directions, and in fact these two inaccuracies neutralize one another. We 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 choice of exchange rate is irrelevant in the context of the SRES scenarios.[2]

As mentioned above, Nakićenović et al. argue, in line with our argument, that theoretically there is no reason to assume that overstated economic growth should mean overstated emissions growth. However, we find the theoretical arguments as formulated by Nakićenović et al. to be unclear and circuitous in relation to the truly simple relationships we are dealing with. While Nakićenović et al. deny that any mistakes were made in relation to the use of PPP corrections, we argue that in fact two mistakes have been made – but fortunately they negate each other.

Manne and Richels (2003) touch upon the crucial issue, but do not clarify the fundamental arguments. It is our view that before the question is analyzed within a CGE model like MERGE, these fundamental arguments should be clarified. What both papers (Nakićenović et al. and Manne and Richels) lack is a simple and straightforward discussion of the basic numerical assumptions made by the SRES team and to what extent they lead to overstating the emission growth. We will apply a simple theoretical framework as the basis for that discussion. We argue that both types of gap closure mentioned above have been important driving forces in the scenarios, and provide a numerical example as a direct follow up to that presented by Castles and Henderson. Both the theoretical framework and the numerical example demonstrate how the two types of mistakes neutralize one another.

[2] In relation to the B1 scenario, which Castles and Henderson use as the starting point for their numerical examples, IPCC (2000) states the following: “The rather high rates in energy intensity reduction in the B1 stem also from the explicit assumption that less industrialized regions catch-up” (p. 206).

