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A comparative study of selected Asian countries on carbon emissions with respect to different trade and climate changes mitigation policy scenarios

By

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Abstract

Trade, economic development, and climate change issues are closely linked and this has significant implications for the design of climate change policies especially for developing countries. Developing countries regard the objective of economic development and growth as being as important as the objective of climate change mitigation, and therefore prefer to use emission intensity reductions as targets for their climate change policies. In theory, this may seem to allow for both economic growth and climate change mitigation objectives to be achieved in a harmonious manner but on closer analysis, no simple choice of a policy target can help to resolve the fundamental issue of how to reconcile the objective of economic growth with the objective of climate change mitigation. In this study we look at the case of China, India, Bangladesh, Indonesia, Thailand, and Vietnam, and consider the following questions: (i) how to measure the impacts of trade and economic activities on the levels of CO_2 emissions, (ii) how to measure the impacts of current climate change policies on trade and economic activities, (iii) how to improve on existing policies to better achieve the targets of economic growth while also contributing to the objectives of climate change mitigation. A general equilibrium model is used to conduct some simulations of a business as usual (BaU) and also some climate change and policy scenarios.

Keywords: Climate change, CO_2 emissions, Energy intensity, Emission intensity, Mitigation policies, Economic growth, Trade, Computable general equilibrium model, Asian countries.

JEL Classification: Q41, Q43, Q54, Q56, Q58

Introduction

Trade, economic development, and climate change issues are closely linked and this has significant implications for the design of climate change policies especially for developing countries. While it is easily recognised that the main objective of climate change policies is to cut back on the level of greenhouse gases (GHGs) emissions, it is not so easily agreed between countries on how this objective is to be achieved. Developed countries, in particular those which ratified the Kyoto Protocol, believe that the most effective way of achieving this objective is to set specific targets for emissions reductions and then use economic instruments (such as emission trading and/or carbon taxes) to help achieve these objectives in the most efficient manner. Other countries (in particular developing countries) fearing the adverse impacts of direct emissions cuts on the level of economic development and growth prefer to keep the options open and therefore do not agree to direct emissions cuts. Instead, a preferred alternative in the case of developing countries such as China and India is emissions *intensities* reduction. In theory, this may seem to be a more reasonable approach because reducing emission intensities (but not necessarily reducing emissions) can ‘accommodate’ for both economic growth and climate change mitigation objectives to be achieved to some extent, but this cannot continue for very long without ultimately also changing the fundamental relationship between these two objectives. Shifting the focus of attention from one policy variable (emission level) towards the ratio of two related variables (emission level over production level) may help to ‘mask’ the underlying relationship in the short run, but in the long run, this may add to further confusion and introduce unintended inefficiencies into the system. In this paper, we look at this issue in more details. We examine the underlying relationship between emissions, production levels and trade patterns of some developing countries in the Asia-Pacific region (China, India, Bangladesh, Indonesia, Thailand, and Vietnam) by asking the following questions: (1) what are the potential impacts of the current and projected future patterns of trade and economic activities of these countries on their levels of GHG emissions; (2) what are the potential impacts of (current) climate change policies on the patterns of trade and economic production, and finally (3) what could be improved in terms of policies to achieve better co-ordination between climate change, economic, and trade policies. To assist in the answering of these questions, we use a computable general equilibrium (CGE) model called WIATEC (Truong and Kemfert, 2010) to carry out some simulations. The model is first used to estimate a ‘Business-as-Usual’ (BaU) or ‘reference’ scenario from which we can use to compare with other scenarios. In the BaU scenario, we assume the current patterns of production and consumption activities in the studied countries will continue into the future without modifications by any particular climate change policies. Next, we construct some hypothetical climate change policy scenarios. Here the impacts of specific climate change policies can be examined. A comparison of the results of the BaU and various policy scenarios can give us an indication of how climate change policies can be improved for the studied countries. The plan of the paper is as follows. Section 2 establishes the reference or BaU scenario. Section 3 considers some alternative climate change policy scenarios. Section 4 examines the linkage between trade and climate change policies, and Section 5 concludes with some policy recommendations.

Impacts of existing trade and production patterns on greenhouse gases emissions in the studied countries – Business-as-usual Scenario

In this section we establish a 'business-as-usual' (BaU) scenario to be used as a starting point for comparison with other climate change policy scenarios. In the construction of this BaU scenario, we assume that the current patterns of production and consumption activities in the studied countries will continue into the future without modifications by any specific climate change policies. We look at the impacts of the BaU patterns of production and trade on greenhouse gases emissions.[1]

1. Historical trend (2005-2007)

First, we examine the historical information. Unlike econometric or partial equilibrium analyses where we can usually look at a longer time series for some specific variables of interest in some sectors of an economy, in general equilibrium-based studies, it is difficult to construct a series of comprehensive and 'balanced' (input-output) databases for many consecutive years which can then be used as inputs into the model to look at a time 'trend'. Instead, we start with a particular base year (in this case, 2004, using the GTAP version 7 database, see Narayanan and Walmsley (2008)) and calibrate the model (WIATEC) to this specific base year. Next, we use historical information in subsequent years for some specific variables (such as population growth, GDP growth, and CO_2 emissions levels) as published by other sources of information such as the U.S. Energy Information Administration (EIA)[2], EUROSTAT and UNDP[3]) to 'project' the model from the base year to these later years. The projection is called 'historical simulation' in which the objective is to 'replicate' the historical data for these specific variables but also to let the model determine the values of other variables or parameters of interest, such as the rate of technological change during this historical period, and then use these historical estimations to project into the future.

In Table 1 we show the historical levels of GDP (at market exchange rate (MER) and purchasing power parity (PPP)) for the regions of this study[4] during historical period 2005-2007. Table 2 shows the rates of population growth and CO2 emissions levels. From these historical data, we can calculate the ratio of total energy used[5] or total emissions over GDP level (energy and emission intensities) for the regions and these are shown in Tables 3 and 4. In calculating these intensities, we use both the GDP valued at market exchange rate (MER) and at purchasing power parity (PPP) to show the differences in their initial levels. From Figures 1a-b, however, it can be seen that despite the differences in levels, the pattern[6] of the variation of rates of change of the emission intensities over different regions does not change very much if we switch from GDP-MER to GDP-PPP measures. Therefore for reasons of simplicity and data compatibility[7], henceforth we use only the emission intensities measured in terms of GDP at MER.

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[1] For simplicity, we look only at CO_2 emissions from energy usage and will not consider CH_4, N_2O, nor CO_2 emissions from other non-energy uses such as land use, land use change and forestry (LULUCF), or from wastes.

[2] http://www.eia.doe.gov/

[3] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database
http://unstats.un.org/unsd/snaama/dnlList.asp

[4] For a description of these countries/regions and the sectors, see Appendix A.

[5] GTAP v7 data base also contains information on energy usage but these are not shown here in Table 2 even though they are used for the calculation of energy intensities shown in Table 3.

[6] Since we are concerned mainly with the relativities of the rate of change over different regions, the shape of these patterns are more important than their absolute levels.

[7] The GTAP data base is available only at MER rather than PPP values.

Table 1: Historical levels of GDP using market exchange rate (MER) and purchasing power parities (PPP) for the period (2005-2007)

GDP using market exchange rate (MER) trillion 2005 US dollars				GDP using purchasing power parities (PPP) trillion 2005 US dollars			
Region (*)	2005	2006	2007	Region	2005	2006	2007
CHN	2.17	2.42	2.72	CHN	8.37	9.14	10.44
IND	0.75	0.83	0.90	IND	3.49	3.75	4.14
BGD	0.06	0.07	0.07	BGD	0.27	0.28	0.30
IDN	0.29	0.31	0.32	IDN	0.78	0.81	0.87
THA	0.18	0.19	0.20	THA	0.52	0.53	0.56
VNM	0.05	0.05	0.06	VNM	0.24	0.25	0.27
JPN	5.09	5.23	5.34	JPN	3.59	3.60	3.72
KOR	0.76	0.80	0.84	KOR	1.00	1.03	1.10
RAS	0.89	0.94	1.00	RAS	2.13	2.21	2.37
USA	12.89	13.27	13.56	USA	11.34	11.42	11.79
CAN	1.08	1.12	1.15	CAN	1.02	1.04	1.08
BRA	0.68	0.71	0.75	BRA	1.48	1.50	1.60
RAM	1.76	1.87	1.98	RAM	3.05	3.19	3.41
E15	13.34	13.75	14.14	E15	10.74	10.83	11.25
E12	0.76	0.82	0.87	E12	1.32	1.38	1.49
RUS	0.65	0.70	0.76	RUS	1.43	1.51	1.65
AUS	0.70	0.73	0.76	AUS	0.64	0.65	0.69
NZL	0.11	0.11	0.11	NZL	0.10	0.10	0.10
ROW	3.21	3.38	3.57	ROW	5.66	5.88	6.30
World	45.42	47.28	49.11	World	57.18	60.11	63.13

Source: U.S. Energy Information Administration and author's calculations.
(*) for details on country/regional definitions, see Appendix.

Table 2: Historical levels of population and CO2 emissions for various regions for the period (2005-2007)

Population (millions)				CO_2 emissions ($GtCO_2$)			
Region	2005	2006	2007	Region	2005	2006	2007
CHN	1322.5	1330.3	1338.3	CHN	5.10	5.65	6.07
IND	1104.1	1121.0	1137.7	IND	1.15	1.24	1.32
BGD	141.2	143.2	145.1	BGD	0.04	0.04	0.04
IDN	222.9	225.7	228.5	IDN	0.33	0.34	0.38
THA	64.1	64.6	65.0	THA	0.21	0.22	0.23
VNM	84.2	85.2	86.3	VNM	0.08	0.09	0.09
JPN	128.0	128.0	127.9	JPN	1.22	1.20	1.24
KOR	47.8	47.9	48.0	KOR	0.47	0.48	0.49
RAS	468.8	476.3	483.9	RAS	0.79	0.81	0.84
USA	298.1	300.9	303.9	USA	5.78	5.70	5.77
CAN	32.2	32.5	32.8	CAN	0.56	0.54	0.57
BRA	186.4	188.8	191.2	BRA	0.33	0.33	0.35
RAM	374.6	379.6	384.6	RAM	1.02	1.06	1.11
E15	384.6	385.4	386.3	E15	3.26	3.26	3.20
E12	104.0	103.9	103.7	E12	0.71	0.72	0.73
RUS	143.2	142.5	141.8	RUS	1.53	1.59	1.59
AUS	20.2	20.4	20.7	AUS	0.39	0.39	0.40
NZL	4.0	4.1	4.1	NZL	0.04	0.04	0.04
ROW	1348.6	1375.2	1402.8	ROW	4.14	4.33	4.53
World	6479.7	6555.6	6632.6	World	27.15	28.03	28.96

Source: U.S. Energy Information Administration and author’s calculations.

Table 3: Regional energy intensities for the period (2005-2007)

Energy Intensity using GDP-MER (toe/'000 2005US$)				Energy Intensity using GDP-PPP (toe/'000 2005US$)			
Region	2005 level	Annual growth (%)		Region	2005 level	Annual growth (%)	
		2006	2007			2006	2007
CHN	1.01	-1.98	-5.85	CHN	0.26	-0.06	-7.20
IND	0.74	-4.41	-2.91	IND	0.16	-2.25	-3.90
BGD	0.29	-3.50	-1.90	BGD	0.07	-1.32	-2.91
IDN	0.66	-2.50	-0.86	IDN	0.24	-0.29	-1.88
THA	0.78	-2.50	-0.73	THA	0.27	-0.29	-1.76
VNM	0.62	-4.64	-2.62	VNM	0.13	-2.48	-3.62
JPN	0.15	-2.64	-3.09	JPN	0.22	-0.44	-4.08
KOR	0.45	-3.50	-1.16	KOR	0.34	-1.32	-2.18
RAS	0.57	-3.95	-2.75	RAS	0.24	-1.77	-3.65
USA	0.26	-3.75	-0.55	USA	0.30	-1.57	-1.57
CAN	0.35	-4.09	-2.73	CAN	0.36	-1.91	-3.73
BRA	0.39	-0.57	0.08	BRA	0.18	1.68	-0.95
RAM	0.43	-3.47	-0.90	RAM	0.25	-1.30	-2.06
E15	0.17	-3.48	-3.96	E15	0.21	-1.29	-4.95
E12	0.49	-3.71	-6.29	E12	0.29	-1.61	-7.26
RUS	1.60	-4.29	-7.44	RUS	0.73	-2.12	-8.39
AUS	0.27	-1.79	-3.27	AUS	0.29	0.43	-4.26
NZL	0.20	-0.36	-2.18	NZL	0.21	1.90	-3.19
ROW	0.67	-1.69	-1.73	ROW	0.38	-0.07	-3.34
World	0.34	-1.46	-1.17	World	0.27	-2.43	-2.26

Source: U.S. Energy Information Administration and author's calculations.
Energy intensity = total energy used in production and consumption activities/value of GDP

Table 4: Regional emission intensities for the period (2005-2007)

Emission Intensity using GDP-MER ($kgCO_2$/2005US$ GDP at MER)				Emission Intensity using GDP-PPP ($kgCO_2$/2005US$ GDP at PPP)			
Region	2005 level	Annual growth (%)		Region	2005 level	Annual growth (%)	
		2006	2007			2006	2007
CHN	2.35	-0.58	-4.44	CHN	0.61	1.37	-5.81
IND	1.53	-1.85	-2.56	IND	0.33	0.37	-3.56
BGD	0.57	-3.54	0.23	BGD	0.14	-1.35	-0.80
IDN	1.15	-1.68	2.99	IDN	0.42	0.55	1.93
THA	1.18	-3.71	-0.90	THA	0.42	-1.53	-1.92
VNM	1.63	-2.61	0.01	VNM	0.35	-0.40	-1.02
JPN	0.24	-3.79	0.61	JPN	0.34	-1.61	-0.42
KOR	0.62	-3.58	-2.44	KOR	0.47	-1.39	-3.45
RAS	0.89	-3.37	-3.07	RAS	0.37	-1.18	-3.97
USA	0.45	-4.34	-0.91	USA	0.51	-2.17	-1.93
CAN	0.51	-6.45	3.58	CAN	0.54	-4.33	2.52
BRA	0.48	-1.95	-1.28	BRA	0.22	0.27	-2.30
RAM	0.58	-2.42	-1.62	RAM	0.33	-0.22	-2.77
E15	0.24	-2.96	-4.64	E15	0.30	-0.76	-5.62
E12	0.93	-4.17	-5.58	E12	0.53	-2.09	-6.56
RUS	2.35	-3.67	-7.62	RUS	1.07	-1.49	-8.57
AUS	0.55	-1.96	-3.12	AUS	0.60	0.26	-4.11
NZL	0.34	0.92	-7.64	NZL	0.36	3.21	-8.59
ROW	1.29	-0.96	-0.91	ROW	0.73	0.67	-2.53
World	0.62	-2.22	-0.77	World	0.50	-3.18	-1.87

Source: U.S. Energy Information Administration and author's calculations.
Emission intensity = total (CO_2) emissions from energy usage/value of GDP.

