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Energy Intensity and CO2 emissions

India's progress towards energy and climate change mitigation goals

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India's energy problem

- Per capita energy consumption - 0.6 toe/capita
- 21% of primary energy supply from non-commercial energy sources
- 95% of commercial primary energy supply from fossil fuels
- 56% from coal, 35% from oil and 7% from natural gas
- Hydro-2%, nuclear-1% and other RE(solar and wind)-1%

India's approach to energy efficiency

- Appliances - information through appliance labels, minimum efficiency performance standards to remove inefficient products and gradual strengthening of standards
- Industry - information through mandatory energy audits, mandatory targets to reduce specific energy consumption, trading of energy saving certificates to meet targets (Perform-Achieve-Trade); information and financing for small and medium enterprises
- Agriculture and Municipal services - mandatory energy audits, demand side management programs for lighting and pumping
- Building - Codes setting minimum performance standards
- Transport - Vehicle efficiency standards, hybrid/electric vehicle

Methodologies to estimate energy savings from energy efficiency

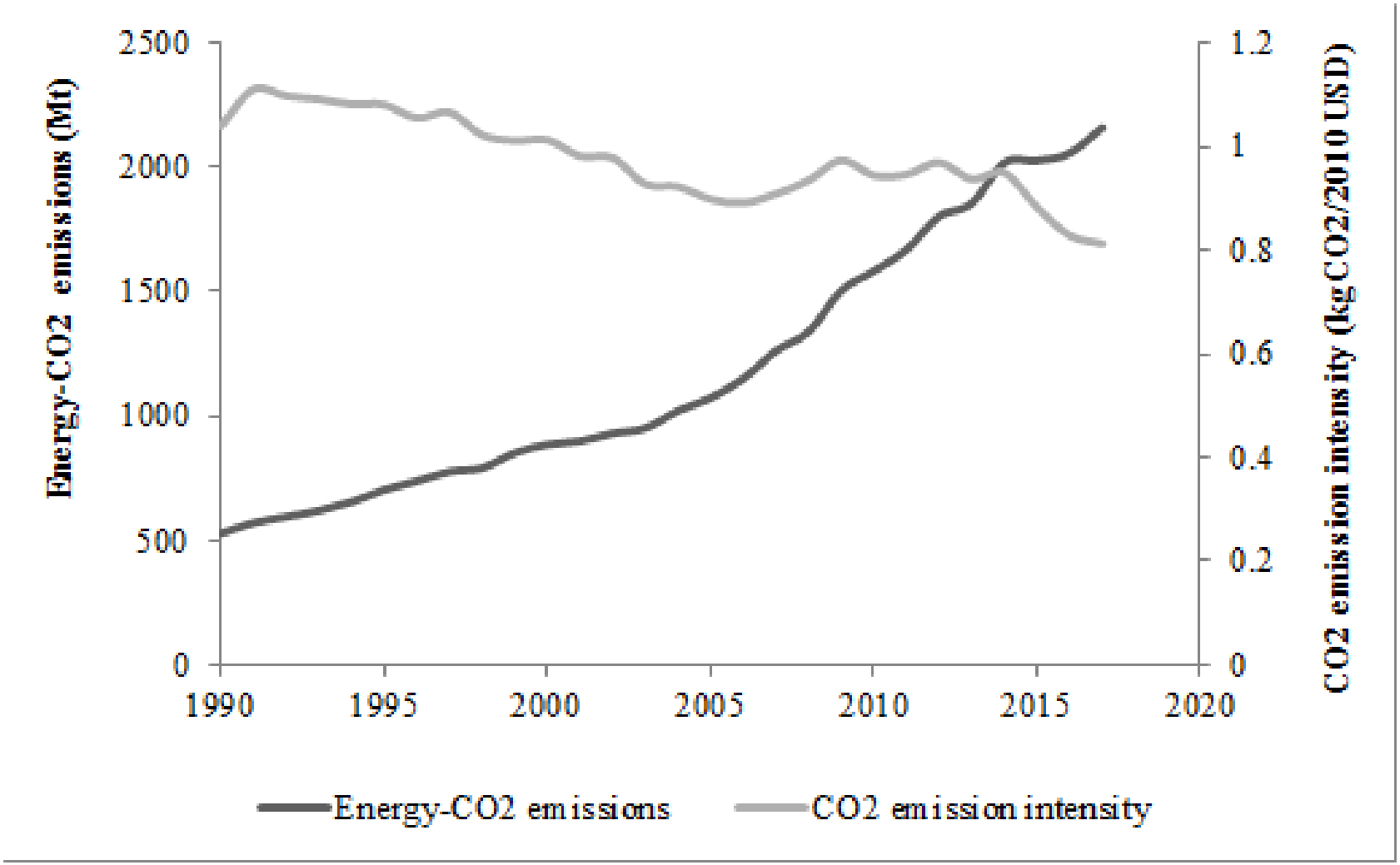
- Field Measurements - expensive/infeasible for large projects, additional costs
- Engineering estimates - Overestimation of savings, rebound effect other behavioural changes are neglected
- Model based studies - Dependence on assumptions
- Index decomposition Analysis - ex-post analysis, effect of policies cannot be isolated

