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Impact of economic structure on mitigation targets for developing countries

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ABSTRACT

Mitigation actions proposed by most developing countries include reductions from a business as usual baseline or reductions in emission intensities. Here we evaluate the implications of such mitigation targets in developing countries, using India as a case study. The analysis shows that for developing countries, the construction of a baseline is subject to substantial uncertainty due to a range of potential structural mixes in the future. Mitigation commitments based on such a baseline are then likely to result either in high costs of mitigation or constraints on the development choices available in the future. Results for India indicate that by 2030 an additional mitigation effort of 19% to 38% would be necessary if the contribution of industry to the GDP was higher than anticipated. Instead of a single baseline with an implicit assumption of structural composition, we propose that for developing countries, a set of alternative baselines should be considered.

Introduction

The greenhouse gas emissions in any country depend on a few key variables — the composition of fuels in primary energy production, the structural composition of the economy, i.e. the relative contribution of primary, secondary and tertiary sectors to the economy, the energy intensity of different sectors, and the emissions intensity of energy. An analysis of past trends reveals the contribution of each of these components to the total change in emissions and can indicate their potential role in the future. This analysis is more important for developing economies, since with unsaturated demands in all sectors, the structure of the economy can vary substantially. Fig. 1 shows the evolution of the relative contributions of three sectors – agriculture, industry and services – to the total value added in the economy for three countries — one developed (UK) and two developing (India and China) for the period 1971–2008.

For India the trend between 1971 and 2008 indicates that the reduction in the contribution of agriculture in the overall economy has been almost entirely compensated by an increase in the share of the services sector in this period. For China on the contrary this trend is markedly different, indicating a similar decline in the contribution of the agricultural sector compensated substantially by industrial sector growth. For developing economies such as India and China in the future, the decline in the share of the agricultural sector may be compensated by changes in the relative share of the industrial and service sectors, the extreme cases corresponding to increase mostly in the industrial sector or mostly in the services sector — shown by points I_I and I_S for India and points C_I and C_S for China in Fig. 1 for an endpoint taken to be 2030 in this paper. The resultant emissions in 2030 from these two countries will depend significantly on the trajectory and endpoint of this shift in the structural composition. A similar argument can be made for several other developing countries as well as shown in Fig. 2.

The range of available structural compositions for the future – denoted by the angle θ in Fig. 2 – implies that a simple extrapolation of historical trajectories for economic growth may be an inaccurate measure of the potential changes in the future. We have examined this hypothesis by back-casting sectoral growth data for a range of countries. We have taken the trends for industrial growth between 1971 and 1990 to project the possible trends for the period 1991 to 2010. The projected values are then compared with the actual industrial

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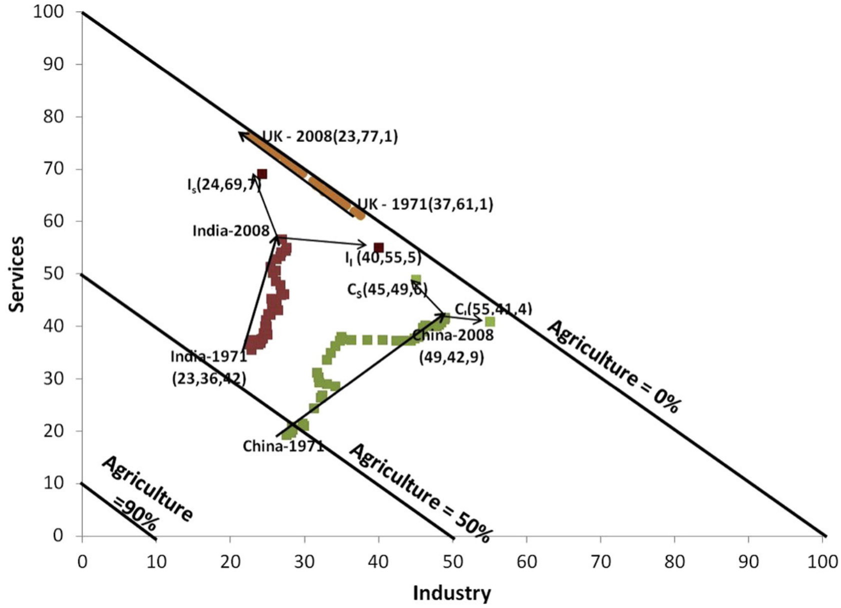