Figure 1a: Emission intensity using GDP-MER and GDP-PPP
Annual rate of change in 2006

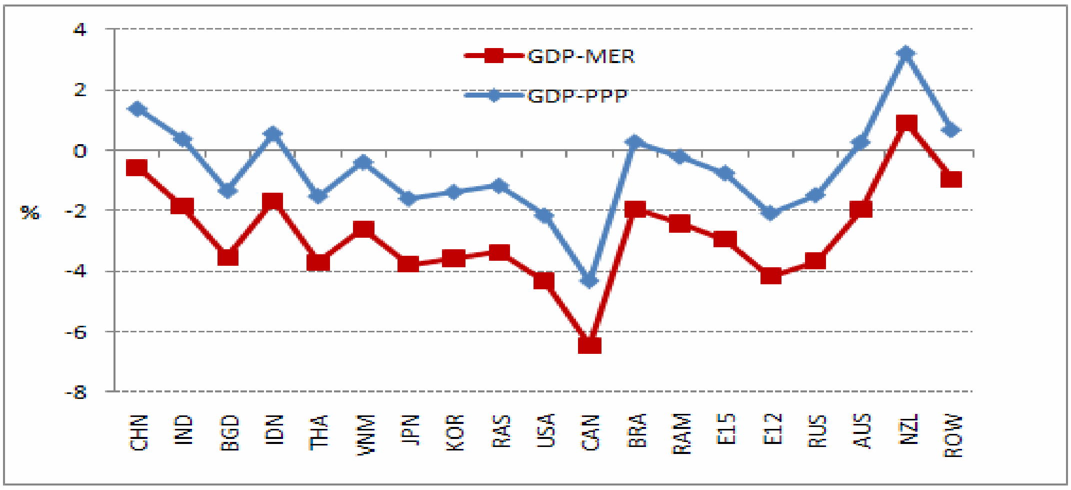
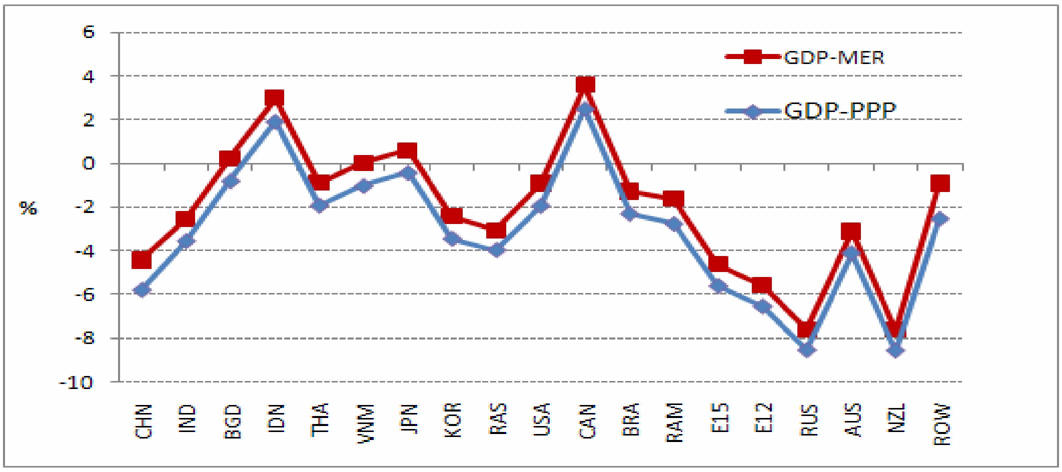


Figure 1b: Emission intensity using GDP-MER and GDP-PPP
Annual rate of change in 2007



2. Projection into the future (2007-2035)

To project the patterns and rates of emissions into the future, we need to know the projected rates of population and GDP[8] growth assuming that these are the main 'drivers' of CO_2 emissions in the future. The US Energy Information Administration has published information on projected future rates of GDP and population growth for all regions included in this study which are shown in Figures 2 and 3. From these published Figures, however, it can be seen that some values need to be modified to be consistent with more recent published data on certain variables such as GDP growth (especially in view of the Global Financial Crisis (GFC)). Furthermore, the projected rates of growth of GDP for China and India seem low in the longer term (2035) even though high in the nearer terms (2007-2015) in the US-

[8] GDP is only a 'proxy' for general resource utilization level. What 'drives' emissions are growth rates of individual resource factors such as employment, capital, land-use and natural resources (energy). In the absence of detailed information on growth rates for all of these primary factors of production, however, GDP growth rate can act as an overall proxy for these growth (subject to the degree of substitution between these factors as specified in the model).

EIA figures. The opposite is true for other developed regions such as the USA, the EU, and Japan. Therefore, we modify these projections as shown in Figures 4-5 and Table 5. [9]

In addition to population and GDP growth, we also need projections for an important variable which is crucial in the projection of CO_2 emissions into the future. This is the rate of *technological change* (especially in the energy area). To do this, we run the WIATEC model in a historical simulation mode over the period 2005-2007 to obtain estimates of the historical values of the so-called rate of (autonomous or induced)[10] 'energy efficiency improvement' (*EEI*). This is defined as the difference in growth rates of production output over energy input (this is therefore the opposite of the rate of change of energy intensity). Once the historical levels of the *EEIs* are known, assumptions can be made about their future levels (see Table 6). From this Table, it can be seen that over the period 2005-7, the *EEIs* fluctuated quite significantly.[11] To project these figures into the future, therefore, we need first to estimate their historical averages. Then, for the nearer term (2007-2010) we assume that the *EEI* will return to some proportion[12] of this historical average level. For the longer term (2010-2035), however, we assume the *EEIs* for all regions will 'converge' to some long run value (see Table 6).[13] Once the *EEI*s are known, the energy and emissions intensities can also be estimated and these are shown in Tables 7-8 and Figure 6. In Table 8, it is seen that given the projected levels of *EEIs* as assumed for the BaU scenario, the emission intensities in China and India over the period from 2005 to 2020 will be reduced by about -23.3% and -20.9% respectively[14], while those of Bangladesh, Indonesia, Thailand and Viet Nam will be reduced by -17.9%, -12.6%, -23.0% and -13.8% respectively over this period. These reductions in emissions intensities of the studied countries are comparable to those of developed regions, such as the USA (-24.7%), Japan (-16.2%), the EU15 (-25.9%). The resultant CO_2 emissions levels for all regions are then estimated and shown in Table 9 and Figure 7. From Table 9, it can be seen that for China, starting in 2005 with a level of emissions comparable to that of the US (but about twice that of the EU15), by the end of 2030, the emissions from China would have tripled, while that from the US and the EU15 would have increased only moderately by about 11%. Similarly, emissions from India in 2005 are comparable to that of Japan, but by the end of 2030, those emissions would have more than doubled while that of Japan would have grown only moderately, by about 16.5%. The vast differences in the projected emissions growth rates for these countries can only be explained in terms of the

[9] In the revised projections, we assume a smaller degree of 'convergence' in GDP growth but a greater degree of convergence in population growth as compared to the projections by the EIA. This may be justified because it seems the small and sometimes negative growth rate of some developed regions population may not continue indefinitely without affecting the (projected) GDP growth rates.

[10] By 'autonomous' this is meant to be 'without the influence of any particular policy' which normally will alter the *relative prices* of commodities and therefore 'induce' some (consumer's, producer's) substitution behaviour. The 'autonomous' change therefore, can be used to refer to the situation of the 'business-as-usual' or 'reference' scenario to be distinguished from the situation of the 'policy' scenario where a *particular* policy will be applied and that will induce certain substitutional changes.

[11] Apart from the year 2005 which is a 'calibration' year and therefore the estimated value of *EEI* in this year may be subject to calibration errors, the values for the years (2006-2007) also show some significant variations. This can be explained in terms of fluctuations in the levels of capacity utilization due to business cycles which can affect the level of energy efficiency.

[12] This 'proportion' is assumed to be 0.75 for all regions (with the exception of EU15, EU12, and Russia where we assume a figure of .5, .4, and .4 respectively). The purpose of these assumptions is simply to limit the projected levels of *EEI* to be in the range of 0.5 – 2 which is the range estimated by other empirical studies in this area (see for example, by Bataille *et al*. (2006), and Luciuk (1996) who reported a figure of 0.25% to 0.5% for *EEI* in top-down models, and 0.75% to 1.5% for *EEI* in bottom-up models).

[13] The convergence value is assumed to be 0.5 and the convergence year is around 2050.

[14] This seems to be in agreement with other studies, for example, Stern and Jotzo (2010) who estimated that the 'business-as-usual' reduction in emission intensity for China will be around -24% between 2005 and 2020. The estimated reduction in emission intensity for India is subject to a larger variation, and can range from a low value of -2% to a high value of -29% over the period 2005-2020.

great differences in the projected GDP growth rates (see Table 5). This is because as Table 8 shows, similar reductions in emissions intensities have been assumed for both developed and developing countries. Therefore, unless additional climate change and/or technological policies are to be implemented which can greatly reduce the emission intensities of the studied countries; in particular China and India, the projected growth rates of CO_2 emissions from these countries will continue to grow strongly and linked closely to the projected GDP growth rates. The crucial issue therefore is whether this link can be broken and GDP growth rate and emissions growth can to some extent be 'decoupled'. This issue is to be considered next.

Figure 2: Historical (2005-2007) and projected (2007-2035) rates of GDP growth (% p.a.) based on EIA published information.

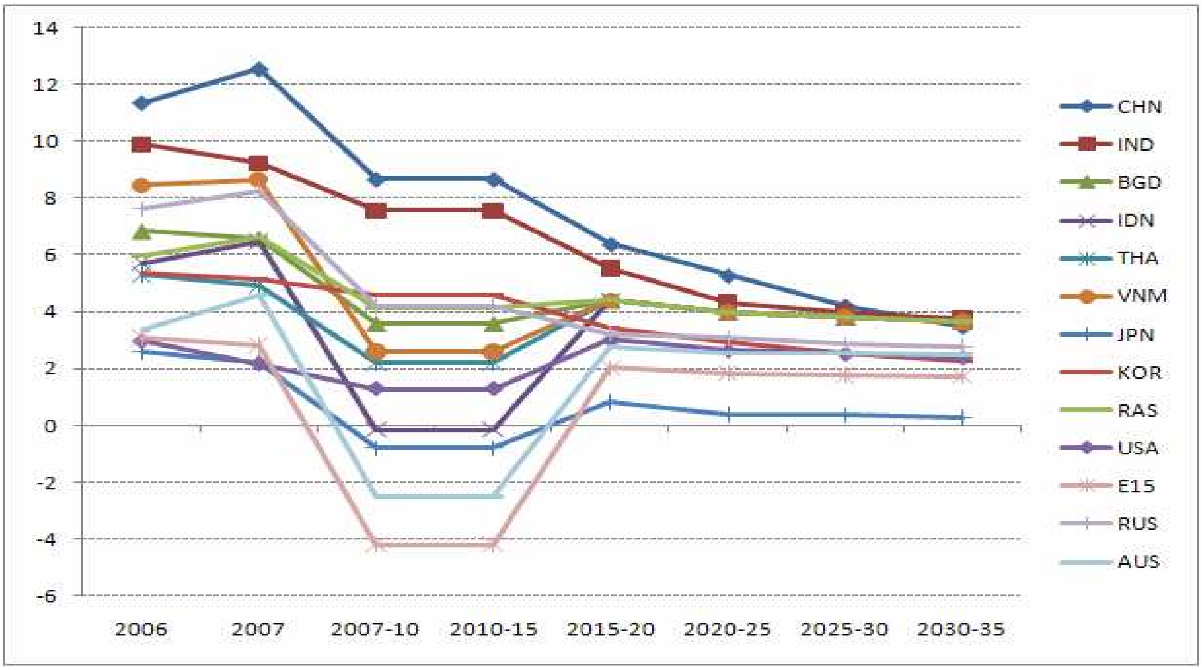


Figure 3: Historical (2005-2007) and projected (2007-2035) rates of population growth (% p.a.) based on EIA published information.

