WP-2021-007

India's progress in meeting its climate goals: A comparative analysis using country-reported and external data

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February 2021

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Abstract

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Keywords: Decarbonization, CO2 emissions intensity, decomposition analysis, Log Mean Divisia Index, industrial energy efficiency

JEL Code: Q48, Q58

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1 Introduction

Researchers are studying how various countries are decarbonizing to monitor their progress in meeting their mitigation goals (Peters et al., 2017; Le Quéré et al., 2019; Kuriyama et al., 2019). The achievement of the Paris agreement goal heavily relies on a rapid transition to low carbon technologies. Hence, researchers are also trying to separate the effect of adoption of low carbon technologies from structural changes in the decarbonization process (Oh et al., 2010; Goh and Ang, 2018; Trotta, 2020). Several recent studies have examined these aspects in both developed and developing economies by analyzing changes in carbon dioxide (CO_2) emissions from fossil fuel combustion (Peters et al., 2017; Le Quéré et al., 2019). However, most studies on developing economies rely on external sources for annual estimates of CO_2 emissions. Under the United Nations Framework Convention on Climate Change (UNFCCC) framework, the developed countries are required to submit their greenhouse gas (GHG) emissions inventory annually. However, the developing countries can submit the data periodically (UNFCCC, 2009). Since the country reported data in developing countries is limited to few years, external sources are unavoidable.

Most commonly used external source in the energy-emissions analysis is the data published by International Energy Agency (IEA). IEA data is one of the few datasets that provide estimates of sector-level CO_2 emissions. Few studies also use CO_2 emissions calculated from national energy statistics using the International Panel on Climate Change (IPCC) 2006 guidelines for national GHG inventories. A widely used approach to analyze a country's decarbonization progress is decomposition analysis such as index decomposition analysis (IDA) and structural decomposition analysis (SDA). In this approach, energy consumption data by fuel type and by sector are required to estimate the contributions of changes in economic structure, energy intensity and fuel mix in the decarbonization process. The energy consumption data are either taken from external sources or nationally reported energy statistics. The country reported data is also estimated using nationally reported energy statistics as per IPCC guidelines for national GHG inventories. Ideally, if standard procedures were followed in reporting energy statistics, the different sources' emissions data would be identical. However, it has been found that the country reported data matches closely with the different external data sources for developed countries but differed for developing countries (Gütschow et al., 2018).

There are fewer studies on India's decarbonisation progress than other major GHG emitters (Nag and Parikh, 2000; Paul and Bhattacharya, 2004; Parikh et al., 2009; Garg et al., 2017; Sun et al., 2017; Zhu et al., 2018; Wang et al., 2020; Karstensen et al., 2020; Das and Roy, 2020; Jain, 2020). Few studies have used national energy statistics to estimate CO_2 emissions and analyzed the drivers of change using IDA in the past (Nag and Parikh, 2000; Paul and Bhattacharya, 2004). A recent study adopted the same approach to examine India's current progress in meeting its mitigation ambition under the Paris Agreement Das and Roy (2020). Another study analysed drivers of India's emissions using IDA on IEA data (Jain, 2020). Most of the other studies have examined India's CO_2 emissions structure using SDA (Parikh et al., 2009; Sun et al., 2017; Zhu et al., 2018; Wang et al., 2020). Some of these studies have used the national input-output tables and nationally reported energy consumption statistics (Parikh et al., 2009; Zhu et al., 2018) and others had taken world input-output tables and energy emissions data from external sources (Sun et al., 2017; Wang et al., 2020). In another study, Karstensen et al. (2020) employed both IDA and SDA to study key drivers of India's GHG emissions. None of these studies has compared their results from country-reported data to validate their findings. The reason for omission of country-reported data in most of the studies could be that it does not provide energy consumption data.

India's emission intensity target under the Paris Agreement is to reduce its GHG emissions intensity by 33-35% in 2030 compared to 2005 levels (UNFCCC, 2015). Hence, an indicator of India's progress in meeting the goal is the emissions intensity target achieved since 2005. In its Second Biennial Update Report (BUR-2), containing the GHG inventory of 2014, India indicated that 21% reduction in GHG emissions intensity was achieved in 2014. In addition to BUR-2 India has submitted three other communications to UNFCCC containing GHG inventories for 1994, 2000, 2007 and 2010. Although 2005 is the base year for India's mitigation goal, its GHG emissions inventory is not available in country-reported data. Hence, the decline in India's CO_2 emissions intensity since 2005 cannot be estimated from country-reported data. The nearest available year for comparison is 2007. India's CO_2 emissions intensity decline in the country reported data during 2007-2014 was 6%. In contrast, the corresponding value in IEA data is an increase of 5%, as shown in Fig 1.