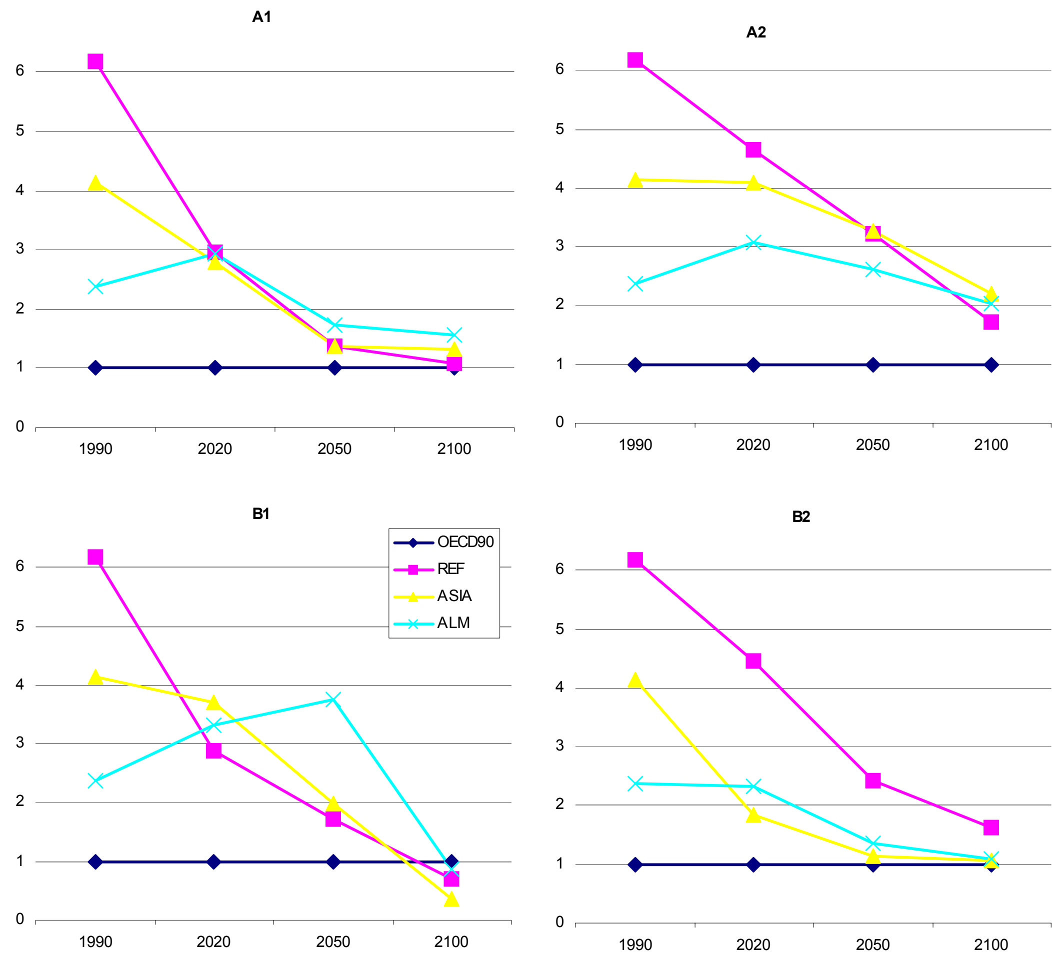

Figure 1: Numbers from the SRES scenarios: CO_2/GDP in the four world regions relative to CO_2/GDP in the OECD region in the four main scenarios. GDP levels are not PPP corrected.

2 The two gaps and a simple model

It is evident from IPCC (2000) that two types of gap closure have been the main driving forces behind the design of the SRES scenarios. First, the income gap between the rich and poor regions is an important driving force behind the projected economic growth in the poor region. That is stated explicitly (IPCC (2000), p. 7). Second, the scenarios are based on assumptions about technological catching up in relation to energy efficiency. In other words, the converging of the emission-intensity gaps between OECD and the other world regions is a driving force behind the emission-intensity drops in these regions. Although it is not very explicitly stated in IPCC (2000) that this type of gap closure is an important driving force, the numbers leave no doubt (see figure 1, which shows the development of the emission intensities in the SRES scenarios in the different world regions in relation to the emission intensity in the OECD region).

Castles and Henderson do not criticize the numerical assumptions related to the emission-intensity gap or the income gap in period 2. Nor do they criticize the assumptions related to economic growth or the choice of emission-intensity level in the rich part of the world (see the numerical examples in Castles and Henderson, 2003a, p. 169). It is therefore reasonable to interpret Castles and Henderson as if they accept the assumed degree of catching up at least as far as the income gap is concerned: In their numerical illustrations, for example, they apply the same income gap as assumed by the IPCC team. Furthermore, Castles and Henderson do not criticize the degree of gap closure related to the emission intensities. Their concern is that assumptions related to the situation in period 2 should be made using PPP values as the starting point. They criticize applying the assumed degree of income inequality between rich and poor in 2100 to income levels that are not PPP corrected. The question is to what extent the criticism is relevant in relation to the estimated emissions.

To shed light on this question, we analyze the issue within a simple model. Thus, we consider a world that exists in two periods and includes only two regions; one rich (*R*), and one poor (*P*). For simplicity, we assume that there are constant and equal numbers of citizens in the two regions over time. Further, we define:

E_{rt}: Emissions of greenhouse gases in region $r = R, P$ in period $t = 1, 2$.
E_t: Global emissions in period t.
P_{rt}: Price level in region r in period t.
Y_{rt}: GDP in region r in period t measured in PPP.
$X_{rt} = P_{rt}Y_{rt}$: GDP in region r in period t measured in MER.

We define γ^{IPCC} and ε^{IPCC} as the size of the income gap and emission-intensity gap in 2100, respectively, as assumed by IPCC. Furthermore, we define Y_{P2}^{IPCC} and X_{P2}^{IPCC} as the size of GDP in the poor region in period 2, measured after and before PPP corrections, respectively, if the IPCC scenario methodology is applied. From the above arguments and definitions it follows that:

$$\frac{X_{P2}^{IPCC}}{X_{R2}} \equiv \gamma^{IPCC} .(1)$$

Correspondingly, we define $Y_P^{C\&H}$ as PPP-corrected GDP in the poor region if the Castles and Henderson methodology is applied. This gives:

$$\frac{Y_{P2}^{C\&H}}{Y_{R2}} \equiv \gamma^{IPCC} . (2)$$

We define E_{P2}^{IPCC} and $E_{P2}^{C\&H}$ as estimated emissions in the poor region if the IPCC and the Castles and Henderson methodologies are applied, respectively. In the IPCC case we have:

$$\frac{E_{P2}^{IPCC} / X_{P2}^{IPCC}}{E_{R2} / X_{R2}} \equiv \varepsilon^{IPCC} , \quad (3)$$

while the Castles and Henderson methodology gives:

$$\frac{E_{P2}^{C\&H} / Y_{P2}^{C\&H}}{E_{R2} / Y_{R2}} \equiv \varepsilon^{IPCC} . \quad (4)$$

