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Role of Productivity and Technical Change in India's Growth: An Input-Output Approach[1]

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Abstract: The present paper is an attempt to understand the sources of Indian growth experience in post-reform period, namely 1998-2007 for 21 major sectors of the economy. Unlike other studies examining the relative contribution of factor accumulation and productivity growth of the Indian economy, we have used an input-output methodology to examine the sources of India's growth. Our analysis indicates that most of these manufacturing as well as services sectors exhibit large intermediate input factor productivity growth during the years under observations. Our striking finding is that India has not been able to register significant capital productivity gains in the labour intensive sectors even though India has comparative advantage in these sectors being a labour rich economy. A significant finding is that energy intensities of the Indian economy have fallen significantly over the years which no doubt has contributed to emission reduction.

Key words: Total factor productivity, input-output technique, technical change, India

INTRODUCTION

In the aftermath of two decades of economic reforms, Indian economy has been on a higher growth trajectory. India's annual growth rate accelerated from a moderate rate of 3.5% till 1980s to over 7-9% per annum since 2005. The upward growth path has been attributed to extensive reforms in trade as well as industrial policies and supplemented by widespread changes in rules and regulations governing the financial sector. However, the India's reform process has followed a path of gradual transition rather than rapid restructuring like other countries (Ahluwalia, 1994).

Of late, there have been quite a few studies identifying the channels through which the transition to a higher sustainable growth path has been achieved[2]. From these studies, two issues generally emerged-one, the inability of the manufacturing sector to contribute substantially to the overall growth and the service sector led growth momentum to the overall growth in the 1990s (Kumar and Sengupta, 2008; Eichengreen and Gupta, 2010). The lacklustre performance of the manufacturing sector in the post-reform period surely calls for an in depth analysis of the factors responsible for this tardy growth in same. However, most of the studies have done the analysis in respect of manufacturing sector at an aggregated level. Understandably, sector perspective gains significance in the context of major reforms undertaken in several manufacturing sectors in the past two decades and for identifying the factors for slow pace of growth. The only exception being the study by Das *et al*. (2010), which has examined the growth performance of the industrial sectors of the Indian economy at a disaggregated level for the period 1980-2004. Following the KLEMS methodology due to Jorgenson (1987), the study examines the relative contributions of factor accumulation and productivity growth in the different manufacturing sectors of the Indian economy. The present paper is an attempt in the similar vein. However, the present study differs from the study of Das *et al*. (2010) in the following ways. Firstly, it is modelled in the input-output framework and thus cover the entire manufacturing sector. We have not created any dataset for our study but have used official input-output tables of India. By contrast, Das *et al*. (2010) study has to create dataset for their analysis using a variety of methods (including survey data) and variety of sources. Thus, there is a possibility of error in the construction. Secondly, we can capture in our methodology productivity growth arising from intermediate input, which was studied by Das *et al.* (2010) fails to throw light on. Thirdly, the end period of analysis of Das *et al*. (2010)'s study is 2004, whereas ours is 2007. Thus, our study captures more recent changes in

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[1]The views expressed in the paper are those of the authors and not of the institutes to which they belong
[2]See Sivasubramonian (2004), Dholakia (2002), Guha-Khasnobis and Bari (2003), Virmani (2004), Bosworth Collins and Virmani (2007), Kumar and Sengupta (2008), Eichengreen and Gupta (2010)

the Indian economy. Following the analysis of sources of productivity growth at the sectoral level, we also investigate how the technical change in the Indian economy in the post-reform period has contributed to the productivity growth. Indian technical coefficient matrix is also compared with selected BRICS countries to identify the sectors where we need to pull our socks and where we are efficient compared to other BRICS members.

MATERIALS AND METHODS

Sectoral productivity changes in india: Productivity is probably one of the most important measures to judge the performance of an economy. The first theoretically founded research on productivity dates back to Solow (1957) in which he uses a neoclassical formulation to understand sources of productivity growth. Following by Solow (1957), others have alternative methodologies to estimate productivity growth. Among them, Leontief works' on structural change using input-output tables and subsequently use of the input-output methodology to estimate productivity growth can be mentioned. In the input-output literature the rate of technological changes for each activity (or each sector) is defined as difference between the growth rate of gross output and the weighted average growth rate of the various inputs of the activity. This measure is called the growth rate of Total Factor Production (TFP). The TFP measure in the input-output framework works under two assumptions: First, the market for output and factors are is perfect competition and the second, production function is constant returns to scale. By the first assumption, the factors inputs are priced according to their marginal productivities. On the other hand, the second assumption implies that the output has a well-defined growth rate. The input growth rate must be some weighted average of the labor growth and capital growth rates in which both are considered as value shares in national income (Ten Raa, 2004).