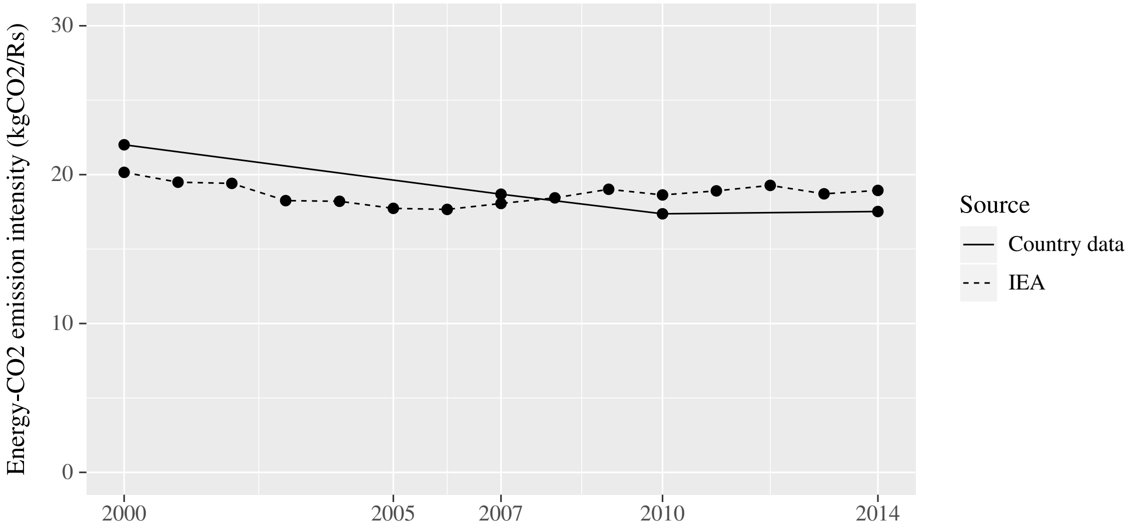

Figure 1: Energy-CO_2 emissions intensity of Indian economy
Note: Energy-CO_2 emissions intensity is the ratio of CO_2 emissions from fossil combustion and GDP at constant prices. Country data is taken from India's second national communication and first and second biennial report submitted to UNFCCC (GoI, 2012, 2015, 2018). IEA data is taken from IEA Data and Statistics (IEA, 2019). GDP data at constant 2011-12 prices is taken from back-series of National Account Statistics published by Government of India. (MoSPI, 2019)

The difference in the estimates of emissions in the country reported data and the commonly used IEA data is definitely going to bring a difference in the narrative of India's decarbonization efforts. This difference is evident in the existing studies using CO_2 emissions data from IEA and data estimated from national energy statistics. Although the findings are not directly comparable due to different periods examined in different studies, few contradictions are apparent. Examining data from national energy statistics during 1990-2013, Das and Roy (2020) found decoupling between India's economic growth and CO_2 emissions during the entire period and sub-period 2006-2013. On the other hand studies using IEA data show that while energy intensity effect contributed to a decline in emissions in most of the years, it contributed to an increase in emissions 2007 and 2008 (Karstensen et al., 2020; Jain, 2020). Karstensen et al. (2020) also conclude that most of India's energy intensity decline is due to shifting towards the service sector. A more contradictory result is reported in Wang et al. (2020) that India's energy intensity pushed India's emissions upwards after 2003. Another study by Zhu et al. (2018) use country data for 2007-08 and external data for 2013-14 and report that India's CO_2 emissions intensity increased by 8% between the two periods.

In this paper, the differences in the country-reported data and IEA data is studied, and its implications on India's progress in meeting its mitigation goals are examined. The change in the production sectors' CO_2 emissions intensity and the role of a shift towards the service sector compared to sector-level intensity are analyzed. In this study, the sector-level CO_2 emissions data is taken for four inventory years from country-reported data and annual IEA Data. CO_2 emissions from emission estimation categories are mapped to end-use consumer categories, and the emissions and emissions intensity by end-use is compared. The role of economic structure and sectoral-intensity is estimated using index decomposition analysis.

This paper is divided into five sections. Section 2 explains the methodology used, including mapping emissions to end-use and index decomposition approach to calculate the activity, structure and sector-intensity effects in the change in emissions. Section 3 provides details of the data sources used in the paper, and Section 4 discusses the results. The conclusions and policy implications from the study are presented in Section 5.

2 Methodology

This study analyses the CO_2 emission intensity of the Indian economy and its production sectors using both country-reported and IEA data. The country-reported data is taken from the GHG emissions inventory submitted by the Government of India to the UNFCCC for the years 2000, 2007, 2010 and 2014 (GoI, 2004, 2012, 2015, 2018). The energy-CO_2 emissions from IEA is taken from dataset published in IEA Data and Statistics for 2000 to 2014 (IEA, 2019). The energy-CO_2 emissions by end-use is estimated by allocating emissions from electricity generation to consumer categories. The economy's emission intensity and production sectors are calculated using the gross domestic product (GDP), and gross value added (GVA) by economic activity at constant prices. The role of the structure and sector-intensity effects in the changes in emissions are estimated using the Log Mean Division Index (LMDI) approach (Ang, 2015).

2.1 Reallocation of emissions by end-use

As per the IPCC 2006 guidelines, the CO_2 emissions from fuel combustion activities are estimated under seven categories. These categories are electricity production industries, industries for refining and manufacturing solid fuels, manufacturing industries and construction, transport, commercial, agriculture and fisheries and residential. Since different end-use sectors consume electricity, the associated emissions must be reallocated to end-use categories to estimate their respective emissions. In this study, the emissions from electricity production are allocated to the end-use consumer categories using electricity sales share as weights.