To further simplify the discussion, we have made a number of other assumptions. First, we assume that price levels are constant over time[3] and normalize the relative price levels:

[3] If inflation is to be taken into account, both the definition of the income gap as and the definition of the emission intensity gap would have to be corrected for inflation. This correction would not affect our conclusions.

$P_{R1} = P_{R2} = 1 \Rightarrow \quad Y_{Rt} = X_{Rt}.,$ (5)

$P_{P1} = P_{P2} = P < 1.$ (6)

Furthermore, we assume that there is constant emission intensity in the rich region and disregard economic growth in this region. Hence, the emissions in the rich region are constant. We define GDP and emissions in the rich regions as numeraires:

$Y_{R1} = Y_{R2} = 1 \quad \Rightarrow \quad X_{R1} = X_{R2} = 1$ (7)

$E_{R1} = E_{R2} = 1$ (8)

We now apply equations (1), (2), (5) - (7) together with the fact that $PY_{P2}^{IPCC} = X_{P2}^{IPCC}$. This gives the following:

$$\frac{Y_{P2}^{C\&H}}{Y_{P2}^{IPCC}} = P < 1. \quad (9)$$

Hence, $Y_{P2}^{IPCC} > Y_{P2}^{C\&H}$, which confirms that the IPCC methodology overstates the economic growth in the poor region, as claimed by Castles and Henderson.

The crucial question is, however, whether overstated economic growth in the poor region also means overstated emission growth. From equations (3), (4) and (5)-(9) we have:

$$\frac{E_{P2}^{C\&H}}{Y_{P2}^{C\&H}} \equiv \varepsilon^{IPCC} \equiv \frac{E_{P2}^{IPCC}}{PY_{P2}^{IPCC}}. \quad (10)$$

Using (9) and (10) it is simple algebra to reach the conclusion that:

$E_{P2}^{IPCC} = E_{P2}^{C\&H}$ (11)

As the estimated emissions in the rich region are unaffected by the choice of methodology, it follows that total emissions will similarly be unaltered by those choices. In other words, from the model we conclude that the choice of MER or PPP as basis is unimportant with respect to global emissions in period 2, if gap closure related to both the income gap and the emission-intensity gap is the important driving force in the scenario.

However, the choices with respect to the degree of gap closure related to the income and the emissions intensity gaps are important. Furthermore, the assumptions about emission intensity and growth in this region are crucial. The numerical assumptions at these crucial points made in the SRES scenarios could and should be discussed, but we think that the approach taken by Castles and Henderson heads in the wrong direction. As the very simple model exercise above shows, the full set of crucial numerical assumptions have to be considered in relation to each other.

3 A numerical example

Our argument is in the following illustrated by a numerical example related to the B1 IMAGE scenario. We use this scenario as a point of departure in the numerical example because Castles and Henderson (2003a), p. 169, also use this scenario as their basis (see also Castles et al., 2003b). The numerical example is set out in Table 1 and Table 2.

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 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.

The scenario assumes that by 2100 the ratio of per capita GDP in the OECD countries to that of the non-OECD countries will have fallen to 1.9 using MER-based GDP measures. Furthermore, the scenario assumes that the emission intensity gap drops to 1.2 by the end of the century (using MER). In addition, the B1 IMAGE scenario for the OECD region projects an increase in GDP per capita between 1990 and 2100, by a factor of 3.9.