Estimated savings from energy efficiency in India

Some estimates of savings from energy efficiency programs

Sector	Energy saved	Avoided capacity	Emission reduction
Industry (2012-15)	8.67 mtoe		31 MtCO2
Agriculture (2012-17)	2.3 mtoe		
Municipal (2012-17)		52 MW	
Appliances (2012-17)		22990 MW	

India's energy-CO2 emissions and emissions intensity



Research objectives

- Estimate the drivers of India's CO2 emission
- Quantify the effects of economic growth, economic structural changes, energy intensity and carbon intensity of energy in the change in emissions
- Compare the estimates of emission reduction from the energy intensity effect of production sectors with official estimates

Extended Kaya Identity and Index decomposition analysis

CO2 emission in year t, i is the production sectors

$$CO2_t = \sum_i \underbrace{GVA_t}_{\text{activity effect}} \times \underbrace{\frac{GVA_{it}}{GVA_t}}_{\text{economy structure}} \times \underbrace{\frac{E_{it}}{GVA_{it}}}_{\text{sector-energy intensity}} \times \underbrace{\frac{CO2_{it}}{E_{it}}}_{\text{carbon intensity}} \quad (1)$$

Change in CO2 emission from year 0 to t

$$\Delta CO2 = CO2_t - CO2_0 = \Delta CO2_{AE} + \Delta CO2_{SE} + \Delta CO2_{SEI} + \Delta CO2_{CI} \quad (2)$$