In India, electricity sales are monitored under six main categories. These categories are residential, industrial, agriculture, commercial, traction, and public services such as lighting and pumping. The mapping of sectors as per IPCC methodology and end-use consumer categories is shown in Fig. 2. The emissions from electricity production were allocated to each of the consumer categories. Commercial and public services were combined under commercial and services. Emissions from other energy industries and manufacturing industries and construction were mapped to emissions from industries. The emissions from commercials and institutional were mapped to commercial and services. The emissions from agriculture and fisheries were mapped to agriculture and allied.

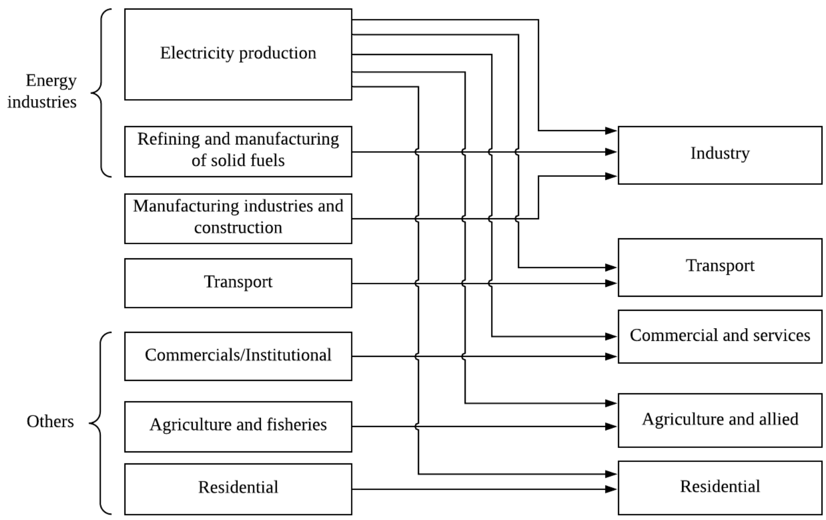

Figure 2: Mapping of energy-CO_2 emissions from GHG estimation categories to end-use consumer categories

2.2 Index decomposition analysis using LMDI

The energy-CO_2 emissions of a region are driven by changes in economic activity and intensity of emissions from the economic activity (Eq. 1). The intensity effect is determined both by technological factors and structural factors. The structural factors could be a change in the economy's structure, such as a change in the services sector's share. It could also be due to sector-specific structural changes such as a shift towards less energy-intensive industries or fuel mix changes. On the other hand, technological factors include adoption of energy efficiency technologies in production sectors. Separating the effect of energy-efficient technologies require data on sector-specific structural changes and energy consumption by fuel and sector. In the absence of such data, this paper only separates the effects of economic structure changes, and the sector CO_2 emissions intensity from the aggregate intensity effect. The sector CO_2 emissions intensity effect referred to as sector-intensity effect in this paper, includes energy-efficient technology effect, fuel mix effect and sector-specific structure effect.

The roles of the structure of the economy and sector-intensity in the aggregate intensity effect can be estimated using CO_2 emissions and value-added by different sectors. In this study, since the focus is on separating the effect of structural changes in the economy from the intensity effect, the analysis is limited to production sectors. In Eq 2, energy-CO_2 emissions are shown as the sum of emissions from n production sectors.

$$CO_2 = \underbrace{GDP}_{\text{activity effect}} \times \underbrace{\frac{CO2}{GDP}}_{\text{intensity effect}} \tag{1}$$

$$CO_2 = \sum_i CO_{2i} = \sum_i \underbrace{GVA}_{\text{activity effect}} \times \underbrace{\frac{GVA_i}{GVA}}_{\text{economy structure effect}} \times \underbrace{\frac{CO2_i}{GVA_i}}_{\text{sector- intensity effect}} \quad ; i = 1, 2..n \tag{2}$$

For convenience, the effects in Eq. 2 can be abbreviated as G, ES and SI for activity effect, economy structure effect and sector-intensity effect respectively. The change in the emissions from time $t = 0$ to $t = T$ can either be calculated as ratio change ($CO2^T/CO2^0$) or difference change ($CO2^T - CO2^0$). The decomposition using ratio change is known as multiplicative, and that of difference change is known as additive. In this study, the additive decomposition technique has been used to estimate the value change in CO_2 emissions as the sum of value changes in all the driving factors. The change in CO_2 emissions between 0 to T is shown in Eq.3.

$$\Delta C_{tot} = CO2^T - CO2^0 = \Delta C_G + \Delta C_{ES} + \Delta C_{SI} \tag{3}$$

Each factor's effect is the weighted average of logarithmic changes of the relevant variables, and the weights are the logarithmic mean of change in emissions. The formula for estimating the effects for the aggregate change in emissions is shown in Eqs (4)-(6). The effects are first estimated for changes in emissions of the i^{th} production sector and then aggregated across all sectors.

$$\Delta C_G = \sum_i \frac{CO2_i^T - CO2_i^T}{lnCO2_i^T - lnCO2_i^0} ln \frac{G^T}{G^0} \tag{4}$$

$$\Delta C_{ES} = \sum_i \frac{CO2_i^T - CO2_i^T}{lnCO2_i^T - lnCO2_i^0} ln \frac{ES_i^T}{ES_i^0} \tag{5}$$

$$\Delta C_{SI} = \sum_i \frac{CO2_i^T - CO2_i^T}{lnCO2_i^T - lnCO2_i^0} ln \frac{SI_i^T}{SI_i^0} \tag{6}$$

3 Data

In this study, energy-CO_2 emissions by sectors are taken from both country-reported data and IEA data. As stated above, as per the IPCC methodology, the energy-CO_2 emissions from electricity generation is not reported by consumer category. Hence, the share in electricity sales is taken as weights to calculate energy-CO_2 emissions by end-use. Gross value added by economic activity is used to calculate the emissions intensity of production sectors. The sectoral GVA is taken from the Back-Series of National Accounts (Base 2011-12), published by the Ministry of Statistics and Programme Implementation, Government of India (MoSPI, 2019). The GVA data by economic activity and production sectors are discussed in Appendix A.