Fig. 1. Relative contribution of the agricultural, industrial and services sectors to total value added in three countries — UK, China and India between 1971 and 2008. The share of the agricultural sector to total GDP is measured on the 45° line while the shares of the industrial and services sectors are measured on the x and y axes respectively.
Data Source: World Bank, World Development Indicators.

growth in each country for this time period. Fig. 3 shows the actual and projected trajectories of growth for the industrial sectors in four developing countries for the period between 1971 and 2010

Given the same improvements in energy efficiency and the same changes in the composition of primary energy sources that the countries actually experienced, the projected numbers would have resulted in 23% lower emissions in China and 13% higher emissions in Brazil as compared to the actual emissions in 2010. Fig. 3 highlights the fact that an extrapolation of the past is not a robust method to project for the future or decide a baseline for emissions. Developing economies can choose among different possible options for development depending upon their unique national priorities.

Analysis of past trends in emissions for India

For a developing economy, the increase in emissions due to changes in structural composition may be offset partially by efficiency improvements and technological innovation in the energy sector. Other than the structural composition of the economy, these parameters can also affect the total emissions significantly. Using the decomposition method, the

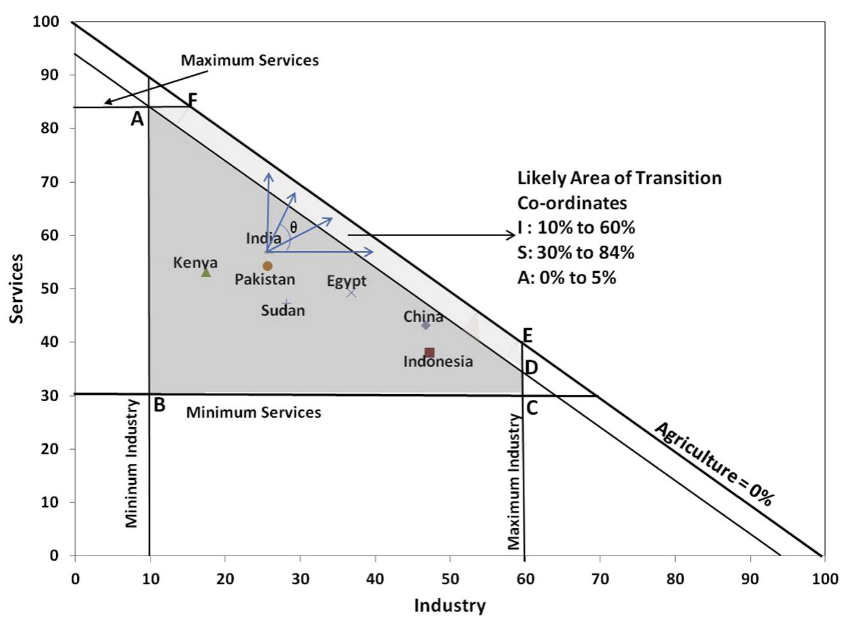

Fig. 2. Relative contributions to total value from the agricultural, industrial and services sectors in seven developing economies — India, Kenya, Pakistan, Egypt, Sudan, China and Indonesia in 2010. Shaded area A–B–C–D roughly denotes the area where most developing countries are currently situated in terms of their relative sectoral contributions. Shaded area D–E–F–A roughly denotes the area of likely transition for developing countries by 2030. The angle θ shown for India denotes the range of possible transitions.
Data Source: World Bank, World Development Indicators.