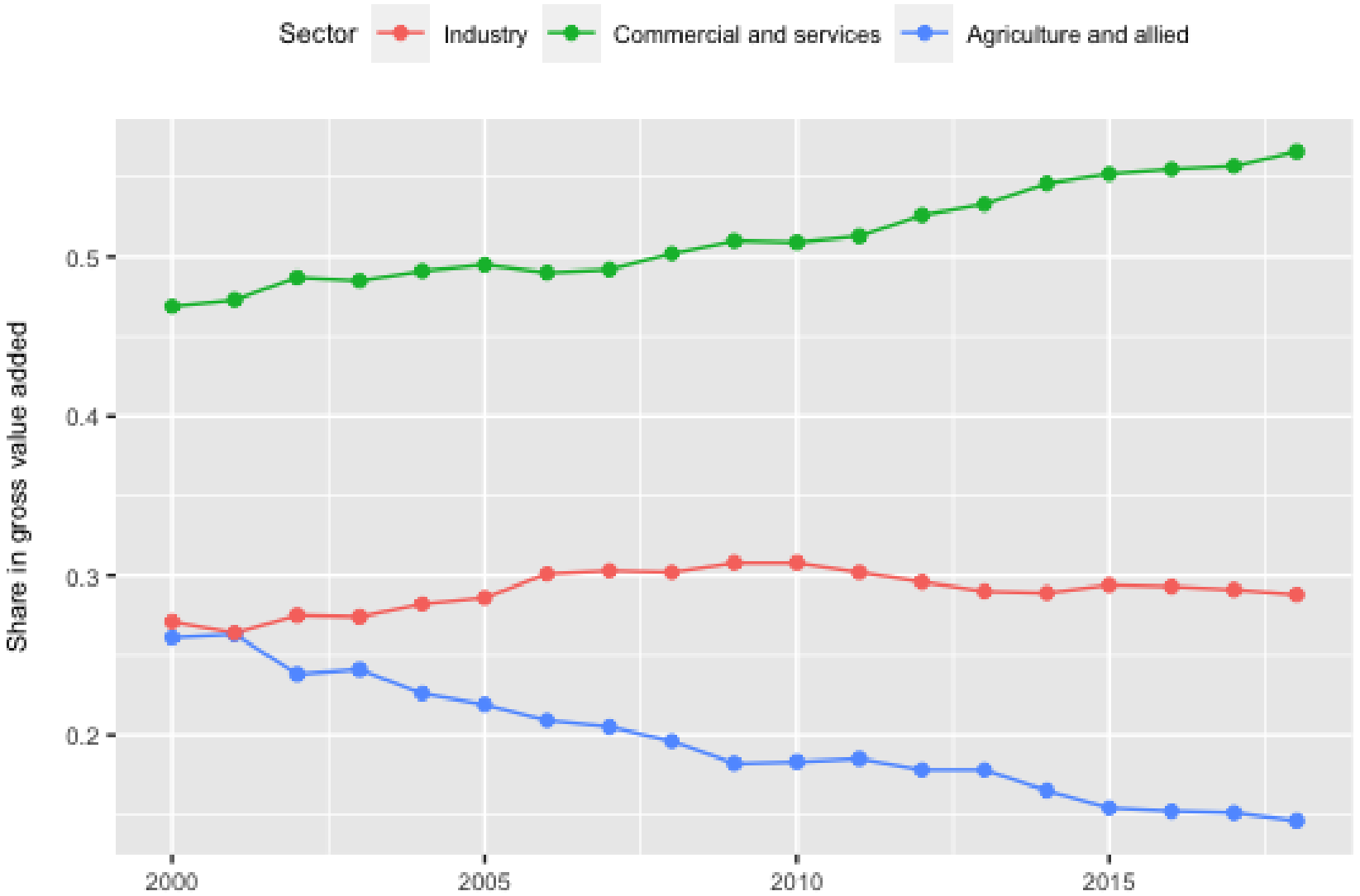
Effect of a factor, say EI is

$$\Delta CO2_{EI} = \sum_i \frac{CO2_{iT} - CO2_{i0}}{lnCO2_{iT} - lnCV_{i0}} \times ln(\frac{EI_{it}}{EI_{i0}}) \quad (3)$$