The country-reported estimates of CO_2 emissions are taken from national communications and biennial update reports submitted by the government of Indian to the UNFCCC. Since 1994, India has submitted two national communications and two biennial update reports to UNFCCC. The Initial National Communication (INC) was submitted in 2004 containing data for 1994 (GoI, 2004). The Second National Communication (SNC) was submitted in 2012, and it contains data for the year 2000 and 2007 (GoI, 2012). In the First Biennial Update Report (BUR-1) submitted in 2016, the data of 2010 was reported (GoI, 2015). Inventory for the year 2014 was submitted in the Second Biennial Update Report (BUR-2) in December 2018 (GoI, 2018). Annual energy-CO_2 emissions by sectors is taken from IEA Data and Statistics for 2000-14 (IEA, 2019). As per IEA documentation, India's energy and emissions data is reported in the financial year such that data for any given year, for example, 2014 is for the financial year 2014-15.

As stated above, as per the IPCC guidelines, the emissions are reported under electricity generation, other energy industries, manufacturing and construction, residential, commercial, agriculture and other services. The emissions from electricity generation were dis-aggregated by end-use using consumer category wise share in electricity sales. The share of the consumer categories in the total electricity sales was taken from the Central Electricity Authority, Government of India, for country data analysis (CEA, 2016). The electricity consumption by consumer category reported in IEA data is taken for IEA data analysis (IEA, 2019). There is an extra category in IEA data in CO_2 emissions data that includes emissions from 'final consumption not elsewhere specified'. The emissions in this category are around 2% of the total emissions. A similar category in electricity sales in IEA data includes consumption not-specified elsewhere is around 5-7%. In this paper, these two categories are excluded from the analysis.

4 Results and Discussion

Past studies analyzing India's progress in decarbonization rely on external sources of emissions data. The evidence on the relative roles of structural factors and technology factors in driving the emissions is also limited. In this study, India's energy-CO_2 emissions intensity is estimated by end-use using both country-reported data and IEA data. The change in the CO_2 emission intensity of the economy and by production sectors is analyzed. The structural changes and changes in energy intensity of production sectors in the change in emissions are estimated from both datasets and compared. In the following subsections, emissions by sectors, emissions by end-use, CO_2 emission intensity by production sectors and sector-intensity effects in the change in emissions are reported. These results are reported for 2000-14, three sub-periods - 2000-2007, 2007-2010, 2010-2014 and the period in India's mitigation target, i.e. 2007-2014.

4.1 Emissions by sectors

The energy-CO_2 emissions by sectors from the two data sources are shown in Table 1. As expected, the largest emissions of CO_2 are from energy industries followed by manufacturing and construction industries. As per the country-reported data, India's energy-CO_2 emissions grew at the fastest pace during 2010-14 at 6.4% and lowest during 2007-10 at 3.9%. On the other hand, the CAGR during 2007-10 in IEA data is significantly higher at 7.8%. The source of this discrepancy is mainly from the manufacturing and construction sector. In 2010 and 2014, the emissions from manufacturing and construction were considerably higher in IEA data than country data.

In contrast, the emissions from both energy and manufacturing and construction industries in 2000 and 2007 are higher in the country-reported data. Notably, the transport and residential sectors' emissions are similar in the two datasets for all years. There is a discontinuity in country-reported data in emissions from the commercial sector in 2014 and the agriculture sector in 2010. There are few differences in the estimates of emissions from these sectors as well in the two datasets.

4.2 Emissions by end-use

The energy-CO_2 emissions by end-use are estimated using the mapping strategy shown in Figure 2. The estimated emissions by end-use are shown in Fig 3. As expected, in both datasets, the industry has the largest share in total emissions followed by residential. The share of agriculture in the total emissions was higher than transport in 2000 and 2007 but lower

Table 1: India's Energy CO_2 emissions

	Country data				IEA			
	2000	2007	2010	2014	2000	2007	2010	2014
Energy								
Electricity generation	522	716	816	1078	459	656	790	1081
Other energy industries	19	69	60	57	32	45	31	37
Manufacturing and constructuion	228	258	299	350	188	290	415	506
Transport	96	139	184	246	95	143	193	236
Other								
Commercial	3	2	4	25	10	13	16	21
Residential	55	69	75	86	63	71	76	82
Agriculture and fisheries	28	33	3	2	25	25	26	31
Total	952	1286	1442	1845	872	1243	1547	1994

Source: GoI (2012, 2015, 2018); IEA (2019)
Note: The emissions under 'Final consumption not elsewhere specified' in IEA data is excluded

in 2010 and 2014. Due to the difference in the estimates of emissions from manufacturing industries and the construction sector, the industry sector emissions are significantly different in the two datasets for all years but one. The emissions from industry in IEA data are lower for 2000 and higher for 2010 and 2014. The emissions from commercial and services are consistently lower in IEA data for all years. For agriculture and allied sector, the emission estimates are similar in 2000 and 2007 but higher in IEA data in 2010 and 2014. The emissions from residential and transport are similar for all years in the IEA data and country-reported data.