In the input-output methodology, gross output is defined as the sum of intermediate inputs and the value added from each industry:

$$X_{j,t} = \sum_i X_{ij,t} + L_{j,t} + K_{j,t}$$

Following Kuroda and Nomura (2004), the rate of TFP growth for sector j can be formulated as:

$$\left(\frac{\dot{T}_j}{T_j}\right)_t = \left(\frac{\dot{X}_j}{X_j}\right) - \sum_i \frac{X_{ij,t}}{X_{j,t}}\left(\frac{\dot{X}_{ij}}{X_{ij}}\right)_t - \frac{L_{j,t}}{X_{j,t}}\left(\frac{\dot{L}_j}{L_j}\right) - \frac{K_{j,t}}{X_{j,t}}\left(\frac{\dot{K}_j}{K_j}\right)_t \quad (1)$$

where, X_j denote the gross output of sector j. likewise X_{ij}, L_j and K_j denote for sector j, respectively, the intermediate input i, the input of labour and input of capital. In Eq. 1 the weights of each input in the monetary term, which are defined by the nominal cost shares of the components in intermediate, labour and capital inputs sum to unity. This equation shows that the sectoral growth rate of Total Factor Productivity (TFP) is defined by the weighted average of the growth rates of partial productivities of all the inputs.

Data analysis: We have used for our analysis 1998-99 and 2006-07 input-output tables for India[3]. The tables have different sectoral classification. However, we have aggregated the tables into 27 main sectors for our analysis. It must be mentioned that the input-output tables are published in current prices. So, for our analysis, we have converted the 2006-07 input-output table at 2006-07 prices to 1998-99 prices.

RESULTS

The results of our analysis are shown in Table 1. During this period, most of the sectors have registered positive output growth, barring wood and allied and real estate and business services sector. What is evident is that most of the manufacturing and services sectors have registered double digit per annum growth during this period. Most of these sectors exhibit large intermediate input factor productivity growth during the years under observations. Notable among them are electrical machinery (41%), coke, refined petroleum etc (26%), radio, television and communication equipments (43%), machinery and equipments (19%), construction (17%) and hotels and restaurants (17%).

Note that barring four sectors namely food products, wood products radio, television, and real estate and other services most of the sectors registered capital productivity gain during this period. The sectors with large productivity gains are coke, refined petroleum etc., post and telecommunications, wholesale and retail trade, transport and storage and machinery and equipment. Note that we have not been able to register significant capital productivity gains in the labour intensive sectors like food products, textile products etc, even though India has comparative advantage in these sectors being a labour rich economy.

By contrast, labour productivity is negative in as many as 15 of our sectors. As Table 1 shows, there is falling labour productivity in many of the labour intensive sectors like agriculture and allied, mining and quarrying, food products, wood products, pulp and paper. This is surprising since, India being labour rich country has comparative advantage in labour intensive goods. We find that significant labour productivity gains are registered in

[3]The sources of the input-output tables are Central Statistical Organization of Government of India

Table 1: Components of productivity growths per annum for the period 1998-99 to 2006-07