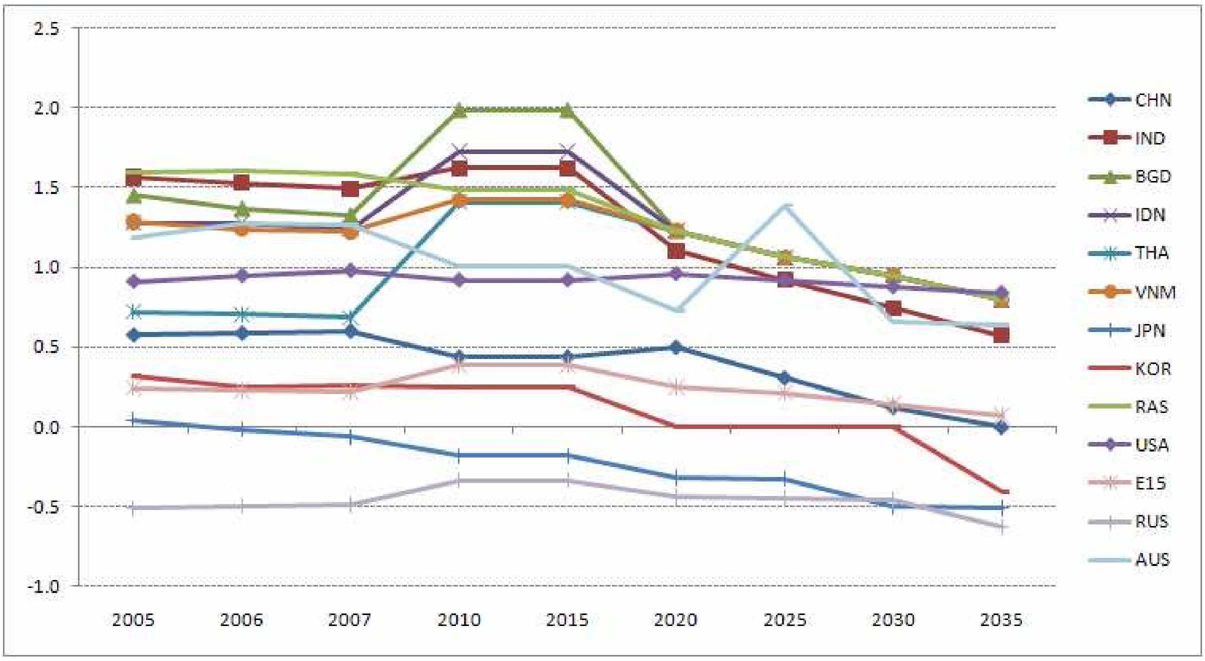


Figure 4: Historical (2005-2007) and projected (2007-2035) rates of GDP growth (% p.a.) modified from EIA published data and used for the BaU Scenario

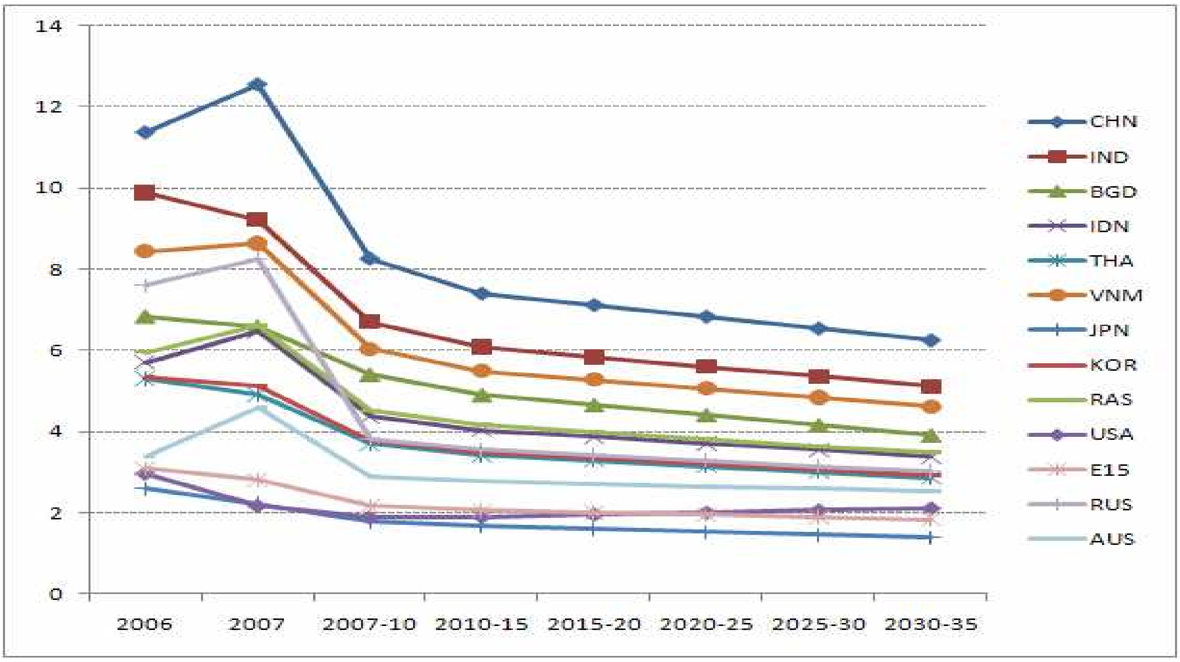


Figure 5: Historical (2005-2007) and projected (2007-2035) rates of population growth (% p.a.) modified from EIA published data and used for the BaU scenario

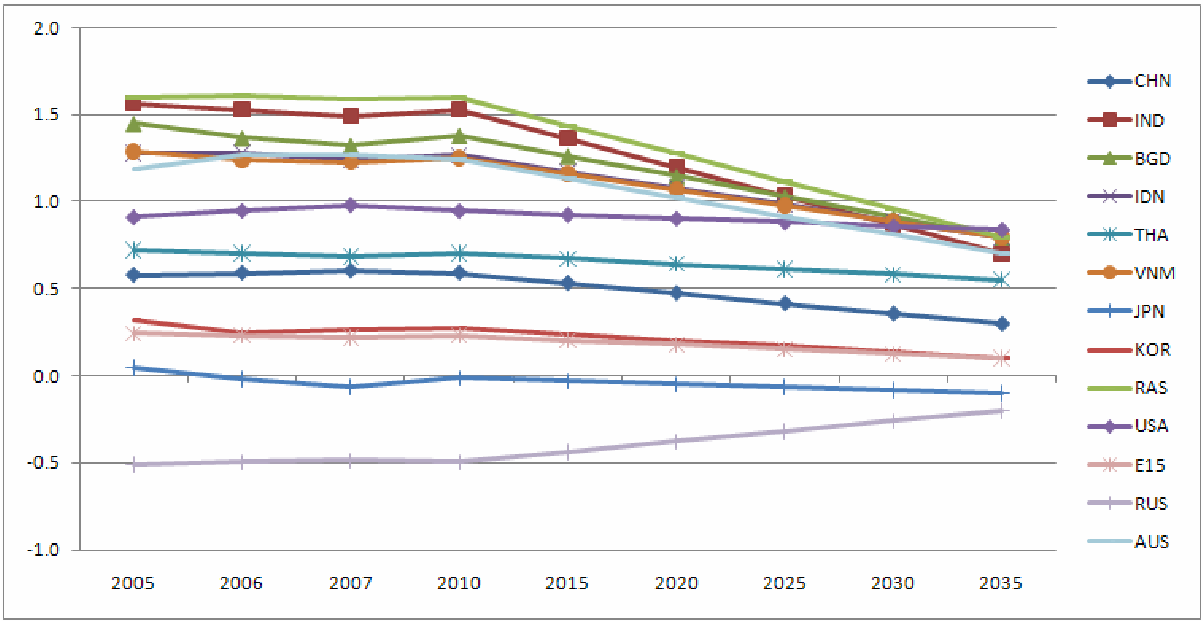


Table 5: Projected GDP and Population growth rates for the period (2007-2035) used for the BaU scenario

Region	GDP growth (% per annum)						Population growth (% per annum)					
	2007-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035	2007-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
CHN	8.26	7.41	7.13	6.84	6.55	6.26	0.59	0.53	0.47	0.41	0.36	0.30
IND	6.70	6.08	5.84	5.60	5.36	5.12	1.50	1.33	1.17	1.01	0.85	0.69
BGD	5.41	4.91	4.66	4.42	4.17	3.92	1.36	1.23	1.12	1.01	0.90	0.78
IDN	4.38	4.04	3.88	3.71	3.55	3.38	1.25	1.14	1.05	0.96	0.87	0.78
THA	3.69	3.43	3.29	3.15	3.01	2.86	0.70	0.66	0.63	0.60	0.57	0.54
VNM	6.03	5.50	5.28	5.06	4.84	4.62	1.24	1.13	1.05	0.96	0.87	0.78
JPN	1.78	1.68	1.61	1.54	1.47	1.39	-0.01	-0.03	-0.05	-0.06	-0.08	-0.10
KOR	3.78	3.51	3.36	3.22	3.08	2.93	0.27	0.24	0.20	0.17	0.13	0.10
RAS	4.51	4.16	3.99	3.82	3.65	3.48	1.57	1.40	1.24	1.09	0.94	0.78
USA	1.90	1.91	1.97	2.02	2.07	2.12	0.94	0.91	0.89	0.87	0.85	0.83
CAN	2.26	2.13	2.04	1.95	1.86	1.77	0.82	0.74	0.67	0.61	0.54	0.47
BRA	3.45	3.21	3.08	2.95	2.81	2.68	1.29	1.14	1.00	0.86	0.72	0.58
RAM	4.51	4.16	3.99	3.82	3.65	3.48	1.32	1.19	1.07	0.96	0.84	0.73
E15	2.17	2.07	2.01	1.95	1.89	1.84	0.23	0.20	0.18	0.15	0.13	0.10
E12	3.15	2.88	2.71	2.54	2.37	2.19	-0.14	-0.09	-0.05	0.00	0.05	0.10
RUS	3.82	3.55	3.42	3.29	3.16	3.02	-0.50	-0.44	-0.38	-0.32	-0.26	-0.20
AUS	2.91	2.77	2.71	2.65	2.59	2.53	1.23	1.11	1.01	0.90	0.80	0.69
NZL	1.80	1.70	1.63	1.55	1.48	1.41	1.01	0.93	0.85	0.78	0.70	0.63
ROW	3.99	3.70	3.55	3.40	3.24	3.09	1.93	1.64	1.39	1.13	0.86	0.60

Source: author's calculations.

Table 6: Historical (2005-2007) and Projected (2007-2035) Energy Efficiency Improvement (EEI) index for various regions used in the BaU scenario (% per annum)

Region	Historical			Projected					
	2005	2006	2007	2007-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
CHN	3.2	0.4	4.3	1.77	1.61	1.45	1.29	1.14	0.98
IND	6.8	1.7	2.5	1.59	1.43	1.28	1.12	0.97	0.81
BGD	10.4	3.7	0.0	1.37	1.24	1.12	1.00	0.87	0.75
IDN	18.1	1.6	-3.1	1.23	1.12	1.02	0.92	0.81	0.71
THA	13.0	3.9	0.9	1.81	1.62	1.43	1.25	1.06	0.87
VNM	19.5	2.7	0.0	1.00	0.93	0.86	0.79	0.71	0.64
JPN	-1.6	3.7	-0.5	1.20	1.10	1.00	0.90	0.80	0.70
KOR	-5.7	3.2	2.4	2.10	1.87	1.64	1.42	1.19	0.96
RAS	8.1	3.1	3.0	2.29	2.03	1.78	1.52	1.27	1.01
USA	13.3	4.3	0.9	1.94	1.73	1.53	1.32	1.12	0.91
CAN	10.9	6.2	-3.6	0.97	0.90	0.83	0.77	0.70	0.63
BRA	1.5	2.1	1.4	1.29	1.18	1.07	0.95	0.84	0.73
RAM	20.2	2.6	1.7	1.63	1.47	1.31	1.14	0.98	0.82
E15	9.0	2.9	4.6	1.87	1.68	1.48	1.28	1.09	0.89
E12	7.0	3.9	5.4	1.86	1.67	1.47	1.28	1.08	0.89
RUS	13.6	3.5	7.5	2.20	1.96	1.71	1.47	1.23	0.99
AUS	1.2	1.9	3.0	1.85	1.65	1.46	1.27	1.08	0.88
NZL	5.2	-1.0	7.7	2.51	2.22	1.94	1.65	1.36	1.07
ROW	-3.5	0.8	0.8	0.63	0.61	0.59	0.57	0.55	0.54
World	5.9	1.0	0.6						

Source: author's calculations.

Table 7: Projected Energy and Emission Intensity over the period (2007-2035) used in the BaU scenario

Region	Projected Energy Intensity (toe/'000 2005US$)						Projected Emission Intensity ($kgCO_2$/2005US$)					
	2007-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035	2007-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
CHN	0.96	0.88	0.81	0.76	0.72	0.68	2.12	1.94	1.80	1.69	1.59	1.51
IND	0.71	0.66	0.62	0.59	0.56	0.54	1.40	1.30	1.21	1.15	1.09	1.05
BGD	0.26	0.24	0.23	0.22	0.21	0.20	0.53	0.50	0.47	0.45	0.43	0.41
IDN	0.58	0.55	0.52	0.49	0.47	0.46	1.12	1.06	1.00	0.96	0.92	0.89
THA	0.66	0.60	0.55	0.52	0.49	0.47	1.07	0.98	0.91	0.85	0.81	0.77
VNM	0.53	0.51	0.48	0.47	0.45	0.43	1.54	1.47	1.41	1.35	1.30	1.26
JPN	0.16	0.15	0.14	0.13	0.13	0.12	0.22	0.21	0.20	0.19	0.18	0.18
KOR	0.48	0.44	0.40	0.38	0.35	0.34	0.55	0.50	0.45	0.42	0.40	0.38
RAS	0.49	0.44	0.40	0.37	0.34	0.33	0.78	0.70	0.64	0.59	0.55	0.52
USA	0.22	0.20	0.18	0.17	0.16	0.15	0.40	0.37	0.34	0.32	0.30	0.29
CAN	0.31	0.30	0.29	0.27	0.26	0.26	0.48	0.46	0.44	0.43	0.41	0.40
BRA	0.38	0.35	0.33	0.32	0.30	0.29	0.45	0.42	0.40	0.38	0.36	0.35
RAM	0.33	0.31	0.29	0.27	0.26	0.24	0.53	0.49	0.46	0.43	0.41	0.40
E15	0.15	0.13	0.12	0.11	0.11	0.10	0.21	0.20	0.18	0.17	0.16	0.15
E12	0.44	0.40	0.37	0.35	0.33	0.31	0.79	0.73	0.67	0.63	0.60	0.57
RUS	1.28	1.15	1.04	0.96	0.90	0.85	1.96	1.77	1.61	1.50	1.41	1.34
AUS	0.24	0.22	0.21	0.19	0.18	0.17	0.49	0.45	0.42	0.39	0.37	0.35
NZL	0.18	0.16	0.14	0.13	0.12	0.11	0.29	0.26	0.24	0.22	0.20	0.19
ROW	0.73	0.71	0.68	0.66	0.65	0.63	1.24	1.21	1.17	1.14	1.11	1.08

Source: author's calculations

Figure 6: Historical (2005-2007) and estimated (2007-2035) levels of Emissions Intensity ($kgCO_2$/2005US$) for the BaU Scenario

