Unveiling Environmentally Adjusted Total Factor Productivity Growth in India

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Introduction

- Issues of resource depletion and global warming (Wang et al 2022; OECD 2022; Chiu and Lee 2020).
- Green economy and environmentally sustainable growth.
- Green total factor productivity (TFP) and the sustainability of a nation's economic growth.
- Issues with traditional productivity estimates:

1. Solow growth accounting measure of TFP fails to account for the negative byproducts of production process like emissions and the resultant environmental damage (Brandt et al., 2014)
2. Traditional estimates of TFP growth are biased.

- The objective of this paper is to estimate the green TFP growth of India and identify the macro drivers of green TFP growth in India.

Literature Review

Estimates of green productivity:

- Xia and Xu (2000) show divergent trends between GTFP and standard TFP indexes ignoring environmental outcomes.
- Chen et al. (2018) find that incorporating environmental consequences reduces the industrial TFP by 0.02 percent each year on average.
- Wang and Shen (2016) find a significant difference in green productivity between polluting and clean production industries, with the former having lower green productivity than the latter.
- Weber and Domazlicky (2001) find that by not accounting for toxic release from manufacturing, productivity growth is over-estimated.

Methods of measuring green productivity:

- Directional distance function (DDF), slack based models, super-slack based models (Chung et. al (1997); Tone (2001); Pang et al., 2015; Liu and Xin, 2019)
- OECD Environmentally Adjusted Multifactor Productivity (EAMFP) based on growth accounting.

Literature Review

Drivers of GTFP:

- Lee and Lee (2022) found industrialization had negative impact on green productivity.
- Liu et al. (2020) found that innovations, property right structure and human capital had a significant impact on green TFP in china.
- Li et al (2022) find that green technology and green energy exerted a significant impact on green productivity.
- Chen and Golley (2014) find that openness to foreign investments and R&D particularly in emission intensive sectors are significant drivers of green TFP.
- Chen et. al (2018) and Wang et al (2019) find that environmental regulation improved green productivity.

Aim and Scope of the Study

- In India, several studies have examined the adverse impact of the environment on labour and agricultural productivity (Datta and Jong 2002; Singh 2016; Kumar and Sharma 2014).
- The OECD database does provide an estimate for environmentally adjusted total productivity (EATFP) for India but that database is available up to 2013.
- Growth accounting framework to estimate environmentally adjusted TFP growth rate for India during 1990 to 2019.
- Difference between our estimate for EATFP and OECD database:

1. Forest depletion cost
2. KLEMS database for factor input use

- Structural, environmental and technological drivers of environmentally adjusted TFP growth.

Methodology and Data for Green TFP estimation

- To empirically estimate environmentally adjusted TFP, we followed the methodology of Brandt et al (2013, 2014) and Cardenas et al (2018).
- Traditional growth accounting framework: $\Delta lnV = \Delta lnT + \nu k \Delta lnK + \nu l \Delta lnL$ (1)
- where ΔlnV is growth rate of value added, which is derived from translog aggregation of industry value added. $K\ and\ L$ are capital and labour. ν is the two-period average share of factor input compensation in nominal value added. νk and vl denote two-period average of aggregate capital and labour compensation in nominal value added. ΔlnK and ΔlnL denotes aggregate capital input and aggregate labour input growth rates. ΔlnT is the total factor productivity growth rate.
- Effective output, that is the 'environmentally adjusted GVA' given as:
- $V = f(Y,W,R)$ (2)
- where, V denotes the effective output. Y is GVA of goods and services produced in an economy and W is the undesirable output indicator, R is the resource depletion indicator.