Sector	Growth percent per annum for the period 1998-99 and 2006-07				
	Output	Intermediate input factor productivity	Labour productivity	Capital productivity	Total factor productivity
Agriculture, hunting, forestry and fishing	5.38	2.67	-0.22	3.04	-0.11
Mining and quarrying	5.92	0.00	-2.23	4.32	3.84
Food products, beverages and tobacco	4.42	4.89	-0.30	-0.29	0.12
Textiles, textile products, leather and footwear	7.22	6.71	-0.12	0.38	0.25
Wood and products of wood and cork	-4.43	-1.38	-1.48	-1.49	-0.07
Pulp, paper, paper products, printing and publishing	6.69	5.41	-0.44	1.44	0.29
Coke, refined petroleum products and nuclear fuel	43.23	25.67	0.07	14.57	2.91
Chemicals and chemical products	10.91	8.36	0.19	1.87	0.48
Rubber and plastics products	15.31	13.08	-0.35	2.02	0.57
Other non-metallic mineral products	12.51	8.02	-0.45	4.27	0.66
Basic metals	17.87	13.74	-0.44	3.71	0.87
Fabricated metal products except machinery and equipment	15.22	11.46	-0.34	3.28	0.83
Machinery and equipment	27.91	19.99	0.66	5.05	2.21
Electrical machinery and apparatus	49.33	41.43	0.58	3.40	3.92
Radio, television and communication equipment	45.38	43.24	-0.36	-1.07	3.57
Manufacturing of Transport equipments	18.58	14.50	-0.18	2.69	1.57
Other manufacturing	6.60	4.82	-1.35	2.71	0.43
Electricity, gas and water supply	4.57	3.79	0.30	0.39	0.09
Construction	18.84	16.59	-1.50	2.93	0.82
Wholesale and retail trade	10.33	1.55	1.40	7.17	0.21
Hotels and restaurants	23.50	17.23	1.41	4.43	0.43
Transport and storage	23.97	9.05	6.09	6.81	2.01
Post and telecommunications	30.23	6.56	6.60	16.80	0.28
Finance and insurance	11.70	2.47	1.90	7.16	0.16
Research and development	4.67	0.47	0.45	3.79	-0.03
Real estate and other business activities	-7.46	-0.30	-6.88	-2.58	2.30
Other services	11.35	-1.13	4.54	7.33	0.61

the following sectors: Other services (5%), post and communications (7%), transport and storage (6%), finance and insurance (2%). By and large, we find that labour productivity growths in manufacturing sectors are generally less than 1% per annum during this period.

With regard to total factor productivity growth, we find the highest growth is registered in the sector electrical machinery etc., (4%) followed by radio, television and communication equipments (4%), mining and quarrying (4%), coke, petroleum etc (3%), machinery and equipment (2%). There are only three sectors which show negative total factor productivity growth. Notable among them are agriculture, research and development.

Technical changes in indian economy: In the earlier section, we have seen that India has achieved significant intermediate input factor productivity growth in recent years. Naturally question arises what are the sources of its gain. In this section, we have attempted to answer the same.

The input-output table provides technology matrix where each column represents different amounts of the various commodities, shown in the rows, required to produce one unit of the commodity represented by the column. A change in the elements of a column vector of the technology matrix over an interval of time represents technological changes in the production of the commodity. Technological changes in the input-consuming commodity production allow changes in inputs and technological changes in some or all of the input commodities allow substitution or other kinds of changes in the input-vector constituents or in their relative weights. Further, a technological change brings about changes in relative prices and thus we might argue that innovation is about bringing about changes in relative prices which reflect the bargaining strength of respective producers as captured by the changes in the column vectors of the input-output matrix in the post-innovation phase.

In this section we have analyzed some sectors of the Indian economy by observing changes in a few select important inputs, such as energy, feedstock including agricultural inputs, machine tools and other machineries. The analysis is done first by analyzing the technical changes of India's input-output table over time. In the following section, we follow the analysis by comparing the same vis-α-vis other selected countries.

We have used three input-output tables of India published by Central Statistical Organization (Government of India, 2008). The input-output tables are following years, 1998-99, 2003-04 and 2006-07. As the sectors of these three input-output tables are different, we have aggregated the three input-output tables into common 21 sectors for comparison purposes.

The data in Table 2 indicate that input cost on agriculture allied activities in food products, beverages

