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Understanding technological progress and input price as drivers of energy demand in manufacturing industries in India

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HIGHLIGHTS

- Energy use behaviour of manufacturing industries in India during 1973/74 to 2011/12.
- Technological progress induced output growth and gain in energy productivity.
- Energy saving bias of technological progress is prevalent in recent years.
- Own price elasticity of energy demand is negative.
- Increase in energy price has induced technological progress.

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ABSTRACT

This paper presents a comprehensive analysis of energy demand behaviour of seven energy intensive manufacturing industries and the aggregate manufacturing sector in India during 1973–74 to 2011–12. The policy Perform, Achieve and Trade (PAT) has mandated energy efficiency targets for these manufacturing industries in India. We focus on two major drivers of energy demand: technological progress and energy price. Productivity growth accounting and estimation of parametric cost function using Annual Survey of Industry data bring out important implications regarding the role of these two drivers. Results suggest that these industries experienced technological progress over the study period (1973–74 to 2011–12) with significant energy-saving bias during 1998–99 to 2011–12. Increase in energy price has led to reduction in energy demand and augmented technological progress in most of the industries. Energy and material inputs are mostly substitutes. During 1998–99 to 2011–12, productivity growth of energy input was induced by both technological progress and increase in energy price. Estimates of inter-factor substitution suggest that price induced reduction in energy demand can be a capital-intensive process in case of some industries. Rebound effect has never taken back full gains of energy efficiency policies in the context of these industries.

1. Introduction

Industries are important actors in the paradigm of low carbon transition. With voluntary/mandatory greenhouse gas mitigation obligations in place, enhanced productivity of energy and other inputs, deployment of efficient technology, fuel switch, etc. can play important roles to achieve long-run sustainability of the industrial sector. In India, an important role has been assigned to energy intensive manufacturing industries to contribute to the country's unilateral mitigation pledge put forward in terms of reduction in energy intensity of GDP. This is well reflected in the proposed National Mission on Enhanced Energy Efficiency (NMEEE) under the National Action Plan on Climate Change (Government of India, 2008a). Under NMEEE, seven energy intensive manufacturing industries, namely, Aluminium, Cement, Chlor-Alkali, Fertilizer, Iron and Steel, Pulp and Paper and Textile, are brought under the purview of the policy Perform, Achieve and Trade (PAT). Mandatory energy intensity reduction targets are set for larger production units in these industries. These units are to adopt suitable measures in order to achieve energy intensity reduction targets during a stipulated compliance period (2012–2015). While the overachievers will be awarded saleable energy-saving certificates, underachievers will be liable to either pay a penalty or purchase those energy-saving certificates from the

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overachievers at a market-determined price. Such additional payment for non-compliance will increase the effective energy price for the underachievers. PAT, in this way, encourages technology adoption to achieve enhanced energy efficiency, but at the same time recognises the fact that if technology adoption remains inadequate then price mechanism has a role to play as a corrective measure. Technological progress and input price-induced behavioural response are in fact two major drivers of change in energy demand in the industries as identified in the literature (Ethridge, 1973; Roy et al., 1999; Fischedick et al., 2014). The current paper analyses the historical energy demand behaviour of similar Indian industries as covered under PAT with a focus on the role of technological progress and energy price. Since the compliance period under PAT began in 2012, this paper, therefore, sets an important historical background for any further comparative analysis between the periods before and after implementation of PAT for these industries in India. The coverage of this study is uniquely large and includes seven energy intensive manufacturing industries along with the aggregate manufacturing sector in India for a period of almost four decades – from1973–74 to 2011–12. The study covers the same industries as under PAT with two exceptions: 'Chemical (excluding Fertilizer and Pesticide)' industry is considered instead of 'Chlor-Alkali' and 'Fertilizer and Pesticide' industry is considered instead of 'Fertilizer'. This modification is done in order to accommodate the availability of relevant long-term data.

The paper aims to address the following research questions: First, what is the contribution of technological progress in output growth of these industries? Second, has technological progress historically evolved to be energy-saving in nature? Third, what is the input-use and input-substitution related behavioural response of these industries with respect to change in energy price? Fourth, what is the impact of technological progress vis-à-vis changes in energy price on the productivity of energy input? However, technological progress and input price-induced behaviour are not mutually exclusive as far as the industries are concerned. An increase in energy price may induce faster energy-saving technology adoption in the industries (Hogan and Jorgenson, 1991). It is, therefore, investigated how price-induced behavioural response interacts with technological progress. Finally, the paper seeks to understand briefly the presence of rebound effect in the context of these industries. It contributes to the literature by estimating comparable parameters and extending the study by Roy et al. (1999) with renewed context, new insights and improvements in the methods of variable construction.