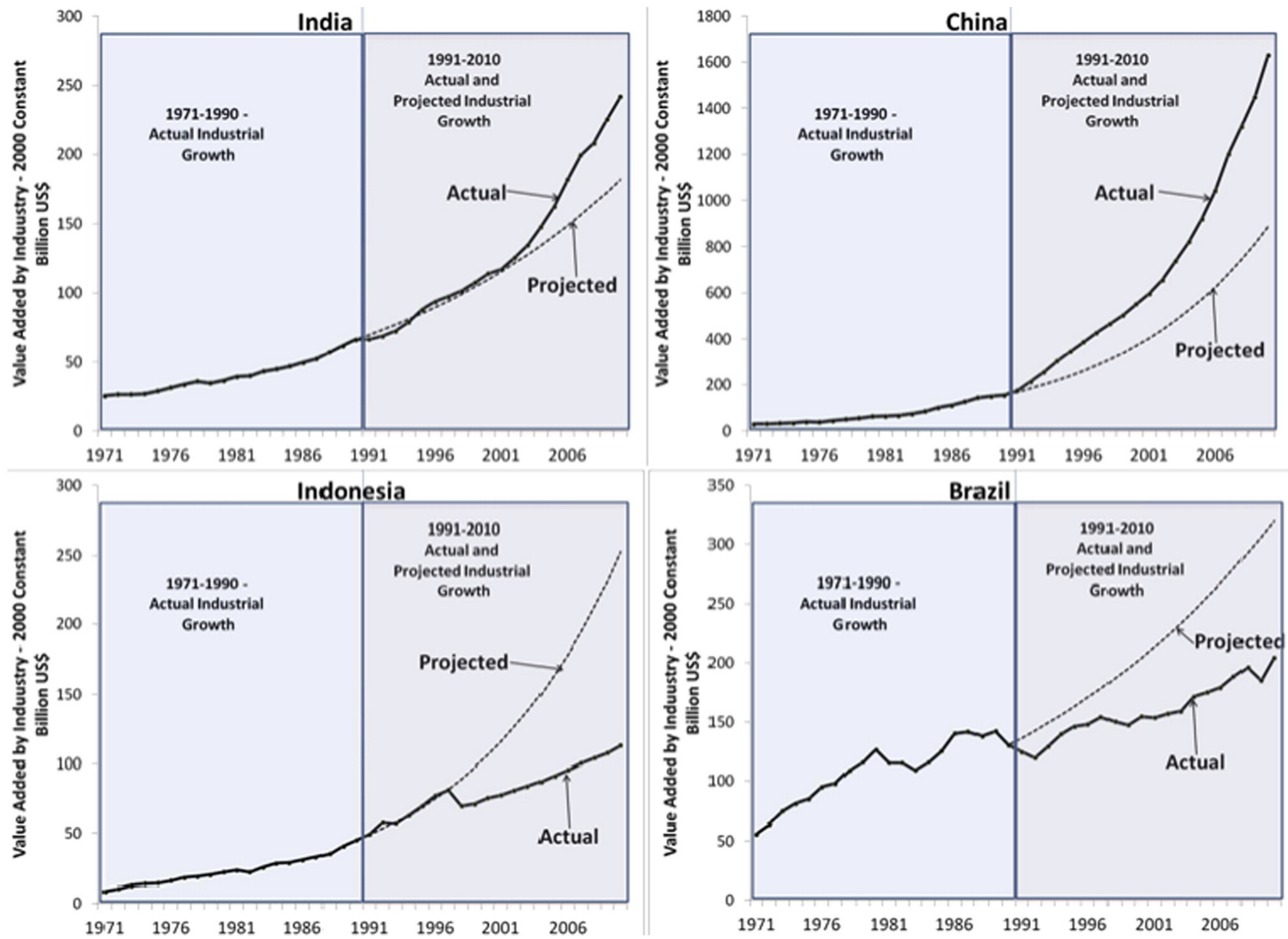

Fig. 3. Actual value added by the industrial sector vs. projections based on historical growth rates between 1971 and 1990 for four countries — China, India, Brazil and Indonesia. The value added is shown in the y axis in 2000 constant billion USD.
Data Source: World Bank, World Development Indicators.

total emissions in any country can be expressed as a function of all these parameters as shown in Eq. (1) (Ang and Zhang, 2000)

$$E = \sum_i I_i \times C_i \times S_i \times G \tag{1}$$

where,

- E denotes the overall emissions in the economy
- i denotes the sectors of the economy; e.g. $i = 1 =$ industry, $i = 2 =$ services and $i = 3 =$ agriculture
- I_i is the energy intensity of value added in the ith sector
- C_i is the emissions intensity of energy of the ith sector
- S_i is the value added by sector i as a fraction of the total value added in the economy
- G is the total value added in the economy.

A decomposition of emissions using this primary equation can provide a method to evaluate the contribution of each factor to the total change in emissions (Ang, 2004). We illustrate this using the case of India. The historical contribution of each factor – I_i, C_i and S_i – is evaluated using decomposition analysis. For the purpose of the analysis for India, the economy is disaggregated into three sectors, viz. industry,[3] services[4] and agriculture.[5] Decomposition analysis is used to evaluate the historical contributions of the three main factors to the economy — i) the energy intensity of GDP — energy consumed per unit GDP in each sector, (ii) the emissions intensity of energy — carbon dioxide emissions per unit of energy and (iii) the structure of the economy — relative contributions from each of the three sectors. The multiplicative and additive Log Mean Divisia Index (LMDI) techniques for decomposition were used as they have been shown to be the most useful for policy purposes due to their theoretical foundation, adaptability and ease of use (Ang, 2005). The calculated LMDI values are based on Eqs. (1) through (4). For multiplicative LMDI, the effect of the kth component can be calculated using,

$$LMDI\ \ k = \exp\left\{\sum_i \frac{L\left(V_i^T, V_i^0\right)}{\sum_i L\left(V_i^T, V_i^0\right)} \times \ln\left(\frac{k_i^T}{k_i^0}\right)\right\} \tag{2}$$

where,

- k is the component for which the index is calculated, i.e. the change in emissions intensity due to structural changes or energy intensity improvements in the economy between year 0 and year T

[3] The value added in industry includes value added in mining, manufacturing, construction, electricity, water, and gas.