Table 2: Technical Changes in Indian Economy, 1998-99 and 2006-07

	Food products, beverages and tobacco			Textiles, textile products, leather and footwear			Pulp, paper, paper products, printing and publishing			Coke, refined petroleum products and nuclear fuel		
Input use per unit of output	1998-99	2003-04	2006-07	1998-99	2003-04	2006-07	1998-99	2003-04	2006-07	1998-99	2003-04	2006-07
Agriculture, hunting, forestry and fishing	0.411	0.372	0.347	0.120	0.097	0.091	0.033	0.051	0.047	0.001	0.000	0.000
Mining and quarrying	0.005	0.001	0.001	0.004	0.002	0.001	0.032	0.012	0.011	0.611	0.611	0.646
Food products, beverages and tobacco	0.092	0.117	0.125	0.001	0.000	0.001	0.001	0.002	0.002	0.000	0.000	0.000
Textiles, textile products, leather and footwear	0.004	0.003	0.003	0.187	0.203	0.204	0.011	0.004	0.004	0.000	0.000	0.000
Wood and products of wood and cork	0.006	0.006	0.005	0.002	0.003	0.003	0.020	0.014	0.016	0.001	0.000	0.000
Pulp, paper, paper products, printing and publishing	0.011	0.014	0.013	0.004	0.006	0.006	0.239	0.266	0.259	0.000	0.000	0.000
Coke, refined petroleum products and nuclear fuel	0.007	0.011	0.012	0.004	0.015	0.016	0.004	0.016	0.017	0.011	0.037	0.035
Chemicals and chemical products	0.024	0.023	0.026	0.071	0.068	0.070	0.073	0.075	0.075	0.015	0.013	0.018
Rubber and plastics products	0.006	0.011	0.011	0.005	0.010	0.011	0.002	0.011	0.011	0.000	0.001	0.001
Other non-metallic mineral products	0.005	0.002	0.000	0.001	0.000	0.000	0.003	0.001	0.001	0.000	0.000	0.000
Basic metals	0.003	0.000	0.000	0.003	0.001	0.001	0.011	0.003	0.004	0.001	0.000	0.000
Fabricated metal products except machinery and equipment	0.005	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.000	0.000
Machinery and equipment	0.004	0.008	0.008	0.006	0.019	0.020	0.003	0.003	0.003	0.001	0.001	0.001
Electrical machinery and apparatus	0.001	0.000	0.000	0.002	0.001	0.001	0.002	0.004	0.004	0.001	0.000	0.000
Manufacturing of transport equipments	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Manufacturing	0.001	0.001	0.000	0.004	0.004	0.006	0.006	0.004	0.006	0.001	0.000	0.001
Electricity, gas and water supply	0.011	0.016	0.008	0.070	0.038	0.029	0.047	0.034	0.027	0.026	0.015	0.012
Construction	0.003	0.009	0.010	0.002	0.012	0.015	0.002	0.011	0.011	0.001	0.001	0.007
Wholesale and retail trade	0.088	0.129	0.135	0.091	0.094	0.102	0.060	0.051	0.053	0.046	0.011	0.010
Transport and storage	0.046	0.051	0.055	0.063	0.077	0.082	0.054	0.070	0.073	0.036	0.021	0.023
Other services	0.066	0.042	0.039	0.068	0.068	0.069	0.054	0.038	0.038	0.047	0.028	0.024

	Chemicals and chemical products			Rubber and plastics products			Basic metals			Other manufacturing		
Input use per unit of output	1998-99	2003-04	2006-07	1998-99	2003-04	2006-07	1998-99	2003-04	2006-07	1998-99	2003-04	2006-07
Agriculture, hunting, forestry and fishing	0.044	0.033	0.023	0.050	0.052	0.051	0.000	0.000	0.000	0.009	0.002	0.004
Mining and quarrying	0.050	0.017	0.017	0.011	0.007	0.008	0.090	0.120	0.118	0.077	0.068	0.074
Food products, beverages, tobacco	0.003	0.011	0.013	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Textiles, textile products, leather and footwear	0.010	0.006	0.006	0.041	0.018	0.017	0.003	0.001	0.000	0.013	0.003	0.004
Wood and products of wood and cork Pulp,	0.004	0.008	0.006	0.004	0.003	0.003	0.002	0.001	0.001	0.009	0.004	0.006
paper, paper products, printing and publishing	0.023	0.007	0.007	0.008	0.008	0.008	0.001	0.001	0.001	0.005	0.005	0.007
Coke, refined petroleum products and nuclear fuel	0.007	0.045	0.047	0.003	0.017	0.019	0.035	0.026	0.027	0.011	0.018	0.024
Chemicals and chemical products	0.284	0.321	0.337	0.275	0.290	0.300	0.013	0.014	0.015	0.041	0.016	0.026
Rubber and plastics products	0.010	0.015	0.015	0.041	0.098	0.109	0.001	0.003	0.003	0.013	0.016	0.023
Other non-metallic mineral products	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.005	0.008
Basic metals	0.006	0.006	0.006	0.013	0.021	0.022	0.263	0.239	0.262	0.294	0.021	0.032
Fabricated metal products except machinery and equipment	0.004	0.001	0.001	0.004	0.006	0.007	0.036	0.022	0.029	0.005	0.006	0.012
Machinery and equipment	0.003	0.006	0.006	0.002	0.010	0.011	0.003	0.007	0.009	0.003	0.008	0.016
Electrical machinery and apparatus	0.001	0.002	0.002	0.001	0.005	0.006	0.001	0.004	0.007	0.004	0.015	0.025
Manufacturing of transport equipments	0.000	0.000	0.000	0.000	0.004	0.006	0.001	0.004	0.002	0.001	0.001	0.001
Other Manufacturing	0.008	0.005	0.007	0.006	0.003	0.005	0.005	0.002	0.002	0.011	0.171	0.192
Electricity, gas and water supply	0.048	0.047	0.040	0.049	0.032	0.025	0.049	0.069	0.060	0.037	0.032	0.030
Construction	0.002	0.005	0.008	0.002	0.003	0.004	0.001	0.002	0.005	0.002	0.005	0.007
Wholesale and retail trade	0.064	0.062	0.059	0.072	0.057	0.056	0.080	0.095	0.084	0.057	0.034	0.038
Transport and storage	0.042	0.047	0.045	0.045	0.045	0.043	0.057	0.062	0.062	0.043	0.061	0.061
Other services	0.049	0.037	0.036	0.063	0.043	0.043	0.059	0.033	0.035	0.048	0.066	0.080