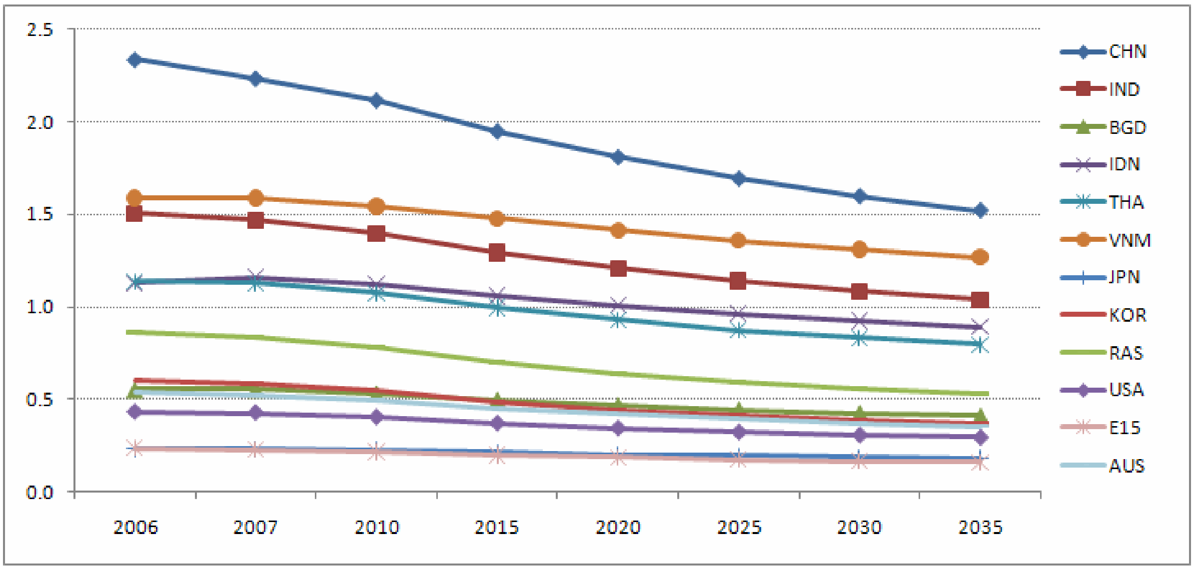


Table 8: Reduction of Energy and Emission Intensity over the projected period for the BaU scenario

Region	Reduction of Energy Intensity over the period shown (%)			Reduction of Emission Intensity over the period shown (%)		
	2005-2010	2005-2020	2005-2030	2005-2010	2005-2020	2005-2030
CHN	-9.8	-23.1	-32.1	-10.0	-23.3	-32.3
IND	-8.8	-20.7	-28.8	-8.9	-20.9	-29.0
BGD	-7.6	-18.2	-25.7	-7.3	-17.9	-25.3
IDN	-2.3	-12.5	-19.9	-2.5	-12.6	-19.9
THA	-10.0	-23.2	-31.8	-9.8	-23.0	-31.4
VNM	-5.6	-13.8	-20.2	-5.5	-13.8	-20.1
JPN	-6.7	-16.2	-23.2	-6.7	-16.2	-22.8
KOR	-11.5	-26.4	-35.6	-11.9	-26.7	-36.1
RAS	-12.5	-28.3	-38.0	-12.8	-28.6	-38.0
USA	-10.6	-24.6	-33.5	-10.7	-24.7	-33.0
CAN	-5.6	-13.6	-19.8	-5.9	-13.9	-19.9
BRA	-7.2	-17.3	-24.6	-7.0	-17.1	-24.2
RAM	-9.0	-21.2	-29.3	-8.7	-20.9	-28.9
E15	-12.6	-25.8	-34.4	-12.6	-25.9	-33.7
E12	-14.2	-27.1	-35.4	-14.6	-27.4	-35.6
RUS	-16.6	-31.2	-40.2	-16.9	-31.4	-40.1
AUS	-10.1	-23.6	-32.3	-10.3	-23.7	-32.3
NZL	-13.8	-30.8	-40.8	-13.8	-30.8	-40.2
ROW	-3.5	-9.2	-14.3	-3.7	-9.4	-14.4

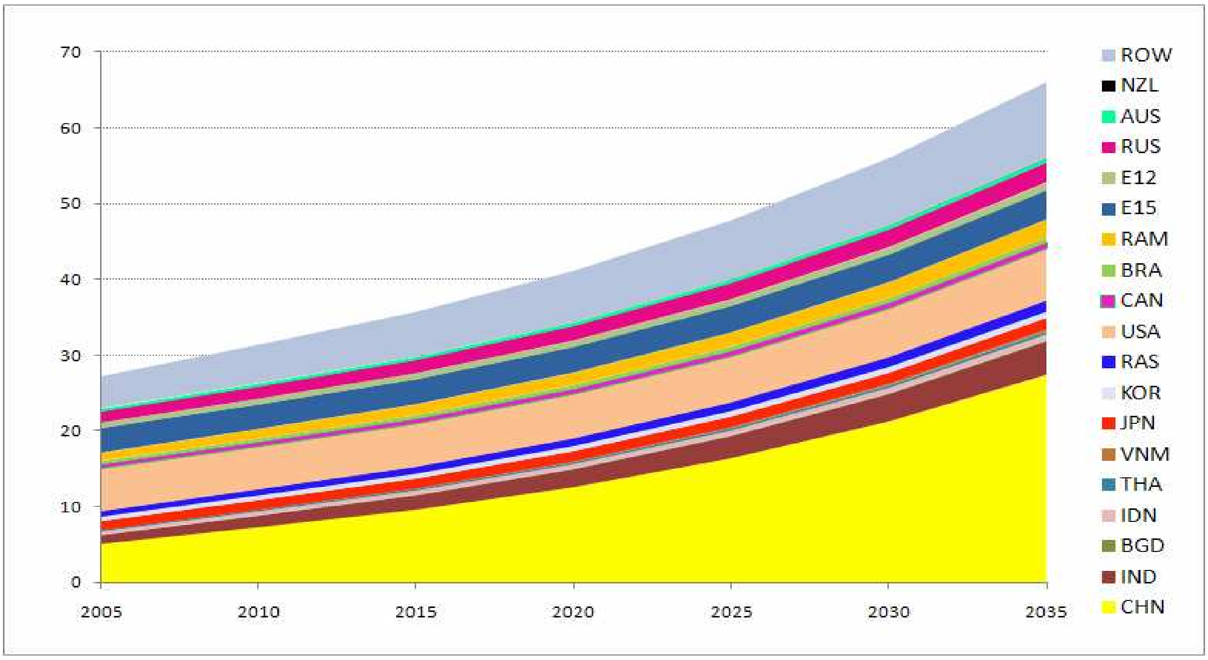
Source: author's calculations

Table 9: Projected (2010-2035) levels of CO2 emissions estimated for the BaU scenario

Region	CO_2 emissions ($GtCO_2$/yr)						Growth rates of CO_2 emissions over the period		
	2010	2015	2020	2025	2030	2035	2005-2010	2005-2020	2005-2030
CHN	7.30	9.58	12.54	16.33	21.15	27.26	43.1	146.0	314.9
IND	1.53	1.91	2.37	2.94	3.63	4.48	32.8	105.9	215.1
BGD	0.04	0.05	0.06	0.07	0.09	0.10	23.6	74.7	142.3
IDN	0.41	0.48	0.55	0.62	0.71	0.81	24.8	64.9	115.8
THA	0.24	0.26	0.28	0.31	0.34	0.38	11.2	32.0	59.4
VNM	0.11	0.13	0.17	0.21	0.25	0.30	32.7	104.8	207.7
JPN	1.26	1.29	1.33	1.37	1.42	1.47	3.2	9.1	16.5
KOR	0.51	0.55	0.60	0.65	0.71	0.78	9.1	27.2	51.4
RAS	0.89	0.98	1.09	1.21	1.36	1.53	12.4	37.2	71.9
USA	5.75	5.77	5.87	6.06	6.40	6.78	-0.6	1.6	10.6
CAN	0.59	0.63	0.67	0.71	0.75	0.79	6.9	20.2	35.0
BRA	0.37	0.41	0.45	0.49	0.54	0.60	13.0	37.2	66.8
RAM	1.20	1.36	1.55	1.76	2.01	2.29	17.7	52.0	97.2
E15	3.22	3.27	3.34	3.45	3.61	3.78	-1.3	2.5	10.8
E12	0.75	0.80	0.84	0.89	0.95	1.02	6.3	19.0	34.6
RUS	1.66	1.78	1.93	2.10	2.32	2.56	8.3	25.9	51.2
AUS	0.41	0.43	0.45	0.49	0.52	0.57	5.8	17.8	35.3
NZL	0.03	0.03	0.03	0.03	0.03	0.03	-4.6	-9.6	-9.2
ROW	5.00	5.81	6.71	7.70	8.79	9.95	20.7	62.0	112.2
World	31.27	35.53	40.84	47.40	55.60	65.49	15.2	50.4	104.8

Source: author’s calculations
Note: For emissions levels in 2005, see Table 2.

Figure 7: Historical (2005-2007) and projected (2007-2035) levels of CO2 emissions (GtCO2/yr) estimated for the BaU Scenario



Impacts of climate change policies on trade and production patterns – Policy scenarios

In this section, we explore the impacts of climate change policy on the level of economic development and trade. Given the potential for CO_2 emissions to grow quite substantially in developing countries if we accept the assumptions regarding GDP growth and technological progress as assumed in the BaU scenario, an important question arises: how feasible is it to reduce growth in emissions without impacting severely on economic growth and trade? Developing countries such as China and India tend to respond to this question by arguing that it is inequitable to ask developing countries to sacrifice growth for the sake of reducing emissions, therefore, an alternative for climate change policy is to try to reduce emission *intensities* rather than reducing emissions levels directly. As Pizer (2005) pointed out, emission intensity targeting may be able to 'accommodate' the objective of economic growth better than emissions levels targeting. Furthermore, it is believed that the potential for emissions intensity reduction is greater in developing countries than in developed countries because the state of technology and structure of the economy in developing countries allows more room for improvements in these countries than in developed countries. However, given any commitment to a particular level of economic growth, reducing emission intensity is simply equivalent to reducing the *rate of growth* of emission even if not reducing its absolute level. In the short run this may 'accommodate' for economic growth without greatly changing the fundamental relationship between emissions and production activities, but in the long run, this fundamental issue cannot be avoided, whether emission level or emission intensity is the chosen target for climate change policies. Nevertheless, given the emphasis assigned by developing countries, in particular China, to the choice of emission intensity as a target for climate change policy, rather than emission level or growth, this section of the study will conduct the experiments and analysis in terms of this choice of target. Section 3.1 defines the emission intensity reduction targets for the studied countries. Section 3.2 explores the issue of how to achieve these targets through the use of market instruments (emission trading scheme and/or carbon tax). Section 3.3 compares the use of market instruments with the use of mandatory regulatory system and looks at the differences in impacts especially with regard to trade issues.

1. Policy scenario - Emission intensity reduction

Assume that, as part of the climate change policies, China and India target to reduce their emission intensities by about 40% and 30% respectively over the period 2005-2020 [15] Assuming also that given the examples set by China and India, other countries in the region will also follow suite with similar announced emission intensity reduction targets. From the projections for the BaU scenario as given in the last section, we can assume that Bangladesh, Indonesia, Thailand, and Viet Nam will set as their emission intensity reduction targets: 20%, 15%, 25%, and 20% respectively for the period 2005-2020.[16] These emission intensity reduction targets are then translated into absolute levels of emissions as shown in Figure 8 and also in terms of reductions *relative* to the BaU scenario as shown in Table 10. From this Table, it can be seen that to achieve the emission intensity reduction targets for this policy scenario, the studied countries must reduce their *energy intensities* over the period 2005-2020 to the order of -85% to -156% for the case of China, -50% to -168% for the case of India, and -44% to -177% for the case of Viet Nam. These are tall orders, especially in view of the fact that the projected reductions in energy intensity over the same period in the BaU scenario are only about -22% for China, -12% for India, -2 to -3% for Bangladesh, Indonesia, and Thailand, and about -7.2% for Viet Nam. The crucial question therefore is how to achieve these tall orders.

2. Emission intensity targeting through the use of market instruments – Policy scenario 'M' (Market mechanism)

A market instrument such as emission trading scheme (ETS) and/or carbon tax (CTAX) [17] can be used to induce emission intensity reduction where this is most efficient. The price signal provided by these instruments gives directions to emission abatement activities and guide these activities to the most efficient outcome. At equilibrium, the emission permit price or carbon tax gives the value of the minimum marginal abatement cost (MAC) and Table 11 reports on the cumulative values of these MAC ($\$/tCO_2$) for different regions as estimated by the model. From these MAC curves, we can also estimate the total economic costs of achieving a particular emission intensity reduction target which is assume to be the area under these MAC curves. These costs are also reported in Table 11.

3. Emission intensity targeting without the use of market instruments – Policy scenario 'N' (No market mechanism)

If market instruments such as emission trading scheme and/or carbon tax are not used, the government may resort to the use of mandatory regulation. In theory, regulation can still achieve the most efficient outcome if it can mimic the working of a perfectly competitive market system and enforce emission abatement activities where this is most efficient. In

[15] Officially, China has announced that it will reduce its emission intensity by 40-45% between 2005 and 2020, and India by 20-25% (see the references for these announcements given in Stern and Jotzo (2010)). We assume a lower target for China and higher target for India because the BaU Scenario has projected a lower potential for reducing emission intensity in China but a higher potential in India (see previous section).

[16] This implies *additional* reductions (over and above the reductions shown in the BaU Scenario) of -1.8%, -2.5%, -1.8%, and -6.2% respectively for Bangladesh, Indonesia, Thailand, and Viet Nam, and for China and India, the additional reductions in emission intensities over and above the BaU scenario reductions are -16.9% and -9.3%, respectively.