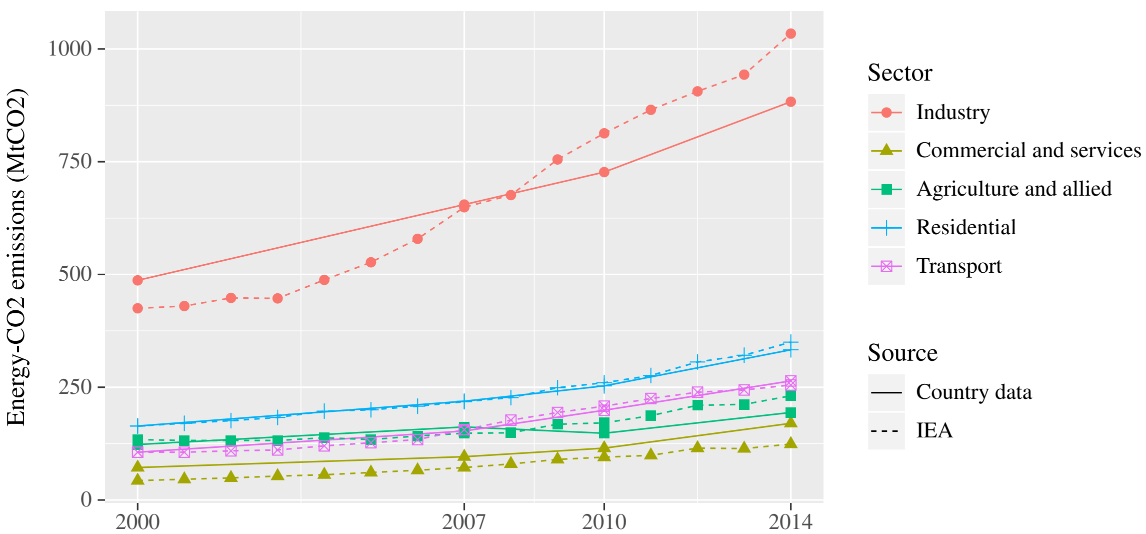

Figure 3: Energy-CO_2 emissions by end-use from country data and IEA data
Note: Estimated by mapping GHG emission categories to end-use consumer categories. The emissions from electricity production are allocated to end-use categories as per their share in total electricity sales.

4.3 CO_2 emission intensity by production sectors

In estimating the GDP's CO_2 emission intensity, emissions from all sectors, production (agriculture and allied, industry and commercial and services) and non-production (residential and transport) are included. The intensity of energy-CO_2 emissions for the three production sectors and the economy are shown in Fig 4. According to both datasets, during 2000-14, the economy's CO_2 emission intensity and industry and commercial and services have declined, but agriculture and allied has not changed significantly. However, as stated earlier, the economy's CO_2 emissions intensity declined by 20% as per country reported data and merely 6% as per IEA data in this period. Most of this difference is due to the difference in the emissions of the manufacturing and construction industries. The emission intensity of industry from IEA data is 15% lower in 2000 and 15% higher in 2014. The emissions intensity of commercial and services is consistently lower in IEA data than country data. On the other hand, the emissions intensity of agriculture and allied is around 10% lower in IEA data for 2007 but 10-15% higher in all the other years.

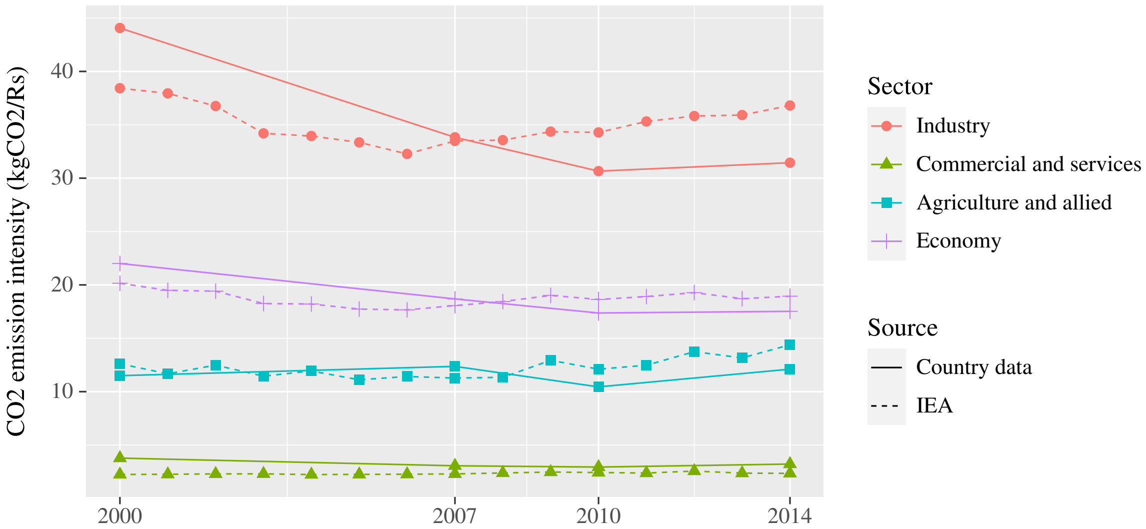

Figure 4: Energy-CO_2 emissions intensity of the economy and by economic activity
Note: GDP and GVA by economic activity is taken at constant 2011-12 prices (MoSPI, 2019).