In Section 2, the methods of analysis are presented. Section 3 summarises the results and discusses the significance of the results. Conclusions and policy implications are provided in Section 4.

2. Methods

2.1. Analytical framework

The broad analytical framework followed in this paper is based on the neoclassical theory of producers' behaviour which analyses the response of cost minimising industries (Berndt and Wood, 1975, 1979; Blackorby and Russell, 1976; Jorgenson, 1991). It accounts for total factor productivity growth (TFPG) to understand the contribution of technological progress in output growth. The nature of technological progress and price induced behavioural responses are then analysed based on estimated parameters of cost functions with a single output and four inputs – capital, labour, energy and material ('*klem*' henceforth). The statistically significant finding of non-separability of primary inputs (Capital, Labour) and intermediate inputs (Energy, Material) in the context of Indian industries (Pradhan and Barik, 1998) justifies use of the *klem* framework and taking into consideration the 'output' instead of 'value added' by the sector. The analytical method in this study is similar to the one adopted by Roy et al. (1999).

2.1.1. Growth accounting

The neoclassical theory of growth suggests that exogenous technological progress leads to enhanced input productivity in the long run (Stiroh, 2001). Growth accounting decomposes output growth into growth in inputs and a residual which is attributed to growth in the productivity of inputs, referred to as the TFPG. The paper considers a single-output (Y) and four-input (*klem*) Translog production function (Eq. (1)). This form is flexible in the sense that it assumes variable elasticity of substitution and does not put forward any binding assumption of Hicks-neutrality unlike the Kendrick and Solow index (Mongia and Sathaye, 1998). The price of output is given exogenously. The production function is assumed to be continuous, twice differentiable, positive, concave and homogenous of degree one – i.e. the production function exhibits constant returns to scale. Also, factors are paid their marginal products.

$$\ln Y_t = \ln A_t + \sum_i \alpha_i \ln X_{it} + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln X_{it} \ln X_{jt}, \quad i, j = k, l, e, m \tag{1}$$

where Y is the output, X_i is the ith input and A represents the index of the state of the technology. Given this production function, TFPG is computed as

$$\ln\left[\frac{A_{t+1}}{A_t}\right] = \ln\left[\frac{Y_{t+1}}{Y_t}\right] - \left[\sum_j \frac{\left(M_{jt+1} + M_{jt}\right)}{2} \times \ln\left(\frac{X_{jt+1}}{X_{jt}}\right)\right] \quad j = k, l, e, m \tag{2}$$

The rate of technological change is represented as the difference between output growth and input growth, weighted by their respective cost shares (M_j). While a positive TFPG implies technological progress, a negative TFPG implies the opposite.

Although productivity growth has been vastly analysed to understand the role of technological progress in the context of Indian industries (both aggregate and sectoral), they mostly aim at exploring the sluggish industrial growth during the 1960s and economic liberalisation during the 1990s (Sawhney, 1967; Krishna and Mehta, 1968; Mahopatra, 1970; Sinha and Sawhney, 1970; Gupta, 1973; Mehta, 1976; Arya, 1981; CSO, 1981; Goldar, 1986; Ahluwlia, 1991; Kumari, 1993; Fujita, 1994; Krishna and Mitra, 1998; Balakrishnan et al., 2000; Srivastava et al., 2001;TSL, 2003; Goldar, 2002, 2004; Goldar and Kumari, 2003; Ulen, 2003; Ray and Pal, 2010). While studies such as Pradhan and Barik (1998), Roy et al. (1999) and Mongia et al. (2001) analyse productivity growth in the context of either polluting or energy intensive industries, none of the studies, to the best of our knowledge, covers the most recent years when significant energy policies were implemented in the country to stimulate energy conservation, mandatory auditing of energy use and reduction in energy intensity.

2.1.2. Estimation of parametric cost function

While TFPG gives an overview of the rate of technological progress reflected in the growth in input productivity, it however does not provide insights regarding the nature of technological progress with respect to energy use, possibility of substitution between energy and non-energy inputs and price induced behavioural responses.

As already mentioned, this paper considers the general form of a single output (Y) and four input (*klem*) production functions:

$$Y = Af\left(X_k, X_l, X_e, X_m, t\right) \tag{3}$$