[17] From a theoretical viewpoint, emission trading is similar to carbon tax where the equilibrium price of emission permit is equal to the carbon price. From a practical policy implementation viewpoint, however, there may be significant differences between the two systems (see for example, Low (2009)) depending on the issue of uncertainty and the values of different demand-supply elasticities for emission abatement activities. In this paper, however, we regard these two (market) instruments as being equivalent because we want to concentrate on the issue of market versus non-market choice of instruments rather than on the issue of implementation of any particular (market) instrument.

practice, however, this is difficult to be achieved because it requires a great deal more information which is costly to obtain. Therefore, mandatory regulation is likely to be less efficient than a market system. To simulate the working of a regulatory system, we assume that an overall emission intensity reduction target is to be imposed on the economy as a whole. The model then will work out which best emission intensity reduction activity is to be pursued and in which sector, based on the current cost structure and emission intensity of the sectors as specified in the model. The results of this simulation (called Policy scenario '*N*' for *N*o market system) are reported in Tables 12-16. In Table 12, we show the decrease in welfare when no market mechanism is used (scenario '*N*') as compared to the case when market mechanism is used (scenario '*M*').[18] To understand why there is a decrease in welfare, we look at Table 13 (for the case of China).[19] Here we look at the results of emission intensity reduction *at the sectoral level* rather than at the aggregate economy level. It is observed from this Table that for the electricity sector (ely), emission intensity is reduced *more* in scenario '*M*' than in scenario '*N*'. The opposite occurs for all other sectors (agriculture (agr), transport (trp), iron and steel (I_S), mineral products (NMM), chemical rubber and plastic (CRP), metal products (FMP), transport equipments (OTN), electronic equipments (ELE), machinery equipments (OME)). This can be explained as follows. When guided by a permit price or carbon tax which represents the optimal shadow price of emission, the electricity sector (which is most emission intensive) will tend to reduce its emission *more* in this case than in the case where no such shadow price is imposed. The counterbalancing effect of this is that other sectors can then reduce their emission intensity *less*. Since it is cheaper to reduce emission intensity in the electricity sector than in other sectors (such as agriculture), it is therefore more efficient to have the electricity sector reducing its emission intensity more than other sectors (which is the case of scenario '*M*') The higher efficiency of scenario '*M*' is the main reason why the welfare level in this scenario is also higher than that in scenario *N*.

Because a shadow price of emission is put on electricity output in scenario '*M*', its price is also experiencing a larger increase (or a smaller decrease) [20] in this scenario as compared to scenario *N*' (an increase of 3.05% over the period 2015-2020 in scenario '*M*' as compared to a decrease of -2.76% in the same period for scenario '*N*', see Table 14). Despite this larger *increase* in electricity *price* in scenario '*M*', *output* of electricity also *increases more* in scenario '*M*' than in scenario '*N*' (see Table 15). This remarkable result can be explained in terms of general equilibrium (substitution, output, and trade) effects as follows. Firstly, *substitution effect*: because of an emission price being put on the production of electricity generated from coal (ElyCoa) in scenario '*M*' which makes it more expensive to produce than electricity produced from other techniques, a substitution process occurs which reduces the output from ElyCoa relative to outputs from other production techniques and this also bring down the overall level of emission electricity generation and allow for a larger increase in electricity output. Secondly, *output effect*: because electricity sector is now less emission intensive, other non-electricity sectors can afford to be more emission intensive. This means production levels of non-electricity sectors can increase more and this further stimulates the demand for electricity and therefore also increases electricity production output. Finally, *trade effect*: because economic activities are generally more efficient and therefore also more expansive in scenario '*M*' as compared to scenario '*N*' (Table 15), trade activities can also benefit (see Table 16). In conclusion, this shows that a reliance on a market

[18] Note that to compare the results of Scenarios '*M*' and '*N*' properly, we must use the same assumptions about GDP growth rates and emission intensity reduction targets for both Scenarios, and the only difference between them is the assumption on the use (or non-sue) of market instruments.

[19] But the analysis applies equally well to other regions.

[20] Negative demand and output effect is the reason for the decrease in electricity price, while the effect of the shadow price of emission is to increase its price. The net effect depends on the relative strength of these two opposite effects.

mechanism can be beneficial for both domestic productions as well as for international trade, as compared to a situation where a mandatory regulatory system is used to achieve the same level of emission intensity reduction target.

Figure 8: Historical (2005-2007) and projected (2007-2035) levels of CO2 emissions (GtCO2/yr) estimated for the policy scenario

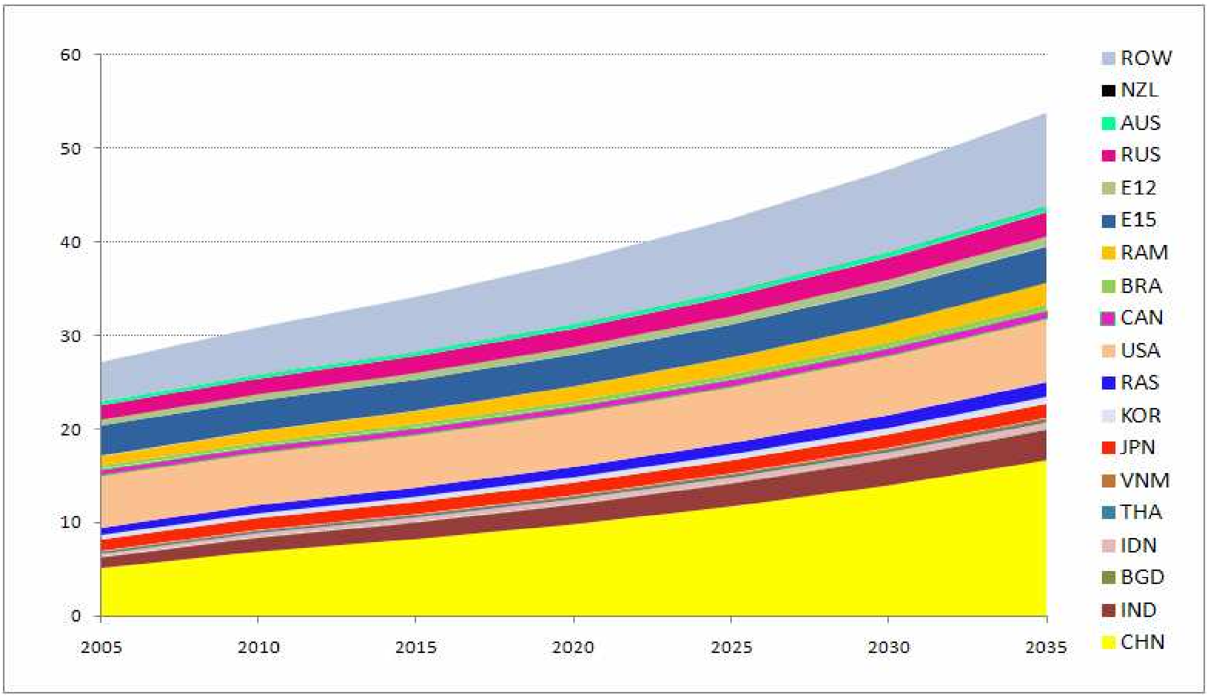


Table 10: Policy scenario - Projected reductions in emissions intensities, in emissions levels and in energy intensities relative to the BaU scenario

Region	Projected reduction in emission intensity over the period shown (%)			Projected reduction of CO_2 emission relative to the BaU scenario (%)			Projected reduction of energy intensities over the BaU scenario (%)		
	2005-2010	2005-2020	2005-2030	2010	2020	2030	2010	2020	2030
CHN	-15.0	-40.2	-56.0	-5.5	-22.0	-35.0	-85.2	-156.3	-135.2
IND	-11.1	-30.1	-44.6	-2.4	-11.7	-22.0	-47.9	-167.9	-182.9
BGD	-7.3	-19.7	-30.7	0.0	-2.2	-7.3	0.0	-36.3	-68.6
IDN	-2.5	-15.1	-27.3	0.0	-2.8	-9.2	-9.0	-63.5	-110.0
THA	-9.8	-24.8	-36.8	0.0	-2.4	-7.9	-3.0	-28.9	-76.0
VNM	-6.7	-19.9	-32.0	-1.2	-7.2	-14.9	-43.6	-176.6	-211.0
JPN	-6.7	-16.2	-23.1	0.0	0.0	0.0	0.0	0.0	0.0
KOR	-11.9	-26.7	-35.9	0.0	0.0	0.0	0.0	0.0	0.0
RAS	-12.8	-28.6	-38.2	0.0	0.0	0.0	0.0	0.0	0.0
USA	-10.7	-24.7	-33.6	0.0	0.0	0.0	0.0	0.0	0.0
CAN	-5.9	-13.9	-20.1	0.0	0.0	0.0	0.0	0.0	0.0
BRA	-7.0	-17.1	-24.4	0.0	0.0	0.0	0.0	0.0	0.0
RAM	-8.7	-20.9	-29.1	0.0	0.0	0.0	0.0	0.0	0.0
E15	-12.6	-25.9	-34.4	0.0	0.0	0.0	0.0	0.0	0.0
E12	-14.6	-27.4	-35.8	0.0	0.0	0.0	0.0	0.0	0.0
RUS	-16.9	-31.4	-40.4	0.0	0.0	0.0	0.0	0.0	0.0
AUS	-10.3	-23.7	-32.4	0.0	0.0	0.0	0.0	0.0	0.0
NZL	-13.8	-30.8	-40.8	0.0	0.0	0.0	0.0	0.0	0.0
ROW	-3.7	-9.4	-14.5	0.0	0.0	0.0	0.0	0.0	0.0

Source: author's calculations

Table 11: Policy scenario 'M' – minimum economic costs for achieving the emission intensity reduction target with the use of market instruments

Region	Reduction in CO_2 emissions relative to BaU scenario ($GtCO_2$)			Cumulative marginal CO_2 emissions abatement cost ($\$/tCO_2$)			Cumulative costs of CO_2 emissions intensity reduction (%GDP)		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
CHN	-1.47	-5.01	-10.12	23.9	52.1	85.5	0.5	4.0	10.9
IND	-0.13	-0.48	-1.02	13.6	37.1	66.5	0.1	0.9	2.9
BGD	0.0	0.0	-0.01	1.4	37.0	115.5	0.0	0.0	0.3
IDN	0.0	-0.02	-0.06	3.0	15.8	44.3	0.0	0.0	0.3
THA	0.0	-0.01	-0.02	1.7	19.6	57.5	0.0	0.0	0.3
VNM	0.0	-0.02	-0.04	21.4	53.2	94.8	0.1	0.9	3.2

Source: author's calculations

Table 12: Welfare measures for policy scenarios 'M' and 'N'

Region	Equivalent Variation welfare measure for policy scenario '*M*' when *M*arket instrument is used ($US billion)			Equivalent Variation welfare measure for policy scenario '*N*' when *NO* market instrument is used ($US billion)			Change in welfare from policy scenario *M* to *N* (%)		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
CHN	629.7	1294.2	1700.4	612.7	1273.3	1679.8	-2.74	-1.63	-1.22
IND	171.1	341.5	425.6	168.8	336.8	419.8	-1.39	-1.39	-1.37
BGD	10.8	20.4	23.8	10.8	20.4	23.7	0.00	-0.14	-0.19
IDN	38.7	74.2	87.0	38.5	73.6	86.0	-0.44	-0.73	-1.15
THA	16.9	35.3	40.9	16.9	35.0	40.3	-0.02	-0.75	-1.45
VNM	629.7	1294.2	1700.4	8.2	16.4	20.0	-2.34	-2.00	-2.51

Source: author's calculations

Table 13: Emission intensity (kgCO2/$US) in selected sectors of the Chinese economy in policy scenarios 'M' and 'N'

sector	Policy scenario '*M*' when *M*arket instrument is used			Policy scenario '*N*' when *NO* market instrument is used		
	2010	2015	2020	2010	2015	2020
TEX	0.88	0.73	0.62	0.86	0.69	0.57
CRP	2.70	2.33	2.01	2.63	2.18	1.80
NMM	11.83	9.90	8.40	11.86	9.88	8.35
I_S	4.89	4.20	3.65	4.78	3.95	3.30
FMP	0.42	0.35	0.30	0.41	0.32	0.27
OTN	0.37	0.30	0.26	0.36	0.28	0.23
ELE	0.11	0.09	0.08	0.10	0.08	0.07
OME	0.39	0.32	0.28	0.38	0.30	0.24
agr	0.52	0.47	0.44	0.50	0.43	0.38
ely	50.35	42.61	34.63	50.33	45.33	40.39
trp	1.88	1.53	1.26	1.81	1.39	1.09
ser	0.17	0.13	0.11	0.16	0.12	0.10

Source: author's calculations

Figure 9: Emission share of various sectors in selected economies in base year (2005)