	Machinery and equipment			Electrical machinery and apparatus			Manufacturing of transport equipments		
Input use per unit of output	1998-99	2003-04	2006-07	1998-99	2003-04	2006-07	1998-99	2003-04	2006-07
Agriculture, hunting, forestry and fishing	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.000	0.000
Mining and quarrying	0.004	0.006	0.007	0.004	0.006	0.006	0.001	0.003	0.007
Food products, beverages and tobacco	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Textiles, textile products, leather and footwear	0.005	0.003	0.002	0.003	0.005	0.005	0.002	0.002	0.005
Wood and products of wood and cork	0.010	0.006	0.006	0.011	0.004	0.004	0.008	0.002	0.002
Pulp, paper, paper products, printing and publishing	0.003	0.004	0.004	0.005	0.006	0.006	0.003	0.002	0.002
Coke, refined petroleum products and nuclear fuel	0.011	0.009	0.010	0.009	0.013	0.011	0.010	0.007	0.010
Chemicals and chemical products	0.018	0.015	0.016	0.040	0.040	0.040	0.033	0.022	0.024
Rubber and plastics products	0.010	0.012	0.012	0.023	0.018	0.018	0.026	0.020	0.023
Other non-metallic mineral products	0.002	0.002	0.003	0.004	0.006	0.006	0.002	0.002	0.002
Basic metals	0.243	0.236	0.247	0.279	0.229	0.239	0.183	0.105	0.117
Fabricated metal products except machinery and equipment	0.014	0.038	0.043	0.005	0.046	0.052	0.012	0.012	0.014
Machinery and equipment	0.112	0.093	0.098	0.007	0.036	0.046	0.013	0.074	0.092
Electrical machinery and apparatus	0.011	0.039	0.043	0.080	0.127	0.149	0.013	0.035	0.045
Manufacturing of transport equipments	0.001	0.005	0.005	0.001	0.001	0.002	0.080	0.101	0.105
Other Manufacturing	0.015	0.010	0.014	0.024	0.012	0.016	0.033	0.007	0.020
Electricity, gas and water supply	0.037	0.025	0.015	0.034	0.023	0.014	0.055	0.031	0.027
Construction	0.003	0.021	0.024	0.002	0.012	0.015	0.002	0.004	0.010
Wholesale and retail trade	0.053	0.036	0.031	0.053	0.038	0.035	0.054	0.042	0.043
Transport and storage	0.027	0.031	0.025	0.022	0.036	0.033	0.026	0.029	0.029
Other services	0.095	0.087	0.086	0.085	0.087	0.086	0.119	0.116	0.128

sector has progressively fallen over the years. By contrast, input value per unit value of output has consistently increased in following sectors: food products, beverages and tobacco, fuel related sector (Sl. No. 7), machinery, transport and storage and wholesale and retail trade. The rise in share of cost on machinery is expected as food products sector is increasingly being capitalized in view of the modernization of the sector. The surge in fuel price is on the expected line in view of the global surge in oil price and so in the transport and storage. However, the surge in input cost on wholesale and retail trade does not augur well. It probably suggests the absence of competitive forces in this sector.

By and large, similar trend is observed in textile, textile products and leather and footwear sector. A rise in per unit input cost on transport and storage, wholesale and retail trade, fuel related sector, machinery and on textile, textile related activities. The modernization of the textile sector implies that per unit input cost on machinery and transport equipment has trebled up between the years 1998-99 and 2006-07. During this period, input cost on electricity etc has declined by more than fifty percent. This probably suggests that the industry could save on electricity bill by upgrading the plants.