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, which is based on this scenario, assumed that the PPP-correction factors are constant from 1990 to 2100. From this follows that the income gap in PPP-based terms are more than closed, i.e. the non-OECD region has a higher real income per capita in 2100 than the OECD-region, a result which probably not has been intentional. Moreover, it has probably not been the intention that the emission-intensity gap is more than closed in real terms, as the emission intensity is lower in the non-OECD region compared to the OECD region in PPP-based terms.

Suppose now that we 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 1. The result is, in accordance with the criticism put forward by Castles and Henderson, that the world's GDP per capita in 2100 is reduced by almost 50 percent.

However, in accordance with the general results set out above, the CO_2 emissions are unaffected by the change from MER- to PPP-based assumptions. As explained in section II, the important point is that the use of MER-based income comparisons in 1990 implies two errors because both the income gap and the emission intensity gap are overstated. The key variable, global carbon emissions, is on the other hand correctly measured. Nevertheless, the use of MER-based income comparisons overstates economic growth as well as the potential for energy efficiency improvements in the poor region. Fortunately, these two mistakes cancel each other out.

Table 1. 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)
		10^3	10^{12} US$		10^3 US$/capita		10^9 tC	tC/10^3 US$	
1990									
OECD	1.00	799	16.5	16.5	20.6	20.6	2.83	171.5	171.5
Non-OECD	2.55	4480	4.5	11.4	1.0	2.5	3.17	708.5	277.6
World	1.33	5279	21.0	27.9	4.0	5.3	6.0	286.1	214.9
2100 SRES B1 IMAGE (MER-based)									
OECD	1.00	1032	82.3	82.3	79.8	79.8	1.1	13.4	13.4
Non-OECD	2.55	6016	246.1	630.1	40.9	104.4	4.1	16.7	6.5
World	2.17	7048	328.4	712.4	46.6	101.1	5.2	15.8	7.3
2100 PPP-scenario based on B1 IMAGE									
OECD	1.00	1032	82.3	82.3	79.8	79.8	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	178.8	328.4	25.4	46.6	5.2	29.1	15.8

Table 2. Average annual GDP-growth 1990-2100. Percentage.

	GDP (MER)	**GDP** (PPP)	**GDP/Cap.** (MER)	**GDP/Cap.** (PPP)	CO_2
SRES B1 IMAGE (MER-based)					
OECD	1.5	1.5	1.2	1.2	-0.9
Non-OECD	3.7	3.7	3.4	3.4	0.2
World	2.5	3.0	2.3	2.7	-0.1
PPP-scenario based on B1 IMAGE					
OECD	1.5	1.5	1.2	1.2	-0.9
Non-OECD	2.8	2.8	2.6	2.6	0.2
World	2.0	2.3	1.7	2.0	-0.1

4 Conclusion

The main point of the Castles-Henderson critique of the SRES scenarios is that the PPP should have been used as the basis for measuring relative income in different regions of the world. We agree that the use of market exchange rates in the comparison of regional income levels in the SRES scenarios could be criticized. Although some scenarios are presented using both MER- and PPP-based GDP measures, PPP-based GDP measures should generally have been applied in the scenario when the degree of gap closure with respect to the income levels and emission intensities was fixed.

Nevertheless, we have argued that it is unlikely that the use of MER in the SRES scenarios has caused an overestimation of the global emission growth. If we expect a certain degree of closure of the emission-intensity gap between the rich and the poor parts of the world to accompany a convergence of the per capita income between the regions, the choice of MER instead of exchange rates based on PPP does not lead to an overestimation of the emission growth. The reason is that the use of MER implies that the scenario designers made two mistakes that cancel each other out. On the one hand, using MER results in overestimating economic growth in the poor regions. On the other hand, using MER results in overestimating the emission-intensity gap between rich and poor regions in the base year and consequently also the emission-intensity improvements in this region.

The important question turns out to be whether the SRES scenarios are based on realistic assumptions related to the convergence of the emission-intensity gaps and the income gaps, as well as the future development of the emission intensity and the GDP level in the rich region. A critique of the SRES scenarios should analyze these questions rather than focusing on the MER/PPP distinction, although we think it is appropriate that Castles and Henderson point to the importance of using PPP-based measures as basis for inter-regional comparisons.

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