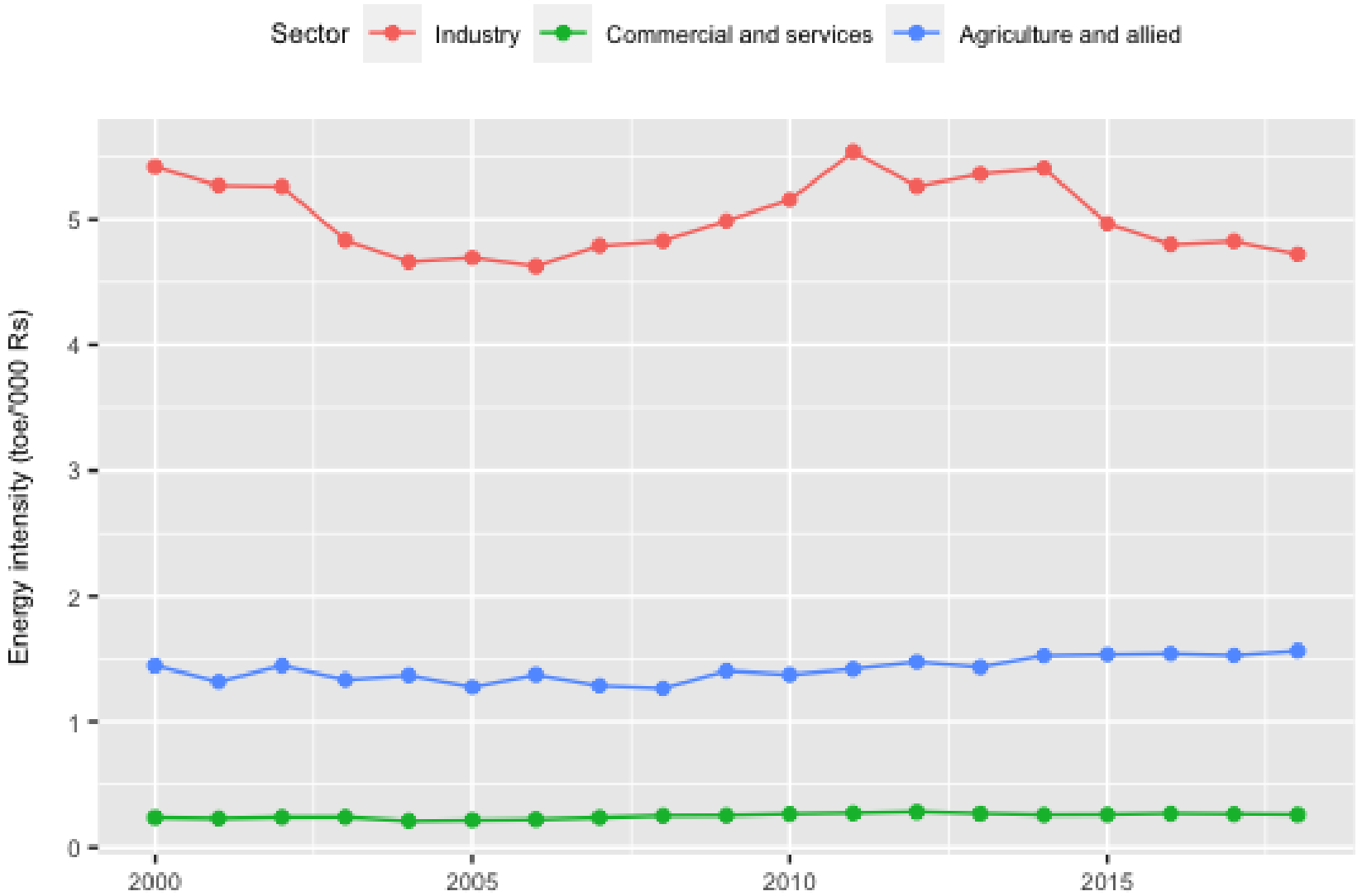
Data

- Final energy consumption by sectors for 2000-18 from International Energy Agency
- Three production sectors - industry, agriculture and allied and commercial and services; transport and residential are excluded
- CO2 emissions by sectors using IPCC methdology
- Gross value added by production sector in constant monetary units from official estimates