Since 2005 is the baseline year for India's NDC, analyzing the CO_2 emission intensity changes from 2005 to 2014 is more relevant. According to the IEA data, India's CO_2 emissions intensity increased by 7% during 2005-2014. The corresponding change cannot be estimated from country-reported data, as the emissions by GHGs and sectors are not available for 2005.

The closest year to the baseline year is 2007. The country-reported data show a decline of 6% in India's CO_2 emission intensity, but IEA data show an increase of 5% during 2007-2014.

The changes in emission intensity in different periods from the two datasets are summarised in Table 2. The decline in emissions intensity is lower for all the sectors in the IEA data during 2000-14, and an increase in emissions intensity is estimated for all sectors during 2005-14 and 2007-14. Notably, the country data shows a larger increase in the commercial and services sector's emission intensity compared to IEA data during 2007-14. This result can be seen in the light of observation on discontinuity in estimates of emissions from the commercial sector in country-reported data for 2014, as stated earlier. Similarly, the significant difference in the agriculture sector's emissions intensity in the two datasets during 2007-14 can be attributed to another discontinuity in estimates of emissions from the agriculture sector in 2010 and 2014 in the country-reported data.

Table 2: Change in India's CO_2 emissions intensity

	2000-14		2005-14		2007-14	
Sectors	Country data	IEA data	Country data[a]	IEA data	Country data	IEA data
Industry	-29%	-4%	NA	10%	-7%	10%
Commercial and services	-15%	5%	NA	4%	5%	2%
Agriculture	5%	14%	NA	30%	-2%	27%
Economy[b]	-20%	-6%	NA	7%	-6%	5%

[a]Emissions by GHGs and sectors are not available for 2005 in country-reported data
[b]Economy includes emissions from residential and transport

4.4 Structural effect and sector-intensity effect

The observed changes in CO_2 emissions intensity are due to the structural factors and changes in the sector-intensity. In this paper, these effects are separated by decomposing the change in energy-CO_2 emissions. The change in energy-CO_2 emissions from the production sectors in the entire period, and the three sub-periods are shown in Table 3. The largest change in energy-CO_2 emissions are from the industry sector in both datasets. The change in emissions is greater in IEA data in all sub-periods but significantly higher in 2007-10.

The drivers of the change in CO_2 emissions from industry, services and agriculture and allied sectors were decomposed into three factors - activity effect, economy structure effect

Table 3: Change in India's energy-CO_2 emissions in production sectors[a]

	Country data			IEA Data		
	2000-07	2007-10	2010-14	2000-07	2007-10	2010-14
Industry	168	72	156	224	164	221
Commercial and services	24	19	55	29	23	29
Agriculture and allied	40	-15	47	14	23	60
Total	232	76	258	267	210	310

[a]Estimated using energy-CO_2 emissions by end-use for the three production sectors

and sector-intensity effect. The decomposition results for the three sub-periods for all three production sectors using country-reported data and IEA data are shown in Fig 5. As expected, activity effect has put upward pressure on emissions in all periods and the entire period in both datasets. The sector-intensity effect is negative in 2000-07 and positive in 2010-14 in both country-reported data and IEA data. However, in 2007-10 the sector-intensity is negative in country-reported data but positive in IEA data. Since the GVA data by economic activity is the same in the two datasets, the structure effect's signs are the same in their decomposition results. The structure effect is positive in 2000-07, negligible in 2007-10 and negative in 2010-14.