[4] The value added in services includes value added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services.

[5] The value added in agriculture includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production.

and

$$L(a,b) = \frac{a-b}{\ln\left({}^{a}/_{b}\right)}. \tag{3}$$

For additive LMDI,

$$LMDI\ \ k = \sum\left(L\left(V_i^T, V_i^0\right) \times \ln\left(\frac{k_i^T}{k_i^0}\right)\right). \tag{4}$$

The indices are evaluated for the time period between 1971 and 2008. The contribution of all three factors is calculated for this time period and this analysis is then used to build scenarios for changes in emissions between 2009 and 2030 (See supplementary material for an analysis of the historical trends in emissions and the driving factors behind this change). Galli (1998), Nag and Parikh (2000), Reddy and Ray (2010), Paul and Bhattacharya (2004), Kojima and Bacon (2009) have analysed past trends in energy and emissions indicators for India for specific sectors. In this paper we take this analysis forward by using the results from the decomposition analysis to construct scenarios for the future. Studies for projecting future emissions such as the Report of the Low Carbon Committee (Planning Commissions, Government of India, 2011a, 2011b),[6] Shukla (2006), Parikh and Gokarn (1993), consider the potential changes in technology and efficiency while estimating future emissions within an overall economic growth rate. However, the evolution of the economic structure in the future is not discussed, making a business-as-usual economic trajectory an implicit assumption in the construction of future scenarios. It is theoretically possible to consider multiple economic futures using existing techniques of analysis such as the computable general equilibrium models or MarkAl models. However in papers presented for policy considerations, scenario building exercises tend to exclude scenarios for different sectoral compositions while including scenarios for changing efficiencies and fuel mix. In this paper, we estimate future emissions including scenarios where the structural composition of the economy changes.

Economic structure and construction of economic baselines

The main variable under exploration in this analysis is the structural composition of the economy. The potential trajectory of future economic choices for developing economies can be measured by the angle θ (refer to Fig. 2), where

$$\tan\theta = \frac{\Delta S}{\Delta I} \tag{5}$$

where,

ΔS denotes the change in the contribution by the services sector to the total economy and

ΔI denotes the change in the contribution by the industrial sector to the total economy.

$\theta \geq 90°$ implies that the entire change in the economic structure is a result of the growth in the industrial sector replacing agriculture as the economy develops whereas $\theta \leq 0°$ implies that the entire change in the economic structure is a result of the growth in the services sector. The potential change in emissions in the future and the resultant changes in mitigation efforts required in India are evaluated for two basic scenarios. Scenarios are developed for two possible routes of economic growth which provide two economic baselines for India.

- Scenario 1 – high growth of the services sector – the service sector in India is currently growing at a faster rate compared to the other sectors and the decline of the contribution of agriculture in the economy has mostly been compensated by the increase in the share of the service sector. Scenario 1 extrapolates a similar trend to the future — the growth rate of each sector in the past 5 years continues into the future (2.8% p.a. for agriculture, 6.6% p.a. for industry and 8.1% p.a. for services). In this scenario the service sector accounts for about 69% of the total value added in the economy by 2030 and the overall rate of economic growth is 7.1% p.a.
- Scenario 2 – high growth of the industrial sector – there is a large infrastructure deficit in developing countries such as India. Government plans project an increase in the growth of heavy industry and primary energy sectors to overcome this deficit — targeted growth rates of 9.6% to 10.9% in the industrial sector and 8.5% to 9% in the energy sector. Scenario 2 presents a scenario of high industrial growth where the total value added by the industrial sector by 2030 accounts for almost 41% of the total value added in the economy. In this scenario the industrial GDP is estimated to grow at the rate of 9.1% p.a. and the overall economic growth rate is 6.7% p.a.