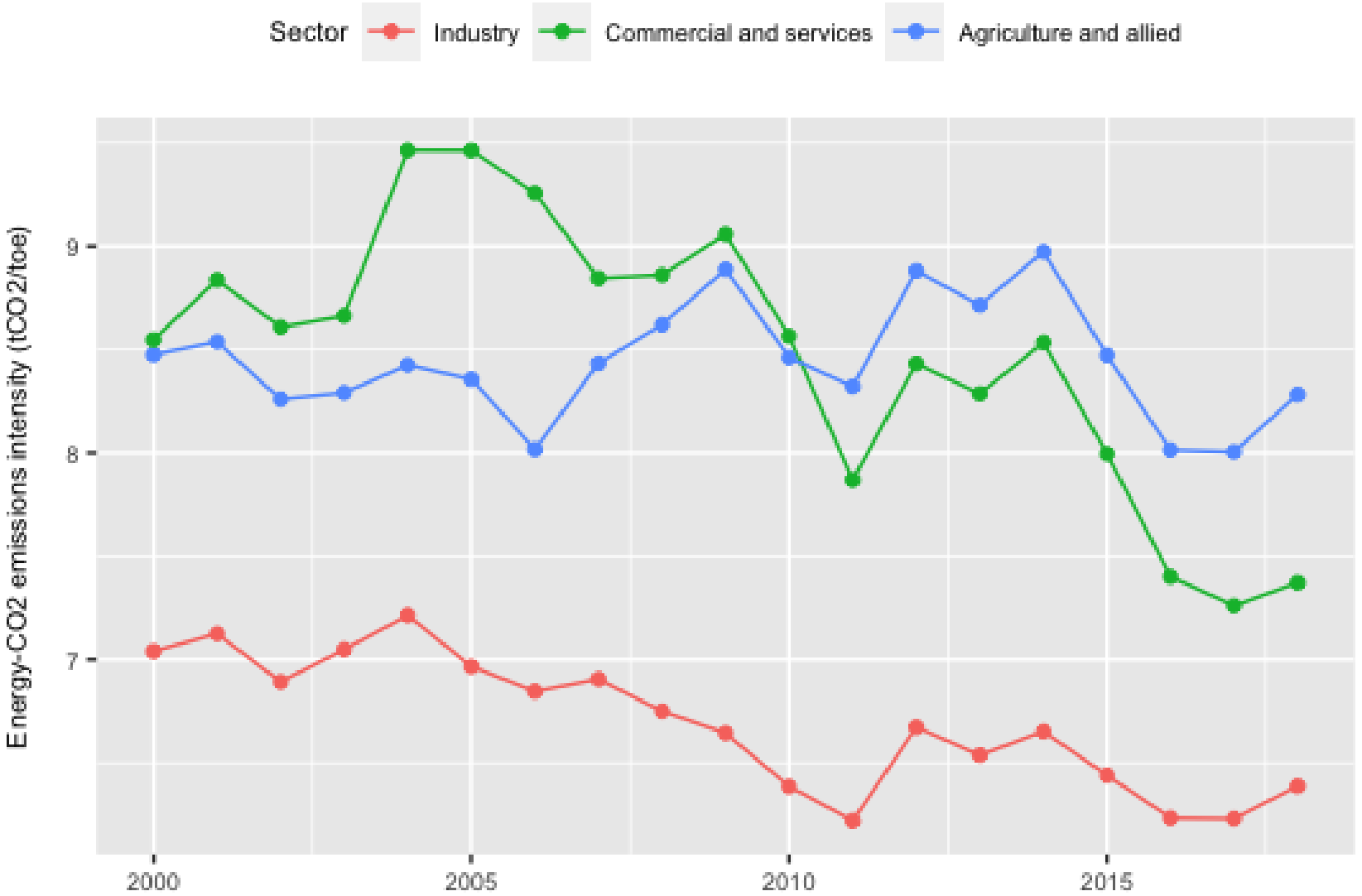
Kaya factors - Production sectors share