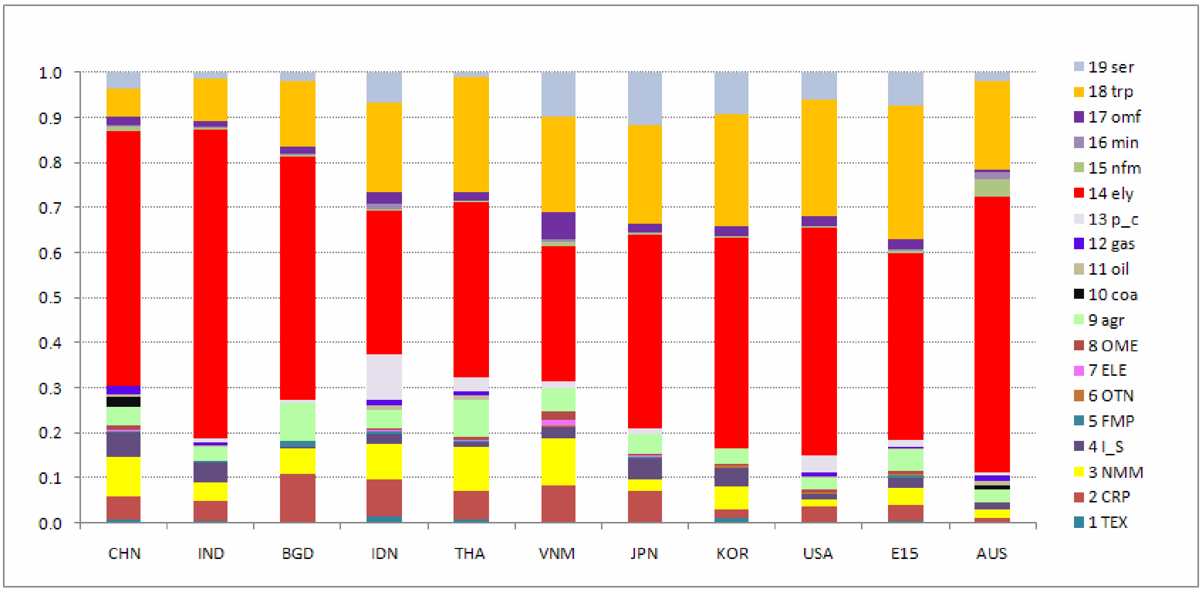


Table 14: Change in output price (% p.a.) in selected sectors of the Chinese economy in policy scenarios 'M' and 'N' over the period 2010-2020

sector	Policy scenario '*M*' when *M*arket instrument is used			Policy scenario '*N*' when *NO* market instrument is used		
	2010	2015	2020	2010	2015	2020
TEX	-1.73	-2.82	-2.60	-1.61	-2.70	-2.53
CRP	-1.63	-1.90	-1.58	-1.93	-2.16	-1.89
NMM	-2.19	-3.33	-2.41	-2.98	-4.13	-3.27
I_S	-1.92	-2.93	-2.13	-2.37	-3.35	-2.58
FMP	-1.84	-2.97	-2.62	-1.89	-3.03	-2.73
OTN	-2.12	-3.64	-3.33	-2.00	-3.54	-3.29
ELE	-0.75	-0.90	-1.26	-0.61	-0.80	-1.22
OME	-1.83	-2.95	-2.81	-1.74	-2.88	-2.81
agr	-0.91	-2.83	-1.11	-0.55	-2.45	-0.77
ely	-2.24	-0.42	3.05	-7.72	-6.52	-2.76
trp	-1.93	-2.50	-3.17	-1.73	-2.27	-3.02
ser	-2.44	-4.08	-4.27	-2.02	-3.72	-4.01
Techniques for generating electricity						
ElyCoa	-1.03	3.05	8.05	-8.57	-6.39	-2.33
ELyOil	-4.07	-2.24	1.12	-7.05	-5.23	-2.02
ElyGAS	1.02	3.01	4.66	-4.04	-2.46	-1.25
ElyBio	-2.23	-1.90	0.04	-4.22	-3.79	-2.02
ElyNu	-3.68	-4.92	-2.43	-6.40	-7.42	-4.37
ElyHyd	-3.37	-3.74	-0.83	-6.91	-7.10	-3.44
ElyOth	-3.70	-4.72	-2.04	-6.70	-7.42	-3.78

Source: author's calculations

Table 15: Output growth (% p.a.) in selected sectors of the Chinese economy in the policy scenarios ‘M’ and ’N’ over the period 2010-2020

sector	Policy scenario ‘*M*’ when *M*arket instrument is used			Policy scenario ‘*N*’ when *NO* market instrument is used		
	2010	2015	2020	2010	2015	2020
TEX	24.7	40.4	39.0	23.6	39.4	38.4
CRP	26.4	42.8	41.9	26.2	42.5	41.9
NMM	27.0	43.3	41.6	27.0	43.3	41.7
I_S	28.4	45.6	43.7	28.1	45.2	43.5
FMP	26.9	42.8	41.3	26.4	42.3	41.0
OTN	30.5	47.8	45.2	30.0	47.1	44.8
ELE	22.4	34.3	36.8	21.1	33.1	36.0
OME	30.5	47.3	45.7	29.7	46.4	45.1
agr	23.0	38.0	35.4	22.4	37.3	35.0
ely	17.4	27.0	28.1	14.4	22.3	23.1
trp	24.2	39.7	39.6	23.3	38.8	38.9
ser	27.9	44.5	42.7	27.5	44.1	42.4
Techniques for generating electricity						
ElyCoa	11.9	11.7	8.8	18.7	21.6	21.0
ELyOil	22.5	32.3	33.6	12.5	18.7	21.1
ElyGAS	9.9	18.6	24.2	5.7	12.2	19.4
ElyBio	17.4	30.8	36.0	6.1	15.5	21.3
ElyNu	21.0	39.5	43.2	11.1	24.7	27.4
ElyHyd	21.9	42.2	47.0	11.3	24.7	26.0
ElyOth	21.0	38.7	41.8	11.9	24.7	25.8

Source: author’s calculations

Table 16: Change in export and import quantities (% p.a.) in selected sectors of the Chinese economy in policy scenarios 'M' and 'N' over the period 2010-2020

sector	Policy scenario '*M*' when *M*arket instrument is used			Policy scenario '*N*' when *NO* market instrument is used		
	2010	2015	2020	2010	2015	2020
	Export					
TEX	20.4	34.2	32.9	19.2	33.1	32.2
CRP	19.1	31.0	31.2	20.2	31.9	32.4
NMM	21.5	35.9	32.4	25.2	39.7	36.0
I_S	21.6	37.6	34.6	23.4	39.2	36.1
FMP	23.3	37.3	35.3	23.2	37.0	35.4
OTN	33.9	53.2	49.2	32.1	51.2	48.0
ELE	17.8	26.3	29.4	16.2	24.9	28.4
OME	28.6	43.5	42.4	27.2	42.1	41.7
agr	16.0	32.8	25.2	14.0	30.4	23.2
	Import					
TEX	19.6	31.0	30.7	19.3	30.7	30.5
CRP	22.7	36.0	34.7	21.8	35.0	33.9
NMM	19.0	28.5	29.8	16.3	25.9	27.2
I_S	22.2	32.9	33.0	20.7	31.4	31.7
FMP	18.7	28.5	28.2	18.5	28.4	28.0
OTN	18.8	28.5	27.7	19.1	28.8	27.8
ELE	21.9	33.8	33.8	21.5	33.6	33.7
OME	20.3	30.7	29.6	20.6	31.0	29.7
agr	19.6	31.0	30.7	19.3	30.7	30.5

Source: author's calculations

Linkage between trade, production and climate change policies

Previous sections have looked at the relationship between production, emissions and climate change policies for the selected countries and it was found that the link between production (GDP growth) and emissions is strong and hard to 'decouple'.[21] Even with great efforts in emission intensity reductions in some countries such as China and India, the proportion of emissions from these countries in the world total continue to remain high (see Figure 10) despite the fact that the share of GDP of these countries in the world total is still low (see Figure 11). This implies the *levels* of the emission intensities in these countries are high (see Figure 4) and may remain high unless a different policy approach is used to tackle them.

1. Trade influence on the level of emission intensity

In considering the linkages between trade, production and climate change, it has been suggested (see for example, Davis and Caldeira (2010) that one reason why the emission intensity in China is high is because China exports a large percentage of its goods to the rest of the world and most of these goods are emission intensive. To give a better description of

[21] We have not looked at the issue of *endogenous* technological change or technology transfer which are crucial in reducing the link between emissions growth and GDP growth but this is beyond the scope of this study. We have, however, taken into consideration 'exogenous' or autonomous energy efficiency improvements in both the BaU and Policy Scenarios. For the BaU Scenario, section 2 and Table 6 gave details on the rate of autonomous *EEI* assumed. These rates are also carried over to the Policy Scenario. In addition, climate change policies in the Policy Scenario also *induce* further *EEI* and these are the reasons behind the reduction in emission intensities in the Policy Scenario over and above those in the BaU Scenario (section 3 and Table 10).

the actual emission intensity of a particular country such as China, it is suggested then that a *consumption*-based approach should be used to account for emissions from economic activities rather than *production*-based approach. This means emissions from export activities should not be counted towards the total emissions levels of the exporting country, but instead, should be attributed to the total emission level of the importing countries. To adjust the emission (and hence emission intensity) levels of different countries, we need to examine the patterns of their trading activities. Figure 12 shows the degree of trade openness or trade exposure[22]for different regions and from this Figure, it can be seen that the degree of trade openness for China is indeed quite high (about 35%). Tables 17 and 18 show the degree of trade openness for different sectors of an economy.[23] For China, the sectors which are most open to export[24] are: Textiles (TEX), Chemical, rubber, plastic (CRP), Metal products (FMP), Transport equipments (OTN), Electronic equipments (ELE), Machinery and equipments (OME), Manufactures (OMF). For India, these are: Textiles (TEX), Chemical, rubber, plastic (CRP), Electronic equipments (ELE), Machinery and equipments (OME), Metals (NFM), Minerals (MIN), and Manufactures (OMF). Some of these export-oriented sectors are emission intensive, but others are not. To estimate the overall contribution of these export-oriented sectors to the level of emission intensity of a particular region, we define some trade-related emission indices. Let x_{jrs} be the proportion of output of sector j in region r which is exported to region s; and let EM_{jr} be the total level of emissions from this sector. Define $XEM_{jrs} = x_{jrs}EM_{jr}$ as the level of emissions associated with the export of good j from region r to region s. Since import is the opposite of export, we can also define $MEM_{jsr} = XEM_{jrs}$ which is the level of emissions associated with the import of good j from region r into region s. Now, we can define:

$$\begin{aligned} TREMI_r &= (EM_r - \sum_j \sum_s XEM_{jrs} + \sum_j \sum_s MEM_{jsr}) / Y_r \\ &= (EM_r - XEM_r + MEM_r) / Y_r \end{aligned} \quad (1)$$

as the Trrade-adjusted emission intensity index for region r. This is to be compared against the conventional definition of emission intensity in region r:

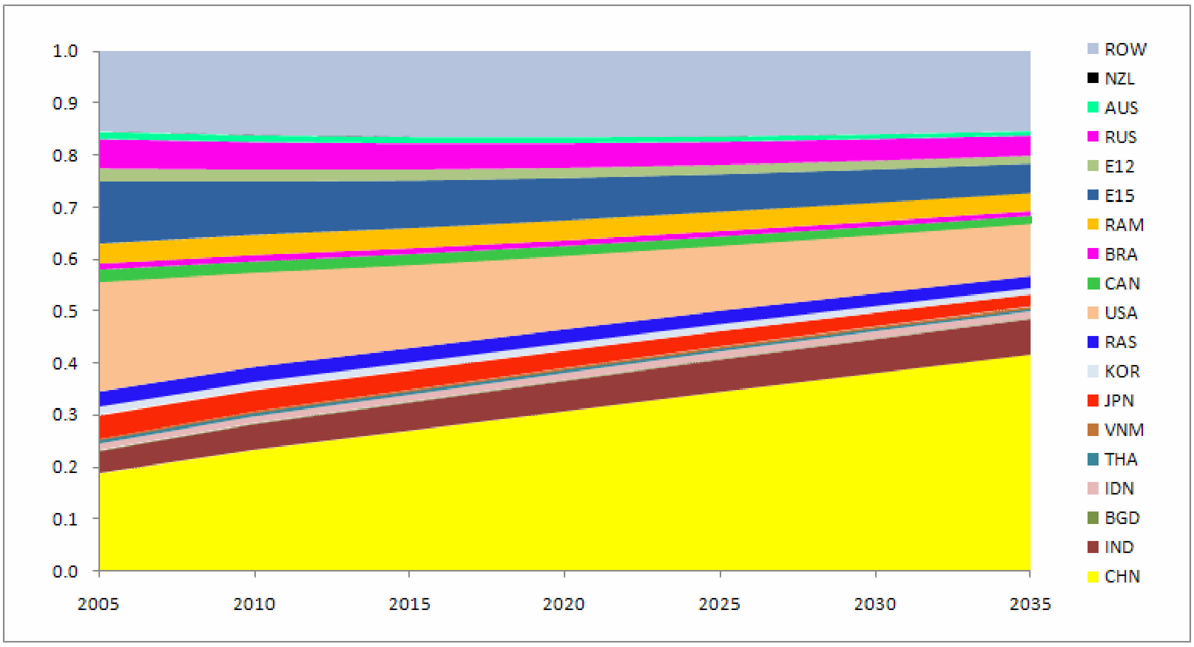
$$EMI_r = EM_r / Y_r \quad (2)$$

Here EM_r is the total (unadjusted) emissions in region r, XEM_r is the total emissions in region r attributed to exports, MEM_r is the total emissions in region r attributed to imports and Y_r is the total output (or GDP) of region r. To adjust emission intensity for trade, we have assumed that XEM_r should be *deducted* from total emissions (EM_r) whereas as MEM_r should be *added* to it. Summing over all regions, the total of all XEM_r's should be equal to the total of all MEM_r's and therefore, the emission intensity of the world as a whole does not change with the adjustments even if individual emission intensity of each region can change.[25] From Table 19, it can be seen that if we adjust the emission intensity for trade , then some regions

[22] We use the terms 'openness' and 'exposure' interchangeably.
[23] To do this, we need to estimate the level of 'activity' of each sector and this is measured by the total *value-added* of each sector (not the value of the production output, as the latter includes the value of intermediate inputs which represents outputs of other sectors). Trade openness for a particular sector is then defined as the ratio of export or import value over the total value added of the sector.
[24] We look at the export side of trade, but the same analysis applies to the import side.
[25] Note that in this *simple* approach for adjustment of emission intensities considered in this section, we do not take account of emissions from international transport, therefore, the adjustment of emission intensities of all regions will not lead to a change in emission intensity for the world as a whole. In a more sophisticated approach (considered in Truong and Mikic (2010)) and also see the next section), emissions from international transport are taken into account, Hence a change in trade patterns (due to a trade or climate change policy) can change not only the emission intensities of different regions but also for the world as a whole (see next section).

such as China, India, Indonesia, Thailand, Canada, Russian Federation, Australia will have their emission intensities adjusted downwards, while others such as Bangladesh, Viet Nam, Japan, Republic of Korea, USA, EU15, New Zealand will have their emission intensities adjusted upwards. This means some countries such as China, India, or Australia can claim that their 'true' emission intensities are *lower* than what they appear to be, while others such as the USA, EU15, and Japan will have to admit that their 'true' emission intensities are higher. The 'adjustment' in the case of China, for example, is significant, and of the order of 5 to 6 percent (from 2.35 reduced to 2.22 (kgCO_2/\$) for the BaU Scenario, or from 1.97 reduced to 1.87 (kgCO_2/\$) for the Policy Scenario, see Table 19).[26] However, despite this significant 'adjustment' downward of the emission intensity of China (being attributed to the fact that export implies consumption in other countries and hence a consumption-based approach should deduct these emissions from the calculation of total emission intensity for China), the final result for the emission intensity of China is still high (1.87 kgCO_2/\$). Therefore, we need to look for other ways of reducing the emission intensity from China rather than just a mere 'adjustment' of this intensity using a consumption-based approach.