Methodology and Data for Green TFP estimation

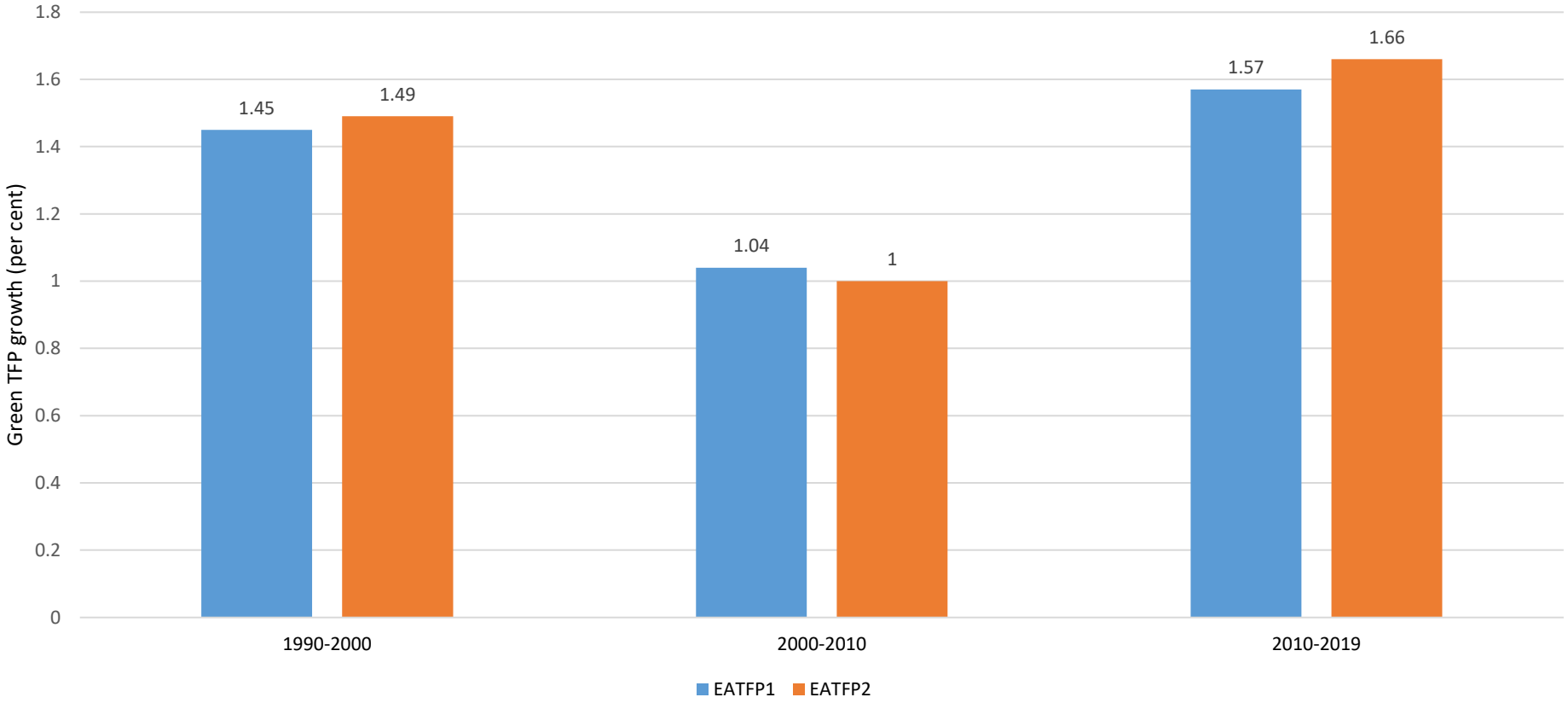
- *V= GVA – carbon dioxide damage -opportunity cost of energy depletion -opportunity cost of mineral depletion-opportunity cost of net forest depletion* *(3)*
- Following the growth accounting method, the effective output growth is decomposed into contribution of labour (L), capital(K) and environmentally adjusted total factor productivity (EATFP). Under specific assumptions of constant returns to scale and competitive markets from equation (1) we get the environmentally adjusted TFP as:
- $\Delta lnEATFP = \Delta lnV - \bar{\alpha}k\Delta lnK + \bar{\beta}l\Delta lnL$ (4)
- Where $\bar{\alpha}$ *and* $\bar{\beta}$ are the two-period average share of input cost in nominal value of output.
- where $\bar{\alpha} = .05(\alpha_{i,t} + \alpha_{i,t-1})$ and $\bar{\beta} = .05(\beta_{i,t} + \beta_{i,t-1})$

Data

- India KLEMS database: *capital, labour, and factor income share*
- National Account Statistics: *GVA*
- World Bank: *carbon dioxide damage, opportunity cost of energy depletion , opportunity cost of mineral depletion and opportunity cost of net forest depletion*