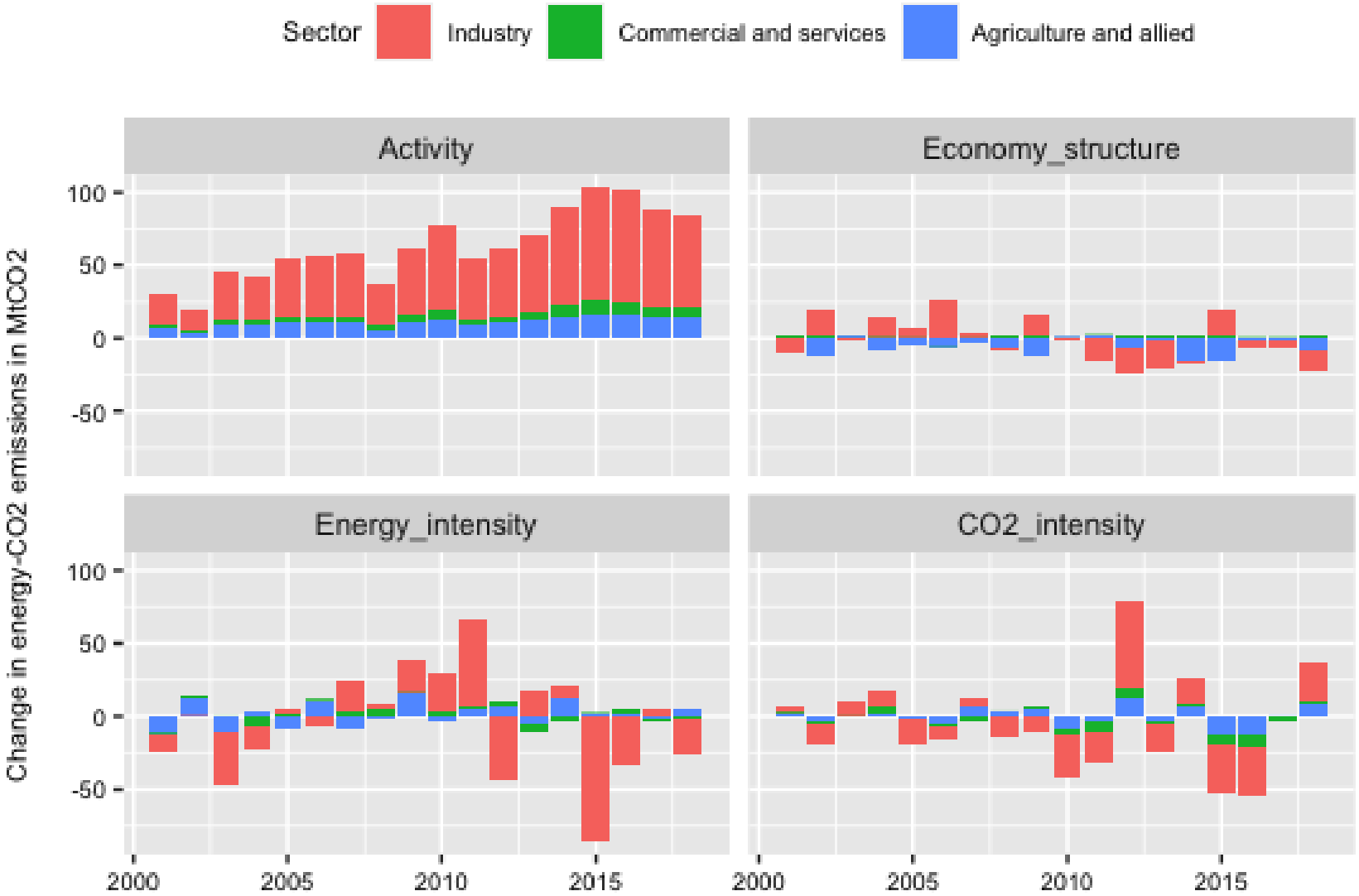
Kaya factors - Energy intensity of production sectors