Figure 10: Share of CO2 emissions in the BaU scenario



[26] These adjustments are significant but not substantial as would be suggested by other studies. For example, Davis and Caldeira (2010, p. 5690) claimed that "net exports represent 22.5% of emissions produced in China". From the results of Table 19, we can see that an adjustment of emissions from the level of 1.12 to 0.49 GtCO_2/yr is only about -6.4% of a total level of emission of 9.78 GtCO_2/yr in the year 2020 for China. This is less than one-third of the figure 22.5% as suggested by Davis and Caldeira.

Figure 11: Share of GDP (MER)

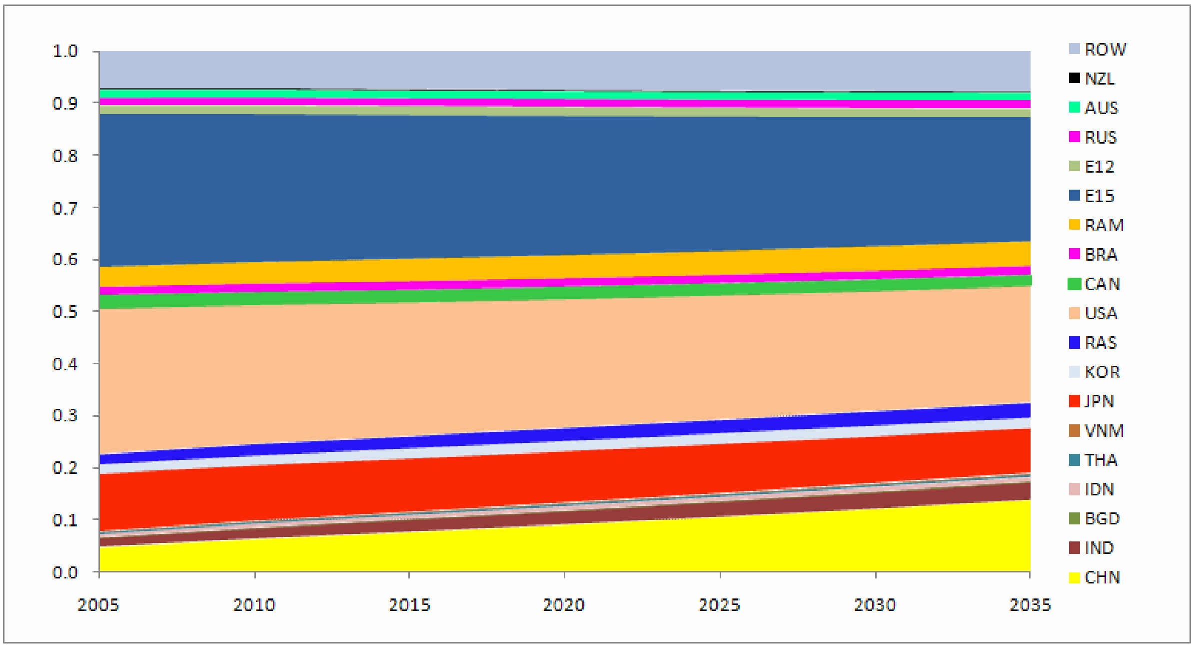


Figure 12: Share of import and export in GDP for various regions in 2005

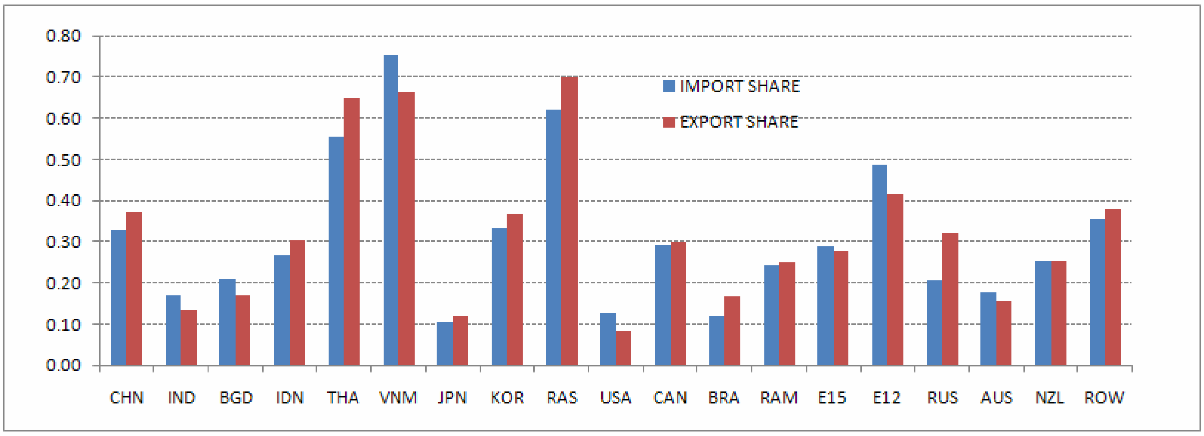


Table 17: Trade exposure of different sectors in the selected economies in 2005

Sector	Export as a share of Value added						Import as a share of Value added					
	CHN	IND	BGD	IDN	THA	VNM	CHN	IND	BGD	IDN	THA	VNM
TEX	1.26	0.69	1.05	0.93	0.86	1.26	0.61	0.18	0.67	0.51	0.42	2.67
CRP	0.68	0.80	0.62	0.77	2.49	0.64	1.25	0.77	4.83	0.80	1.93	2.80
NMM	0.36	0.39	0.17	0.47	0.78	0.36	0.14	0.18	1.11	0.23	0.40	0.29
I_S	0.29	0.61	(*)	0.92	1.50	(*)	0.47	0.49	(*)	3.86	6.38	(*)
FMP	1.03	0.41	0.07	0.25	1.55	1.26	0.28	0.17	1.47	0.52	1.30	1.95
OTN	1.04	0.21	0.14	0.22	2.64	0.42	0.74	0.69	2.14	0.57	2.06	1.76
ELE	2.89	0.47	0.44	6.93	3.03	1.41	2.33	3.30	10.8	4.24	1.89	1.78
OME	1.13	0.52	0.50	1.63	2.89	2.17	1.44	1.17	10.4	3.58	3.44	6.44
agr	0.08	0.05	0.05	0.19	0.59	0.53	0.12	0.03	0.21	0.12	0.22	0.24
coa	0.08	0.01	0.01	0.83	0.00	0.69	0.03	0.32	(*)	0.00	1.01	0.00
oil	0.02	0.00	0.04	0.41	0.10	1.12	1.24	3.49	(*)	0.23	10.2	0.00
gas	3.53	0.00	0.00	0.65	0.00	0.00	1.00	0.00	0.00	0.00	0.37	0.00
p_c	0.98	1.63	0.09	0.67	1.09	0.00	1.97	1.10	16.8	2.96	0.22	15.8
ely	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
nfm	1.09	1.42	0.11	2.27	7.33	0.18	1.64	7.84	2.88	0.85	33.6	3.29
min	0.09	0.87	0.00	0.33	0.33	1.60	0.57	1.61	0.25	0.07	0.82	1.40
omf	1.14	1.05	3.02	1.25	1.07	2.30	0.38	0.27	0.45	0.45	0.52	0.68
trp	0.17	0.08	0.02	0.29	0.99	2.18	0.13	0.11	0.05	0.18	0.33	2.50
ser	0.13	0.05	0.04	0.03	0.09	0.19	0.09	0.05	0.02	0.12	0.12	0.25

Source: author's calculation using GTAPv7 data base.
(*) very large.

Table 18: Trade exposure of different sectors in selected countries in 2005

Sector	Export as a share of Value added						Import as a share of Value added					
	JPN	KOR	USA	E15	RUS	AUS	JPN	KOR	USA	E15	RUS	AUS
TEX	0.8	1.7	0.3	1.4	1.2	0.5	1.3	0.6	0.8	1.6	3.9	1.2
CRP	0.6	1.5	0.5	1.6	2.1	0.5	0.4	1.0	0.5	1.4	1.5	1.3
NMM	0.2	0.2	0.1	0.5	0.2	0.1	0.1	0.4	0.3	0.4	0.4	0.3
I_S	0.5	0.7	0.2	1.5	1.6	0.4	0.1	0.8	0.5	1.5	0.2	0.4
FMP	0.2	0.4	0.1	0.4	0.5	0.1	0.1	0.2	0.2	0.4	0.9	0.3
OTN	1.1	1.9	0.7	1.9	2.4	0.5	0.6	0.6	0.4	2.0	2.4	2.6
ELE	0.9	3.2	1.7	1.9	0.7	0.5	0.5	1.4	3.0	2.8	11.0	4.2
OME	1.1	0.9	0.4	1.3	0.4	0.6	0.4	0.8	0.5	1.0	1.4	2.4
agr	0.0	0.1	0.2	0.5	0.2	0.6	0.3	0.4	0.2	0.5	0.3	0.1
coa	0.0	0.0	0.2	0.0	0.8	1.1	335	20.8	0.0	1.0	0.2	0.0
oil	0.0	0.0	0.0	0.5	0.7	0.3	413	1218	2.3	4.0	0.0	0.8
gas	0.0	0.0	0.0	0.2	0.4	0.4	32.7	346	0.3	1.6	0.0	0.0
p_c	0.5	1.7	2.0	4.8	2.5	0.7	3.8	1.4	4.0	4.9	0.0	2.4
ely	0	0	0	0	0	0	0	0	0	0	0	0
nfm	0.46	1.68	0.56	1.57	1.60	2.69	0.84	3.47	1.06	2.24	0.15	0.45
min	0.07	0.04	0.23	0.90	0.41	0.76	2.07	1.49	0.24	1.31	0.17	0.04
omf	0.59	1.14	0.29	1.13	0.63	0.26	0.29	0.43	0.84	1.11	1.32	0.86
trp	0.06	0.22	0.14	0.29	0.21	0.27	0.13	0.49	0.18	0.31	0.23	0.22
ser	0.01	0.03	0.02	0.07	0.03	0.04	0.02	0.06	0.02	0.07	0.07	0.03

Source: author's calculation using GTAPv7 data base.

Table 19: CO2 emissions (GtCO2/yr) from trade (excluding emissions from international transport) in 2020

Region	BaU Scenario				Policy Scenario '*N*'			
	Emissions from Import (*MEM*) $GtCO_2/yr$	Emissions due to Export (*XEM*) $GtCO_2/yr$	Trade-adjusted emission intensity (*TREMI*) $kgCO_2/\$$	Convent-ional emission intensity (*EMI*) $kgCO_2/\$$	Emissions from Import (*MEM*) $GtCO_2/yr$	Emissions due to Export (*XEM*) $GtCO_2/yr$	Trade-adjusted emission intensity (*TREMI*) $kgCO_2/\$$	Convent-ional emission intensity (*EMI*) $kgCO_2/\$$
CHN	0.22	0.52	2.22	2.35	0.49	1.12	1.87	1.97
IND	0.06	0.09	1.49	1.53	0.12	0.17	1.26	1.29
BGD	0.01	0.00	0.66	0.57	0.01	0.00	0.57	0.50
IDN	0.03	0.04	1.10	1.15	0.04	0.06	0.98	1.02
THA	0.04	0.06	1.07	1.18	0.06	0.07	0.84	0.87
VNM	0.02	0.02	1.69	1.63	0.03	0.03	1.63	1.62
JPN	0.21	0.07	0.27	0.24	0.26	0.07	0.22	0.19
KOR	0.11	0.06	0.69	0.62	0.16	0.06	0.49	0.42
RAS	0.19	0.17	0.91	0.89	0.33	0.21	0.70	0.62
USA	0.48	0.25	0.47	0.45	0.57	0.25	0.35	0.33
CAN	0.08	0.10	0.50	0.51	0.09	0.10	0.44	0.45
BRA	0.03	0.04	0.46	0.48	0.04	0.05	0.38	0.39
RAM	0.11	0.14	0.56	0.58	0.15	0.18	0.48	0.49
E15	0.97	0.39	0.29	0.24	1.28	0.31	0.23	0.18
E12	0.09	0.08	0.94	0.93	0.13	0.09	0.72	0.69
RUS	0.04	0.23	2.07	2.35	0.07	0.29	1.60	1.81
AUS	0.04	0.07	0.50	0.55	0.05	0.08	0.40	0.42
NZL	0.01	0.01	0.37	0.34	0.01	0.00	0.26	0.23
ROW	0.41	0.83	1.16	1.29	0.64	1.37	1.15	1.30

Source: author's calculations

2. Trade policies to promote the reduction of emission intensity

Although trade can contribute to emissions and add to the emission intensity of a country, this does not mean that reducing or eliminating trade will necessarily reduce the emission intensity for the world as a whole. Even in complete autarky, countries still have to produce goods for domestic consumption; and therefore, it depends on whether domestic production is more emission intensive than import or export activities (taking into account also emission from international transport), reducing trade may actually increase rather than reduce emission intensity for the world as a whole. To assist in the analysis of the impacts of trade on emissions and climate change, Truong and Mikic (2010) devised a set of emission intensity indices (EII_{ir}) for export and import activities in each sector *i* and for each region *r*. An Export emission intensity index ($XEII_{ir}$) is defined as the ratio of total emission from all export activities (including emission from international transport to destinations) of sector *i* in region *r* to all destinations of the world, divided by the hypothetical emissions which would have occurred had exports been produced locally, at the destinations. If the ratio is greater than 1, then export activities of sector *i* in region *r* is more emission intensive than the hypothetical autarkic situation. Similarly, an Import emission intensity index ($MEII_{ir}$) can also be defined for sector *i* in region *r*. This is the ratio of emissions associated with the production (at the source) of all imports of sector *i* from all sources (plus the emissions from international transport of these goods) into region *r* divided by the hypothetical emissions which would have occurred had these imports been produced locally in region *r*. If this ratio is greater than 1, then import activities of sector *i* in region *r* is more emission intensive than it would have been had region *r* produced all these goods domestically. Tables 20-21 report on the values of (*XEII*) and (*MEII*) for different sectors of the studied countries and also for selected developed countries. It is clear from these Tables that some countries (such as China (CHN), and Indonesia (IDN)) are highly emission intensive in export activities as compared to import activities, while the reverse is true for other countries, especially developed countries. This points to some directions for a recommended trade policy: encourage technology transfer into sectors which are export-oriented but also emission intensive (such as Textiles (TEX), Chemical, rubber, plastic (CRP), Mineral products (NMM), Iron and steel (I_S), Metal products (FMP), Machinery and equipments (OME), Metals (NFM), Minerals (MIN), and Other manufacture (OMF) in regions such as China and India while also promoting trade liberalization and encourage imports into sectors which are less emission intensive in import activity (and also at the same time climate friendly) [27] such as Mineral products (NMM), Iron and steel (I_S), Other transport equipments (OTN) (for China only), Machinery and equipments (OME) (for China only).