With regard to pulp, paper, paper products etc sector, input value per unit value of output has declined in few of the sectors like electricity, wholesale and retail trade. There has not been appreciable change in most of the sectors. The major rise in input cost per unit of output has occurred for fuel sector and transport related sector.

Table 2 suggests that input cost on chemicals and chemical products for per unit value of output of coke, refined petroleum products has risen for the period under observation. By and large, the sector has to decrease in most of the other sectors. However, the sector has not machinery during these years, as the input cost on same indicates no perceptible change.

With regard to chemical and chemical products sector, there has not been any significant change between the 2003-04 and 2006-07. The point to note is that input value per unit value of output in this sector has increased for construction activities since 1998-99.

Table 2 suggests that input cost on fuel etc, chemicals etc, rubber and plastic products, has increased substantially in respect of rubber and plastic products sector. In this sector, there has marginal rise in input cost on all categories of capital goods. On the other hand, this sector has been able to reduce input cost on other services and wholesale and retail trade.

With regard to basic metals sector, input cost per unit of output has increased in respect of mining and quarrying from 0.09 in 1998-99 to 0.12 in 2003-04 to 0.118 in 2006-07. The other component of rise in input cost is electricity etc. There has not been any major change in other components of input cost. Also, there has been marginal increase in input cost of machinery indicating investment in new technology in this sector.

With regard to other manufacturing sector, we find increased input cost on machinery items. There has been marginal saving in respect of expenditure of electricity etc., However, input cost on other services per unit value of output in this sector has increased between the years 2003-04 and 2006-07. The sector has also been able to economize cost on chemical related item.

Between the years 2003-04 and 2006-07, there is no significant change in input cost on various components per unit output of machinery and equipment sector. There is marginal rise in input cost on electrical machinery as well as on construction per unit of output. On the other hand, we find from data in Table 2 that input cost on account of machinery and equipment as well as wholesale and retail trade has declined.

The input cost structure per unit output of electrical machinery etc. sector suggests that this sector has been able to cut down progressively (almost by 50%) its cost on electricity etc between the years 1998-99 and 2006-07. This sector seems to be in a spate of technological upgradation: input cost on machinery and equipment has increased from 0.007 in 1998-99 and 0.046 in 2006-07 while the same on electrical machinery has risen from 0.075 in 1998-99 to 0.122 in 2003-04.

By and large, a similar trend is observed in case of manufacturing of transport equipments. Over the years, there has been a cut down in input cost on electricity etc concomitant with rising expenditure on different categories of machinery.

Energy intensities of indian economy: structural changes, 2003-04 to 2006-07: In the last section, we have seen some evidences that Indian economy has become energy efficient over the years. However, we have not quantified the change. In this section, we attempt to do the same using input-output modeling framework.

Let, A_{0304} and A_{0607} be India's input-output coefficient table (technology matrix) for the years 2003-04 and 2006-7. Let I be the identity matrix of the same order. Let TFU_{0607} and TIU_{0607} be the total final use and intermediate use vectors, respectively for the economy in the year 2006-07. Then actual intermediate use in 2006-07 to produce the observed output is given by the Eq. 2:

$$TIU_{0607} = (I-A_{0607})^{-1} TFU_{0607} \quad (2)$$

If there has not been technical change over the years, ne can use technical coefficient matrix of 2003-04 to estimate the likely demand of intermediate good to produce the observed output of 2006-07 by the equation as given below:

$$\overline{TIU_{0607}} = (I - A_{0304})^{-1} TFU_{0607} \quad (3)$$

where, $\overline{TIU_{0607}}$ is the estimated demand of intermediate good using 2003-04 technology matrix. Subtracting

TIU_{0607} from $\overline{TIU_{0607}}$, one can estimate the saving on account of any intermediate use. If in the above two input-output tables, there are n types of energy sources (commercial as well as primary), then energy saving on account of ith type of energy:

$$\overline{TIU_{i0607}} - TIU_{i0607} \quad (4)$$

So, total energy saving in the economy is given as follows:

$$\sum_0^n \overline{TIU_{i0607}} - \sum_0^n TIU_{i0607} \quad (5)$$

For the analysis, we have considered the following forms of primary and commercial energy namely, coal, petroleum, natural gas, biomass and electricity. The source of our input-output tables Pal *et al*. (2012) which are modification of India's input-output table with more disaggregated energy sector. The analysis of the results is shown in Table 3. As this table shows, energy intensities of Indian economy have declined by more than 14% between the years 2003-04 and 2006-07. This is significantly big change for growing economy. Note that, this is true irrespective of the type of energy except petroleum. The biggest gain in the energy efficiency has been in the area of electricity followed by coal and biomass.