The scenarios are further developed by introducing potential changes in technology (improvements in efficiency) and the introduction of green technologies in the energy sector. This is captured by three possibilities — (i) the sectoral values for energy intensity and emissions intensity remain constant. This would imply that no further improvement in energy efficiency in any of the sectors is possible. For agriculture it will also imply that the level of mechanisation will undergo no significant change. This scenario of 'frozen efficiency' can be used to provide a benchmark or baseline against which other scenarios may be evaluated. (ii) The trends in energy intensity of GDP and emissions intensity of energy seen in the last time period continue into the future. This would imply that for agriculture there would be a gradual increase in the level of mechanisation and for the industrial sector and services sector, efficiency improvements would take place at the same rate without saturation between 2009 and 2030. However, constant trends for emissions intensity of energy would imply that there would also be a steady increase in the share of carbon energy in the fuel mix for this time period counter-balancing the achievements in energy efficiency. In this paper we present result for scenarios in which the energy intensity of the Gross Domestic Product (GDP) and the emissions intensity of GDP follow business as usual trajectories. The energy intensity of GDP reduces by 2.8% p.a. till 2030. The emissions intensity of energy increases by 1.7% p.a. even with a steady increase in the use of renewable energy sources. The resulting emissions trajectories from these scenarios provide a range of baselines over which mitigation requirements would then have to be calculated.

Mitigation targets proposed by developing countries

As part of the Nationally Appropriate Mitigation Actions (NAMAs), many developing countries have proposed voluntary mitigation actions. The actions proposed by developing countries may be classified as follows:

a) Reduction from business as usual emissions — many developing countries have proposed targets that specify reductions in carbon emissions from a business-as-usual baseline. For example, South Africa has proposed to implement mitigation actions that would reduce its emissions by 34% below the 'business as usual' emissions by 2020 and by 42% below business as usual emissions by 2025 (UNFCCC, 2011). Brazil, Mexico and South Korea are some of the other emerging economies that have used this framework for setting mitigation targets.
b) Reductions in the emissions intensity of GDP — China and India have proposed mitigation targets in terms of a reduction of the emissions intensity per unit of GDP. India has proposed a 20 to 25% reduction in its emissions intensity of GDP from 2005 levels by 2020.

[6] Interim report of the 'Expert Group on Low Carbon Strategies for Inclusive Growth' set up by the Planning Commissions, Government of India (2011a, 2011b).

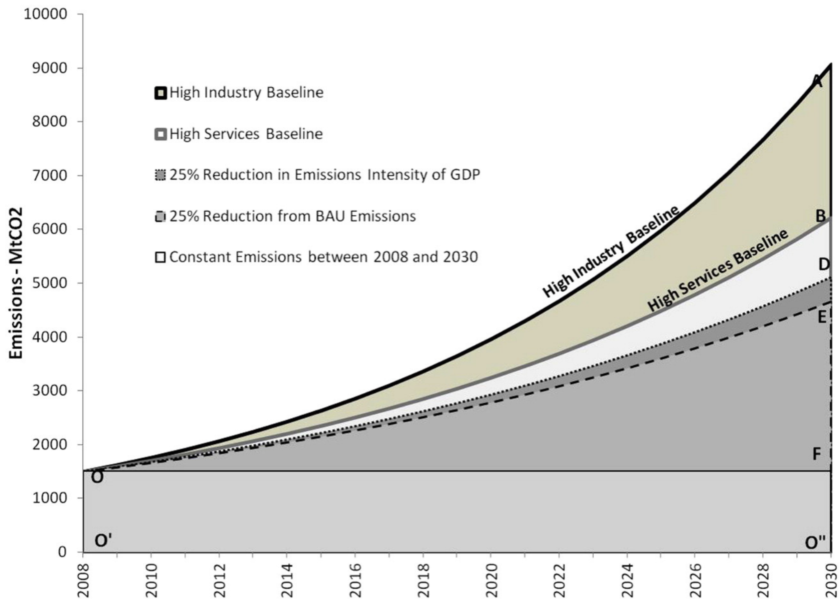

Fig. 4. Mitigation effort required based on two baselines — i) high industrial growth — curve OA and ii) high services growth — curve OB. Curve OD shows the emissions for a mitigation scenario of 25% reduction in emissions intensity of GDP by 2030. Curve OE shows the emissions for a mitigation scenario of 30% reductions by 2030 from a business as usual baseline. Curve OF shows the emissions for a mitigation scenario wherein the emissions are not allowed to increase — constant emissions between 2008 and 2030.