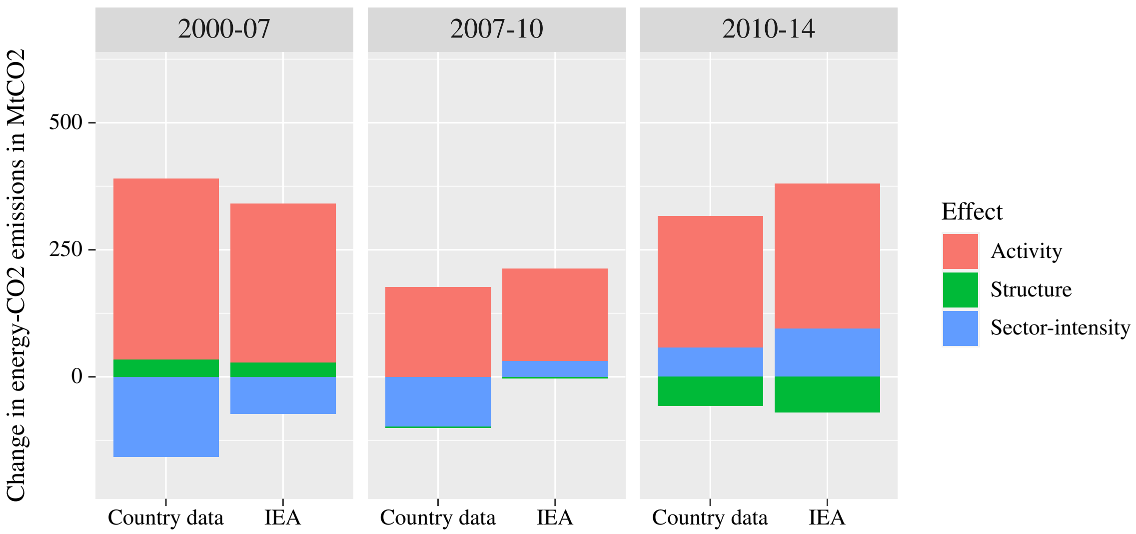

Figure 5: Drivers of energy-CO_2 emissions in production sectors during three sub-period (2000-07, 2007-10 and 2010-14)

The decomposition result for 2007-14 for the three productions sectors is shown in Fig 6. In this period, as per the IEA data, the sector-intensity effect of agriculture and industry has pushed emissions upwards, leading to a positive sector-intensity effect in the aggregate change. On the other hand, as per country data, the sector-intensity effect is negligible in agriculture but negative in the industry, causing a downward push in aggregate change emissions. The structural effect is negative for both agriculture and industry due to shifting towards service sector during 2007-14 in both datasets.

Figure 6: Drivers of energy-CO_2 emissions in production sectors during 2007-14

4.5 Discussion

This paper finds that the difference in the estimates of emissions from the manufacturing and construction sector in IEA data and country-reported data alters India's decarbonization narrative. The estimates of emissions in the manufacturing and construction sector in 2010 and 2014 in IEA data are 39% and 44% higher than country-reported data. This difference is reflected in a faster increase in industry emissions from 2007 onwards in IEA data. It translates into an increase in industrial CO_2 emissions intensity during 2007-14 in IEA data compared to a decline in country-reported data. The increase in CO_2 intensity is seen as a positive contribution of sector intensity to emissions change. In contrast, country data shows a negative contribution of sector-intensity effect in the change in emissions.

As discussed earlier, the sector-intensity effect includes effects due to changes in sectoral energy intensity and changes in fuel mix. Since the country-reported data does not provide energy consumption data, the effect of fuel mix cannot be separated. As stated earlier, Das and Roy (2020) used national energy statistics to estimate India's CO_2 emissions and analyzed the drivers of change using IDA. The authors examined India's emissions during 1990-2013 and three sub-periods, including 2006-13. They decomposed the emissions into activity growth, energy intensity, structural changes and fuel mix. The combined effect of energy intensity and fuel mix in their study is similar to the sector-intensity effect estimated in the present study. Their findings for 2006-13 are tabulated with the present study's findings from IEA data and country data for 2007-14. Additionally, the drivers are estimated from IEA data for 2006-13 for direct comparison with Das and Roy (2020) results.

Table 4: Comparison of drivers of India's energy-CO_2 emissions from different data sources ($MtCO_2$)

<table>
<tr><th></th><th>National Energy Statistics[a]</th><th colspan="2">IEA[b]</th><th>Country data[b]</th></tr>
<tr><th></th><th>2006-13</th><th>2006-13</th><th>2007-14</th><th>2007-14</th></tr>
<tr><td>Total</td><td>572</td><td>482</td><td>520</td><td>334</td></tr>
<tr><td>Activity</td><td>693</td><td>434</td><td>466</td><td>434</td></tr>
<tr><td>Structure change</td><td>-118</td><td>-57</td><td>-73</td><td>-61</td></tr>
<tr><td>Energy intensty</td><td>-3</td><td rowspan="2">105</td><td rowspan="2">126</td><td rowspan="2">-40</td></tr>
<tr><td>Fuel mix</td><td>0.33</td></tr>
</table>

[a] Das and Roy (2020)
[b] This study

It is evident from Table 4 that the drivers of India's energy-CO_2 emissions differ across all the three data sources. The aggregate change in emissions during 2006-13 is higher as per national energy statistics data compared to IEA data. The effect of structural changes is greater as per national energy statistics compared to IEA data during 2006-13. However, sectoral-intensity effect in this period is negligible from national energy statistics but positive from IEA data. The fuel mix's negligible effect in driving India's emissions has been reported in Das and Roy (2020) and other studies using IEA data (Peters et al., 2017; Karstensen et al., 2020; Jain, 2020). It can be assumed that the sector CO_2 emissions intensity effect is almost equal to the sectoral energy intensity effect. Hence, the sector-intensity effect's sign and magnitude informs about the combined effect of adoption of energy efficiency technologies and in the sectors' structural changes.

India has implemented a range of energy efficiency policies after adopting the Energy Conservation Act in 2001 and the Bureau of Energy Efficiency formation in 2002. There are several key policies implemented by BEE and the resulting savings in energy and emissions are found to be substantial (BEE, 2019). One of the important policies implemented by BEE is the Perform Achieve and Trade (PAT) scheme to reduce energy consumption in energy-intensive industries. There are three cycles of the PAT scheme, and the first cycle started in 2012. The first cycle of PAT scheme resulted in an energy savings of more than 8 million tonnes of oil equivalent (Mtoe) during 2012-13 to 2014-15 translating into 31 $MtCO_2$ emission reduction. The IEA data analysis findings indicate that this program's effect has been negated by an increase in energy intensity of industrial production. On the other hand, the results from country-reported data suggest a possible role of the scheme in driving the emissions down.