Inter-country analysis of input-output coefficient: Input-Output Table of a country represents the input mix of producing a commodity in value term. If a firm used better technology, it would probably use less input to produce per unit of output. Of course there is a caveat. Since, IO coefficients are calculated in value term, a significantly high input price may show increased input cost even when input use (in quantity) may decline due to use of better technology. However, such outlier is generally believed to be rare. If there are two input-output tables, one which uses less input to produce per unit of output would imply more efficient use of resources. In other words, the same technology mix would be more productive. Productivity improvement usually comes from innovation. So, inter-country comparison of IO tables, viz. India versus others may give idea whether India is resourcing to innovating technology to improve productivity in production process. Our focus of analysis is manufacturing sector. The countries of comparison are China and Brazil, the two of the BRIC countries, which are generally compared with India in discussion. The time-frame of India's IO table is 2006-07 discussed earlier while the same for China are Brazil are of 2006, downloaded from OCED websites. The comparison is restricted to 7 major manufacturing sectors, namely, (a) food products, beverages and tobacco, (b) textile, leather and their products, (c) chemicals and chemical products, (d) other manufacturing, (e) machinery and equipments (f) electrical machinery and (g) manufacturing of transport equipments. The relevant data id complied is Table 4.

The first observation is that in all these seven sectors, per unit cost on electricity, gas and water supply is highest in India in comparison to China and Brazil. Incidentally in most of these sectors, per unit cost of same in China is lowest. If these costs can be reduced, India manufacturing would be more competitive in the global arena. Since, this holds across diverse sectors, the cause is probably inefficiency in the electricity, gas and water supply sector. Thus, innovation is needed in this cost to make this sector more efficient.

The second observation is that per unit cost on fuel (represented by coke, refined petroleum products, etc.) is generally higher in India than in China or Brazil. Incidentally, China also depends on imported fuel like that of India. So, it probably suggests that India's fuel sector is inefficient as compared to China. Innovation is needed to reduce cost of fuel.

The third observation is that transport and storage cost is on the higher side relative to China or Brazil. Transport and storage sector in India is still at the nascent stage of development. Only in recent times, investment has been taking place to develop efficient transports and storage system in India. It is interesting to know that China is way ahead in reducing per unit cost in this sector through innovation. This is an important factor why China is export power-house in today's world.

The fourth observation is that per unit cost on whole and retail trade for food products, beverages and tobacco cost stands at 0.13 whereas the same in Brazil and China are, respectively 0.06 and 0.03 only. This is not a good

Table 3: Changes in energy intensities (Rs Lakhs), 2003-04 and 2006-07

Energy type	Actual energy mix (2006-07)	Share	Estimated energy mix (2006-07)	Share	Change in intermediate use (%)
Coal	5724427	11.31	6709595	11.60	14.68
Petroleum	26608415	52.58	26585664	45.94	-0.09
Biomass	1230412	2.43	1515345	2.62	18.80
Natural Gas	1572761	3.11	1741909	3.01	9.71
Electricity	15468393	30.57	21312446	36.83	27.42
Total	50604408		57864959		14.35

Source: Authors' estimates

Table 4: Technical coefficient of India's input-output: A cross-country comparison