Green TFP estimation

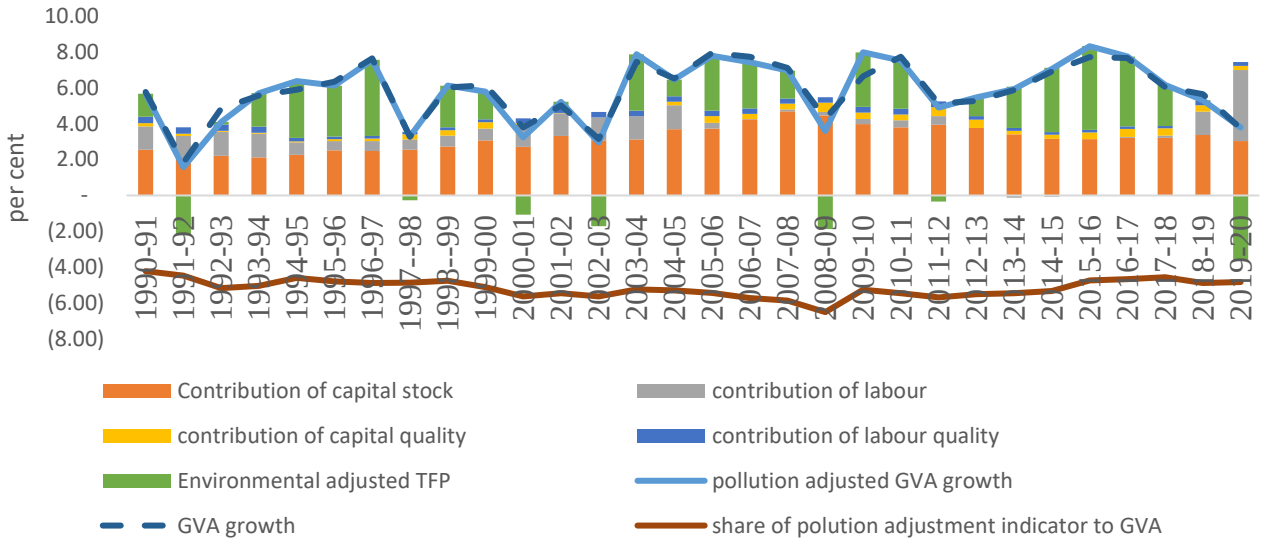
Chart 1: Estimate of green TFP growth



Source: Authors own calculation

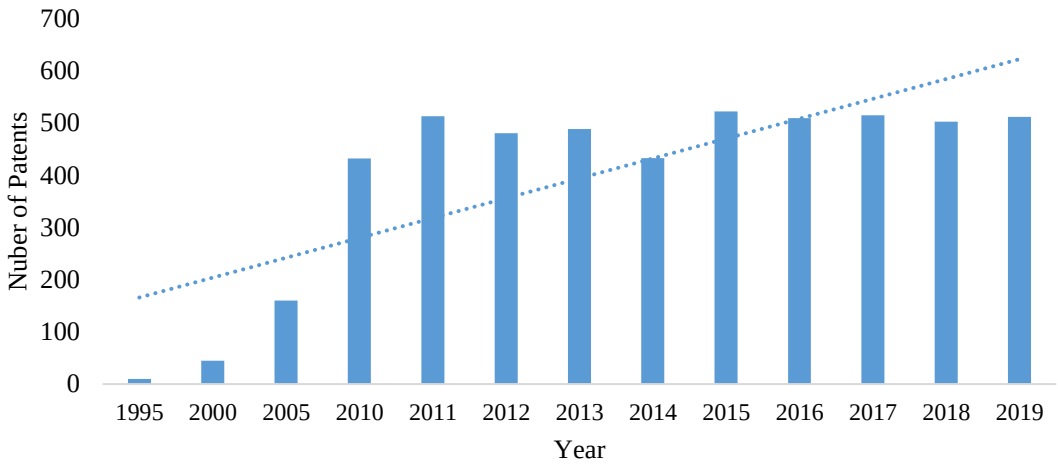
Green TFP estimation

Chart 2: Drivers of Pollution adjusted GVA growth in India



Source: Authors' estimate

Chart 3:Number of environment technology related patents



Source: OECD stat

Drivers of EATFP Growth

- The existing literature on determinants of EATFP highlights that the nexus between growth and environment is viewed as a function of economies of scale, institution, technology and structure (Copeland and Taylor 2004).
- The basic function is: $EATFP = f(institution, technology, structure, other\ factors)$ (5)
- In equation 5, EATFP represents environmentally adjusted green TFP growth, which is a function of institution, technology, structure, and other factors.

1. Institutions : environmental policy stringency (Chen et al 2022).
2. Technology is captured by two indicators - environmental technology as a percentage of all technology and foreign direct investment as percentage of GDP (Lee and Lee 2022; Chen et al 2022).
3. Structural effect is captured via the industry share in value added (Tao et al. 2017).
4. We also use degree of openness (Yu et al. 2022), and productivity of infrastructure as additional factors which can affect green productivity.