Table 20: Export and Import Emission Intensity Indices (EII) for different sectors in the studied countries in 2005 (taking into account emissions from international transport)

Sector	Export Emission Intensity Index (*XEII*)						Import Emission Intensity Index (*MEII*)					
	CHN	IND	BGD	IDN	THA	VNM	CHN	IND	BGD	IDN	THA	VNM
TEX	3.69	2.92	2.02	4.34	2.29	1.96	0.95	2.45	47.0	0.92	2.28	5.51
CRP	2.14	1.27	3.83	1.99	1.51	2.95	0.71	1.07	0.41	0.72	0.87	0.50
NMM	3.98	3.70	3.63	3.37	2.77	2.81	0.36	0.57	2.12	0.47	0.51	1.24
I_S	1.66	1.86	1.75	3.07	0.55	13.1	0.52	0.63	0.52	0.32	1.63	0.12
FMP	4.18	2.52	7.81	6.78	3.10	5.14	1.20	2.18	0.52	0.67	2.90	1.31
OTN	5.81	1.56	7.13	3.68	1.43	8.65	0.47	12.8	0.69	1.64	4.20	0.73
ELE	2.97	1.32	1.76	4.45	2.32	10.5	1.55	1.82	2.50	0.69	2.91	0.20
OME	5.33	2.32	1.87	2.52	3.15	17.8	0.65	1.98	4.77	1.66	1.18	0.18
agr	3.96	2.21	2.17	2.11	4.25	2.90	0.99	2.49	3.85	2.31	0.85	1.49
coa	7.49	2.56	0.60	0.55	0.41	0.92	0.23	1.85	177	202	963	835
oil	6.64	3.59	0.23	0.66	2.25	0.14	0.21	0.62	5.26	1.14	0.18	650
gas	12.5	0.79	0.00	8.61	0.75	0.00	0.09	0.76	(*)	3.61	1.24	383
p_c	0.18	0.32	1.09	8.69	0.33	10.5	21.3	6.96	4.34	0.22	3.56	0.14
ely	0	0	0	0	0	0	0	0	0	0	0	0
nfm	3.17	1.22	1.09	0.83	1.91	2.01	0.49	1.14	4.39	2.39	0.79	0.86
min	2.43	3.01	0.94	2.13	0.87	7.34	2.38	0.47	6.37	1.46	1.30	0.30
omf	3.64	2.53	2.46	4.57	2.05	5.81	1.05	1.06	4.17	0.75	2.17	0.98
trp	0.81	0.87	0.40	2.35	2.13	5.95	1.30	1.15	2.58	0.45	0.48	0.17
ser	2.14	1.00	0.38	3.05	0.56	10.3	0.51	1.03	3.02	0.31	1.85	0.09
Total	*2.91*	*1.75*	*2.44*	*2.42*	*1.86*	*2.24*	*0.69*	*0.95*	*1.39*	*0.54*	*0.75*	*0.27*

Source: author's calculations
Note: (*) very large.

[27] For a definition of these goods, see Appendix Table A2.

Table 21: Export and Import Emission Intensity Indices (EII) for different sectors in some selected countries in 2005 (taking into account emissions from international transport).

Sector	Export Emission Intensity Index (*XEII*)						Import Emission Intensity Index (*MEII*)					
	JPN	KOR	USA	E15	RUS	AUS	JPN	KOR	USA	E15	RUS	AUS
TEX	0.83	2.45	2.04	1.62	1.62	1.40	14.3	1.47	3.07	3.33	5.58	4.46
CRP	0.71	0.43	1.02	0.40	2.40	0.56	2.42	5.41	1.43	3.51	0.33	3.09
NMM	0.24	0.59	0.93	0.68	1.92	0.68	8.44	2.17	2.32	2.53	0.60	3.97
I_S	0.43	0.37	0.59	0.66	1.92	0.56	3.63	3.26	2.13	2.22	0.73	1.97
FMP	1.68	1.91	1.53	1.26	2.61	1.32	14.0	7.63	3.71	3.04	0.69	17.2
OTN	1.40	3.32	1.41	1.31	0.79	0.96	14.5	0.56	1.70	2.89	13.0	1207
ELE	2.02	1.19	1.42	0.47	2.84	0.88	3.86	9.70	3.11	6.69	0.19	20.9
OME	1.12	0.98	1.75	1.20	2.43	1.39	13.3	7.85	3.52	4.37	0.67	11.9
agr	1.42	2.56	2.25	1.48	2.16	1.74	3.34	1.98	1.62	2.46	1.34	2.33
coa	2.66	0.64	1.35	6.35	5.83	2.08	280.	4.90	14.4	20.1	1.48	2.97
oil	0.20	0.47	0.92	1.07	0.76	1.90	(*)	90.8	0.91	0.78	0.91	0.42
gas	0.00	0.01	0.27	0.66	1.10	2.44	28.7	7.71	3.81	2.86	1.07	2.43
p_c	0.84	0.26	1.22	0.46	0.85	0.66	7.93	(*)	1.16	3.75	3.09	3.70
ely	0	0	0	0	0	0	0	0	0	0	0	0
nfm	0.34	0.28	1.12	0.80	3.94	2.34	7.22	6.96	1.38	2.46	0.46	0.47
min	2.64	1.56	0.30	0.59	0.95	1.61	2.60	4.34	78.3	4.79	53.0	3.32
omf	0.85	1.26	1.85	1.24	2.22	1.24	8.89	3.38	1.67	4.07	1.93	6.01
trp	0.36	1.15	1.59	0.60	2.73	0.79	2.65	0.89	0.69	1.74	0.42	1.33
ser	0.83	2.45	2.04	1.62	1.62	1.40	14.3	1.47	3.07	3.33	5.58	4.46
Total	*0.69*	*0.69*	*1.22*	*0.71*	*1.51*	*1.61*	*5.44*	*4.43*	*1.64*	*2.73*	*0.69*	*2.67*

Source: author's calculations.
Note: (*) very large.

Policy recommendations and conclusions

Climate policies in developed countries have almost exclusively concentrated on the issue of emission reduction as the primary objective. This is partly justified because climate system does not know of 'economic growth' but only of the physical impacts (GHGs emissions) of this growth. Developing countries, on the other hand, are more concerned about the adverse impacts of emission cutbacks on economic development therefore prefer to set the objectives of climate change mitigation policies in terms of emission (or energy) intensities rather than emission levels. Equity issue aside, the difference in emphasis in climate change objectives between developed and developing countries may lead to confusion and divert attention away from the real issue of how to decouple economic growth from emission growth.

Emission intensity (*EMI*) is the ratio of two variables: emissions (*EM*) and production level (*Y*) the relationship between these variables is crucial in analysing the impacts of climate change policies: Decomposing this ratio into various terms:

$$EMI = \frac{EM}{Y} = \frac{EM}{EG}\frac{EG}{Y} \qquad (3)$$

Here *EG* stands for the level of energy usage and the ratio (*EM*/*EG*) stands for emission intensity of energy usage. This ratio is dependent on the structure of technologies and fuel mix used, and also on the level of abatement activities employing end-of-pipe technologies (such as carbon capture and sequestration) or through land-use land use change and forestry (LULUCF) activities. The ratio (*EG*/*Y*), on the other hand, represents energy intensity per unit of economic activity level and is dependent on factors such as energy efficiency as well structure of production and consumption activities. To reduce emissions intensity, therefore, requires (1) increase in abatement activities through end-of-pipe technologies, (ii) changing the structure of technologies and fuel mix, (iii) improved energy efficiency, and (iv) changing the patterns of economic activities. Each of these steps may require different policy objectives and instruments. For example, to change the structure of technologies and fuel mix, renewable energy targeting may be used with instruments such as green certificate (subsidy for a unit of renewable energy produced), feed-in tariff (guaranteed price for renewable electricity supplied), or simply a carbon tax/emission permit system which discourages the use of fossil fuel technologies and hence indirectly encourages the switch to renewable and/or carbon-free technologies (such as nuclear power). To improve on energy efficiency, either a mandatory fuel efficiency standard, the use of white certificate (subsidy to investments in residential and commercial lighting and heating areas where it can save on energy usage) or a system of energy taxes which discourages the demand for fuel-inefficient technologies and equipments. Finally, to encourage a switch to less emission intensive economic production and consumption patterns, government can use instruments such as urban consolidation (to increase urban density and reduce urban spread which in turn reduces the need for travel) public transport subsidy (to discourage the use of private automobile and reduce congestion which uses up more fuel per kilometre travelled), introducing telecommuting or telework programs (which allows workers to trade off telecommunication inputs and/or locational inputs for travel inputs).

In addition to the above standard policy objectives and instruments which can be considered as part of a comprehensive climate change policy package used to achieve a particular climate change objective (whether emission level, emission growth, or emission intensity reduction), trade policies can also assist in this overall objective. For example, through the import and export of final or intermediate goods and services, trade can be used as an important instrument for the *indirect* transfer of technologies between regions via the transfer of technologies 'embodied' in the traded goods and services.[28] More direct transfer of technologies can also occur through international investment activities.

From the analysis in Section 4 of this study (see for example, Table 20) it has been found that many of the sectors of the Chinese and Indian economy are export-oriented and also highly emission intensive (relative to the same sectors in countries to which these goods are being exported). This implies the 'trade-adjusted' emission intensity index (*TREMI*) for China and India can be considered as *lower* than the actual or unadjusted emission index (*EMI*) (see for example Table 19). However, this simple 'adjustment' of emission intensity index (attributed to a 'consumption-based' approach to the measurement of emissions and emission intensity) by itself is not sufficient to allow countries such as China and India to pursue comfortably the climate change policy objectives of emission intensity reductions easily without further additional efforts in altering the basic relationship between emissions levels and economic activity levels. These further efforts will require different types of economic and trade policies as elaborated above and also a coordination among these policies

In summary, whether developing countries are to continue with the pursuit of climate change policies through the use of emission intensity reduction targets or through direct control on the levels of emissions, the crucial question is the type of policies and instruments to be used to assist in the achievement of these targets. This means the following issues should be given attention:

(1) *Economic efficiency*: this implies choice of *instruments* to achieve a given policy objective should be given the same attention as the choice of policy objective. Economic efficiency ultimately impacts on both economic development objective and (the cost of achieving) climate change objectives.

(2) *Sectoral analysis*: different sectors of an economy present different challenges but also different potentials for mitigation of emissions or emission intensities, and therefore should also given different treatment. Sectoral analysis and indices (such as those related to production, consumption, or trade activities) should be considered and used in formulating climate change, trade and investment policies to give adequate attention to the efficiency as well as equity issue (sharing of the benefits or burdens across sectors).

(3) *Policy co-ordination*: coordination between different policies which impact on different sectors of an economy is essential. This requires a comprehensive framework for policy impact analysis and an applied model capable of producing quantitative results for the assessment of these different policies.

[28] See, for example, van Meijl, Hans and van Tongeren (1999).

Appendix

Table A1: Details on Regional Aggregation

No.	Region	Description
1	CHN	China and Hong Kong
2	IND	India
3	BGD	Bangladesh
4	IDN	Indonesia
5	THA	Thailand
6	VNM	Vietnam
7	JPN	Japan
8	KOR	Korea
9	RAS	Rest of Asia (Taiwan, Cambodia, Lao, Myanmar, Malaysia, Philippines, Singapore, Pakistan, Sri Lanka, Rest of East, South East, and South Asia)
10	USA	United States of America
11	CAN	Canada
12	BRA	Brazil
13	RAM	Rest of America (Mexico, Rest of North America (Bermuda, Greenland, Saint Pierre and Miquelon), Central and Latin America except Brazil)
14	E15	EU15 (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom)
15	E12	Rest of EU27 (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Cyprus, Malta)
16	RUS	Russia
17	AUS	Australia
18	NZL	New Zealand
19	ROW	Rest of the World (Middle East, Africa, Western Asia, Rest of Europe, etc.)

TableA2: Details on Sectoral Aggregation.

No.	Code	GTAP Sector Description	Harmonised System Code (for climate friendly goods only)
1	TEX	Textiles	560314
2	CRP	Chemical, rubber, plastic	38021, 392690, 392010
3	NMM	Mineral products nec	701931, 700800
4	I_S	Ferrous metal	730431, 730441, 730451,730900
5	FMP	Metal products	730820, 730900, 732490, 761290, 840219, 840290, 840410, 840490
6	OTN	Transport equipments nec	890790
7	ELE	Electronic equipments	854140
8	OME	Machinery, equipments nec	732111, 732190, 840510, 840681, 841011, 841012, 841013, 841239, 841090, 841181, 841182, 841581, 841861, 841869, 841919, 841940, 841950, 841989, 841990, 842129, 842139, 847989, 848340, 848360, 850161, 850162, 850163, 850164, 850231, 850300, 850440, 850680, 850720, 850720, 850720, 850720, 853710, 853931, 900190, 900290, 902830, 903020, 903031, 903039, 903210, 903220,
9	AGR	*Agriculture, forestry and fishing*: paddy rice, wheat, cereal grains nec, vegetables, fruit, nuts, oil seeds, sugar cane, sugar beet, plant-based fibers, crops nec, bovine cattle, sheep and goats, horses, animal products nec, raw milk, wool, silk-worm cocoons, forestry, and fishing	
10	COA	Coal mining	
11	OIL	Crude oil	
12	GAS	Natural gas extraction & gas distribution	
13	P_C	Refined oil products	
14	ELY	Electricity	
15	NFM	Metals nec,	
16	MIN	Minerals nec	
17	OMF	Manufactures nec, motor vehicles & parts, paper products, publishing, wood products, leather product, wearing apparel	
18	TRP	*Transportation*: Transport nec, sea transport, air transport	
19	SER	*Services*: water, construction, trade, communication, financial services nec, insurance, business services nec, recreational and other services, public admin., defence, health, education, dwellings	

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