c) Reduction in absolute flows of emissions with respect to a base year — although this framework of setting mitigation targets is usually considered to be applicable only to developed countries (based on the UNFCCC and the Kyoto Protocol), some developing countries have also proposed an absolute reduction in emissions as part of their NAMAs, e.g. Indonesia 26% reduction in emissions by 2020 expected to be achieved mainly through management of land use, and Antigua and Barbados — 25% reduction below 1990 levels by 2020. It is not possible for all developing countries to adopt such a target at this stage, given the requirements of poverty alleviation and development in most of these countries. However, as some developing countries have proposed mitigation targets of this kind, we do include it in our analysis.
d) Sectoral mitigation actions — MANY developing countries have proposed specific actions to be taken within each sector instead of proposing an overall emissions reduction target, e.g. Argentina, Armenia, and Columbia. As most of these targets are not quantified in terms of emissions it is difficult to compare this framework with the other methodologies discussed here. Therefore this class of mitigation targets is excluded from the analysis in the paper.

The first three types of targets are applied to the baselines constructed for India to calculate the amount of effort required to achieve emission reduction — shown in Fig. 4. Three notional mitigation targets for India are considered — i) the emissions intensity of GDP to be reduced by 25% as compared to current (2008) levels, ii) the annual emission flows to be reduced by 25% by 2030 relative to a business as usual baseline and iii) the annual emission flows to be kept constant between 2008 and 2030.

Results and discussion

The difference in mitigation effort for the two scenarios with different targets is measured by the differences in the corresponding cumulative emissions over the reference period, from 2009 to 2030.

The mitigation efforts implied by the areas marked in Fig. 4 are shown in Table 1 to provide the magnitude of difference made by choosing two alternative routes for development. The baseline cumulative emissions between 2009 and 2030 are estimated to be about 70 $GtCO_2$ for Scenario 1 and 88 $GtCO_2$ for Scenario 2.

In the event of a higher contribution in the future by the industrial sector, the mitigation effort required would be higher by about 19% to 38% for a range of mitigation targets. For India, the magnitude of effort required to achieve its NAMA (Nationally Appropriate Mitigation Action) target of 25% reduction in the emissions intensity of GDP, from 2005 levels, by 2020 will be different for the two scenarios. In Scenario 1, it is possible to achieve the target by a substantial improvement (~3.7% p.a.) in energy efficiency (as compared to the currently projected rates of efficiency improvement of 2–2.5%) without any significant change in the mix of primary energy sources. For Scenario 2, the rate of efficiency improvement required would be 5.1%. This is based on an assumption of an increase in the emissions intensity of energy

Table 1
Mitigation effort required for scenarios 1 and 2.

	Cumulative emissions between 2009 and 2030 ($GtCO_2$)	Emission reduction required — measured as difference between baseline trajectories and mitigation trajectories (GtCO2)	
		From high services baseline (70 $GtCO_2$)	From high industry baseline (88 $GtCO_2$)
Mitigation target 1–25% reduction in the emissions intensity of GDP by 2030	67	3 $GtCO_2$ (4% reduction from baseline)	21 $GtCO_2$ (24% reduction from baseline)
Mitigation target 2–25% reduction from business as usual emissions by 2030	59	11 (16% reduction from baseline)	29 (33% reduction from baseline)
No increase in emissions between 2009 and 2030[a]	33	37 (53% reduction from baseline)	54 (61% reduction from baseline)

[a] An absolute reduction in emissions in not a feasible target for India. However the calculation for such a case is presented here to provide a benchmark for minimum emissions.

(following a business as usual trajectory of increased share of fossil fuels in the fuel mix). The rate of energy efficiency improvements can be reduced if the share of renewable energy sources in the fuel mix increased but either option has substantial costs attached to it.

Conclusion

The analysis presented in this paper indicates that the structural composition of the economy matters and should be explicitly considered when setting mitigation targets for developing countries. The level of mitigation effort required is higher in case the future economic growth profile involves a higher share of industry. Mitigation targets measured from business-as-usual baselines, without the mention of a potential economic structure, nevertheless contain an implicit assumption of future economic growth trajectories. Such targets may then lead to locking developing countries into a specific set of economic choices. A more robust framework would consider multiple baselines for any country and as a result a range of potential mitigation targets. While a consistent effort towards developing a framework for a global climate agreement is important, developing economies will have to assess their unique national circumstances in order to allow for a range of development options for the future. It is necessary to devise an alternative architecture within which both, the goals of mitigation as well as the freedom of nation states to choose their economic futures are protected.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.esd.2015.03.003.

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