Data

- Annual time series data from 1990-2019

1. OECD stat : Environmental stringency index; Development of environmental related technology as a percentage of all technology
2. CEIC dataset: FDI as a percentage of GDP
3. World Bank: Trade share and industry share in value added
4. India KLEMS database: productivity of infrastructure

Drivers of EATFP Growth

Table 2: Unit root Test

Variable	T-statistic for variables in level form	T-statistic for variables in 1st difference form	Decision
Environment policy stringency	-1.89	-5.86	I(1)
	(0.622)	(0.00)	
Environment related technology as a fraction of total technology	-2.95	-5.73	I(1)
	(0.166)	(0.00)	
FDI as a percent of GDP	-4.33		I(0)
	(0.00)		
Industry share in value added	-0.31	-4.55	I(1)
	(0.98)	(0.03)	
Trade Share	-0.51	-4.79	I(1)
	(0.97)	(0.00)	
Productivity of infrastructure	-3.02	-6.00	I(1)
	(1.377)	(0.00)	
EATFP	-3.18	-7.07	I(1)
	(1.07)	(0.00)	

The table reports the t statistics of the ADF test which includes the constant and trend variable. The t statistic is reported for variables in level and in first difference, and p values are reported in parentheses.

Drivers of EATFP Growth

- Mixed order of integration and small sample.
- Robustness of ARDL in small samples.
- ARDL model: $EATFPG_t = \alpha + \lambda t + \sum_{i=1}^{p} \phi_i ETFPG_{t-i} + \sum_{j=0}^{q} \beta_j X_{t-j} + u_t$ (6)

- In equation 6, EATFPG is the growth in environmentally adjusted TFP ,$ETFPG_{t-i}$ is the lag of EATFP, t, is the time subscript and represents the trend variable. X denotes the vector of explanatory variables including environmental policy stringency, environmental technology as percentage of all technology, foreign direct investment as percentage of GDP, trade share, and productivity of infrastructure. In the above equation growth in EATFP depends on its own lagged values (upto p lags), as well as the current and lagged values of the independent variables.
- Different combination of explanatory variables across the models, as it has not been possible to include all the variables in one model as our N is small (30 observations).

Results

Table 2: Long run relation from ARDL Model

	(1)	(2)	(3)	(4)	(5)	(6)
	EATFP	EATFP	EATFP	EATFP	EATFP	EATFP
LR						
Environment policy stringency		17.75**	30.32*	19.80***	25.84***	
		(4.19)	(2.31)	(4.43)	(28.30)	
Environmental related technology	0.483***		-3.339		0.455*	
	(4.88)		(-1.68)		(2.36)	
FDI	0.0141	-4.615		22.49		1.789*
	(0.05)	(-1.53)		(1.64)		(2.89)
Trade Share		0.668***	1.290			0.897***
		(6.05)	(1.02)			(15.38)
Productivity of infrastructure	33.21***				10.6**	10.7***
	(4.64)				(4.84)	(5.02)
Share of industry				14.14		
				(2.02)		
				(-2.41)		
_cons	-4.273*	147.1*	4148.0	-85.43*	102.3***	85.79***
	(-2.58)	(2.86)	(1.53)	(-2.68)	(6.99)	(5.83)
N	25	26	26	26	25	25
Adjustment coeff	-1.892***	-1.539*	-0.702*	-0.325*	-0.992***	-0.766***
ARDL Model	(1,2,1,1)	(4,4,2,4)	(3,3,1,3)	(1,0,2,2)	(4,4,4,3)	(1,2,1,4)
Bound Test						
F stat	7.314	9.317	9.362	9.274	15.472	11.550
DW	2.26					

*indicates significant at 10% level of significance. **indicates significant at 5% level of significance, and ***indicates significant at 1% level of significance.

Conclusion

- The study has estimated green productivity for India during 1990 and 2019.
- The study reveals that EATFP experienced a slight decline between 2000 and 2010s but witnessed improvement in the last decade
- The study also highlights the significance of innovation and environmental regulation as key drivers of EATFP.
- Looking ahead, it is anticipated that India's EATFP will continue to improve, supported by the growing contributions of private entities towards environmental sustainability, such as low carbon emissions and green energy promotion. Recent initiatives by the government and increasing corporate responsibility are evident from the rising investments in renewable energy.

Conclusion

Thank You