5 Conclusions and Policy implications

Carbon dioxide emissions intensity of economies, the ratio of CO_2 emissions and economic output, are monitored to inform their decarbonization progress. Moreover, drivers of fossil fuel combustion emissions are decomposed to know the effects of changes in activity, structure, and intensity in the change in emissions over a period. Prior work on India's progress in reducing its CO_2 emissions intensity efforts have been analyzed mainly using external data sources such as IEA Data and in few cases, national energy statistics. These studies have not used country reported data to validate their findings.

India's country reported data is available for selected years, excluding 2005, which is the baseline for assessing India's mitigation targets. In its Second Biennial Update Report, India has shown that India's GHG emissions intensity declined by 21% in 2014 compared to 2005. As shown in Fig 1 according to IEA data India's CO_2 emissions intensity has been increasing during 2005-14. This difference leads to two different narratives of India's decarbonization progress. It also leads to contradictory findings on the roles of changes in energy intensity and structural changes in the economy in driving India's emissions.

In this paper, the differences in the country-reported data and IEA data is studied, and its implications on India's progress in meeting its mitigation goals are examined. The decline in the production sectors' CO_2 emissions intensity and the role of a shift towards the service sector compared to sector-level energy intensity are analyzed. The emissions by sectors are taken from the two data sources, and the origin of the difference is identified. The emissions are mapped to end-use consumer categories, and emission intensity by production sectors are calculated using gross value added (GVA) by economic activity at constant prices. Changes in emissions of the productions sectors are studied and the effect of structural changes in the economy is separated from sector-intensity effects using the Log Mean Division Index (LMDI) approach.

This study finds that the main difference between the two data sources is the estimates of emissions from the manufacturing and construction sectors in 2010 and 2014. The effect propagates to estimates of emissions by end-use and emissions intensity of production sectors. As per country data, India's CO_2 intensity of industrial production during 2007-14 has declined by 7%. However, as per IEA data, it has increased by 10%. The country data shows that sectoral-intensity effect has put downward pressure on emissions in this period. However, the IEA data shows that sector-intensity effect increased India's emissions in 2007-14 and the decline in emissions is driven merely by structural changes. This finding has implications on India's mitigation efforts' effectiveness, particularly in promoting energy-efficient technologies in industrial production.

The present study contributes to the ongoing discourse on India's decarbonization and its achievement of the mitigation goals. It brings forward a marked difference in estimates of emissions across two important datasets used in this discourse. While the data related issues have been raised in the past, this study draws policy implications of one such discrepancy in the data. It examines the source of difference between country data and IEA data and how it propagates to change India's decarbonization narrative. It also contributes to the ongoing discussion on the relative role of structural changes towards the service sector in India's emissions. Enhancing energy efficiency is a key strategy to meet India's climate goals. Study of drivers of emissions is critical as it provides evidence of the effectiveness of these strategies. This study emphasizes that the differences across data sources must be resolved to address contradictory findings on India's decarbonization progress and effectiveness of its mitigations strategies.

Acknowledgement

The author received no financial support for the research, authorship, and/or publication of this article.

Appendix

India's gross value added (GVA) by economic activity is reported under eleven categories. These categories are mapped to the three production sectors, as shown in Figure 7. India's GDP and GVA by three production sectors are taken from the recently published back series of National Account Statistics (base 2011-12). The GVA data is reported in the calendar year. The study adopts the same methodology as that of IEA data, i.e., GVA data for 2014-15 is referred to as the GVA data for 2014.

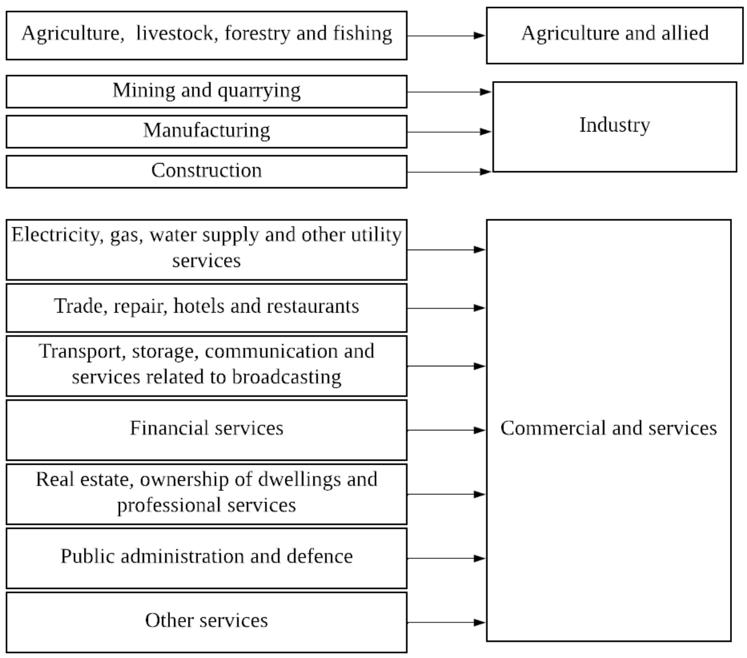

Figure 7: Mapping of economic activities to the three production sectors

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