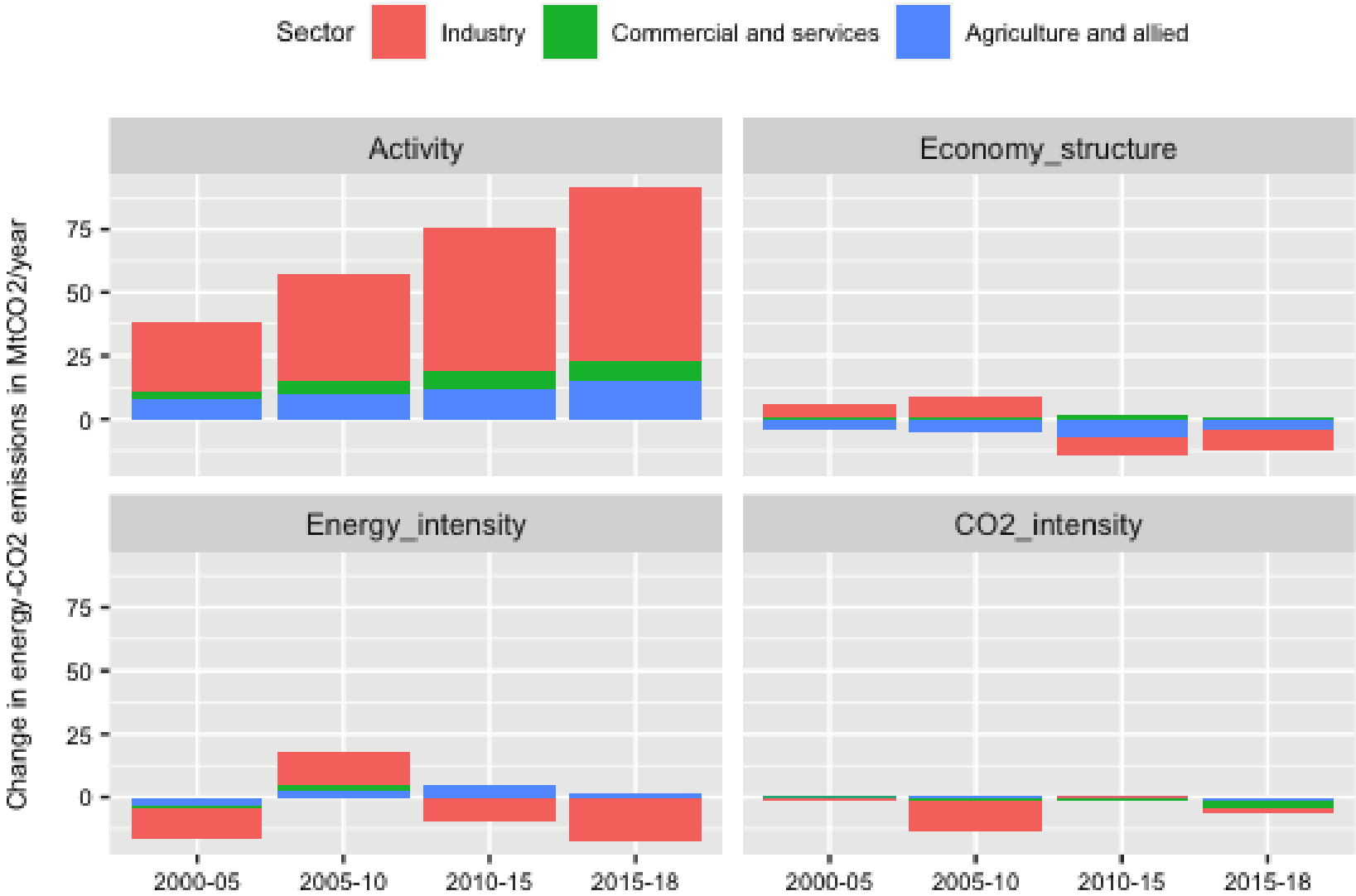
Kaya factors - Carbon intensity of energy



Decomposition results - Annual estimates



Decomposition results - Period estimates



Key findings(1/2)

- Activity effect
  - Key driver of India's CO2 emissions
  - Gradually increased over time
  - 38 MtCO2/year during 2000-05 to 91 MtCO2/year during 2015-18
- Economy structure effect
  - There is a shift from agriculture to industry during 2000-10; net effect is negligible
  - During 2010-18 the shift is towards services sector resulting in negative effect on emissions - 12 Mt/year

Key findings(2/2)

- Sector-energy intensity effect
  - Pushed the emissions downwards by 17 MtCO2/year during 2000-05
  - During 2005-10 caused increase in the emissions at similar rate
  - Again began pushing emissions downward and at a much higher rate during 2015-18 - mainly from industries; effect of agriculture sector is positive
- CO2 intensity effect
  - Negligible effects in most years
  - Marginal decline since 2015

Discussion

- Sector-energy intensity effect of industries
  - Includes the effect of energy efficiency and shifts towards or away from energy intensive industries
  - Emission reduction of 60 MtCO2 during 2012-15
  - Greater than the official estimates of emission reduction (31 MtCO2)
- Sector-energy intensity effect of agriculture and allied sector
  - Includes the effect of energy efficiency and shifts within the agriculture sector
  - Emission increase of 8 MtCO2 during 2012-17; official estimates show reduction in emissions

Future work

- Compare with estimates from official energy data
- Compare with other studies estimating energy savings and emissions reduction from energy efficient technologies
- Quantify effect of structural changes within industrial sector
- Include transport and residential sectors in analysis

Thank you for your attention!
Comments, suggestions and observations are welcome!