	Food products, beverages and tobacco			Textiles, textile products, leather and footwear			Chemicals and chemical products			Other manufacturing		
Sectors	India	Brazil	China	India	Brazil	China	India	Brazil	China	India	Brazil	China
Agriculture, hunting, forestry and fishing	0.37	0.35	0.34	0.10	0.03	0.11	0.03	0.01	0.04	0.00	0.00	0.05
Mining and quarrying	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.05	0.07	0.00	0.01
Food products, beverages and tobacco	0.12	0.16	0.15	0.00	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00
Textiles, textile products, leather and footwear	0.00	0.00	0.00	0.20	0.26	0.33	0.01	0.00	0.01	0.00	0.02	0.03
Wood, paper and their products	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.09	0.03
Coke, refined petroleum products and nuclear fuel	0.01	0.01	0.00	0.02	0.01	0.00	0.04	0.07	0.04	0.02	0.01	0.01
Chemicals, rubber and their products	0.03	0.02	0.03	0.08	0.05	0.08	0.34	0.20	0.33	0.03	0.09	0.09
Other non-metallic mineral products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
Metals and metal products	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.07	0.09
Machinery and equipment	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Electrical machinery and apparatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.07
Manufacturing of transport equipments	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.02	0.03
Electricity, gas and water supply	0.02	0.02	0.01	0.04	0.03	0.02	0.05	0.04	0.06	0.03	0.02	0.01
Wholesale and retail trade; repairs	0.13	0.06	0.03	0.09	0.07	0.03	0.06	0.05	0.03	0.03	0.05	0.03
Transport and storage	0.05	0.05	0.03	0.08	0.02	0.02	0.05	0.03	0.03	0.06	0.02	0.02
Other services	0.05	0.04	0.04	0.08	0.04	0.06	0.04	0.08	0.05	0.07	0.03	0.05

	Machinery and equipment			Electrical machinery and apparatus			Manufacturing of transport equipments		
Sectors	India	Brazil	China	India	Brazil	China	India	Brazil	China
Agriculture, hunting, forestry and fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01
Food products, beverages and tobacco	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textiles, textile products, leather and footwear	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Wood, paper and their products	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00
Coke, refined petroleum products and nuclear fuel	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01
Chemicals, rubber and their products	0.03	0.05	0.06	0.06	0.06	0.10	0.04	0.07	0.07
Other non-metallic mineral products	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00
Metals and metal products	0.27	0.27	0.23	0.28	0.09	0.11	0.12	0.13	0.13
Machinery and equipment	0.09	0.03	0.12	0.04	0.01	0.02	0.07	0.02	0.06
Electrical machinery and apparatus	0.04	0.03	0.05	0.13	0.11	0.25	0.04	0.02	0.02
Manufacturing of transport equipments	0.00	0.01	0.01	0.00	0.01	0.00	0.10	0.22	0.26
Other manufacturing	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00
Electricity, gas and water supply	0.02	0.02	0.03	0.02	0.02	0.01	0.03	0.02	0.02
Wholesale and retail trade; repairs	0.04	0.04	0.03	0.04	0.05	0.03	0.04	0.07	0.03
Transport and storage	0.03	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.02
Other services	0.11	0.07	0.06	0.10	0.08	0.06	0.12	0.07	0.06

Source: The input-output tables are drawn from OECD website

sign. This probably indicates either absence of competitive forces in whole and retail trade sector or the sector is highly inefficient.

CONCLUSION

This study makes a modest attempt to apply input-output methodology to understand the structural changes in Indian economy in recent years. Our observations cover the period 1998-99 to 2006-07, the latest year for which India's input-output table is published. The following observations can be made from our analysis:

- Most of these manufacturing as well as services sectors exhibit large intermediate input factor productivity growth during the years under observations. Notable among them are electrical machinery, coke, refined petroleum etc., radio, television and communication equipments, machinery and equipments, construction and hotels and restaurants
- Barring few sectors, most of these sectors registered capital productivity gain during this period
- India has not been able to register significant capital productivity gains in the labour intensive sectors like food products, textile products etc, even though India has comparative advantage in these sectors being a labour rich economy. This is in line with the finding form other studies
- We find that there is falling labour productivity in many of the labour intensive sectors like agriculture and allied, mining and quarrying, food products, wood products, pulp and paper
- We find that the highest total factor productivity growth is registered in the sector electrical machinery etc followed by radio, television and communication equipments, mining and quarrying, coke, petroleum etc., machinery and equipment
- Our analysis of technical coefficient of India's input-output table suggests that input cost on agriculture allied activities in food products, beverages sector has progressively fallen over the years
- We find that input costs on machinery related items in many of our sector are increasing which suggest that economy is on a path of modernization. This has also helped in reducing energy cost on production (Das *et al.*, 2010)

- Energy intensities of the Indian economy have fallen significantly between the years 2003-04 and 2006-07, the period of our observation
- A comparison of input-output tables of India with that of Brazil and China indicates that per unit cost on electricity, gas and water supply as well as fuel is highest in India in comparison to China and Brazil at our level of sectoral aggregation
- The transport and storage cost in India is on the higher side relative to China or Brazil. The same is true for wholesale and retail trade sector. The absence of competitive forces as well as innovation in these sectors adds to higher cost in India

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