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Abstract

The extent to which Indian organized manufacturing performance changed after the Economic Reform of 1991 has been an important question among empirical analysts. Using input-output data from the Annual Survey of Industries for the period 1970-71 through 2007-08, this paper compares the pre- and post-reform performances of Indian manufacturing in terms of total factor productivity growth. We use the non-parametric method of Data Envelopment Analysis to construct the Biennial Malmquist Index of total factor productivity for Indian states to determine if the states have experienced improvement in manufacturing productivity during the post-reform years. Results show that at the all-India level, total factor productivity growth rate in manufacturing is higher during the post-reform period. Although the majority of states experienced accelerated productivity growth, some states experienced declines in productivity after the reforms. However, the regional variation in the rates of productivity change diminished during the post-reform years. A non-parametric decomposition of the Malmquist productivity index into its components shows that both before and after the reforms technological progress was the most important component of the manufacturing growth process

JEL Classification: C14, C61, D24, L60, O53

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Economic Reforms and Total Factor Productivity Growth of Indian Manufacturing: An Inter-State Analysis

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1. Introduction

It has been over six decades since India began the process of planned economic development with a clear emphasis on industrialization. The industrial policies, which remained more or less stagnant from post-war independence to 1980, assigned a pivotal role to the public sector operating directly under state control and central planning. In addition to delays, high administrative costs, and rent-seeking opportunities associated with the system of obscure industrial regulation and licensing, the incentives generated by the system were detrimental to economic efficiency and productivity (Srivastava (1996)). Inward looking trade policies coupled with import substitution efforts heavily protected domestic industries and created a highly non-competitive and inefficient industrial structure. By the end of 1970s, the manufacturing sector, a major segment of Indian industry, suffered from high production costs, sub-standard product quality, and lack of export competitiveness. Unsurprisingly, the regulatory framework of the pre-1980s, among other factors, has been held responsible for the low growth rate of output and productivity in Indian manufacturing (Ahluwalia (1991)). Moreover, a corrupt bureaucratic system, diverting valuable resources from more efficient uses became a major stumbling block to sustainable growth of this sector. Meanwhile, the success of post-Mao market-oriented reforms in China, the collapse of the Soviet Union, and transition of Eastern Europe from collectivism to market capitalism challenged the validity of India's socialist development strategy and called for necessary modification of industrial policy.

The economic reform process of 1991 was triggered by a severe foreign exchange crisis. Introduced gradually, these reforms led to a significant reduction in the number of industries reserved for the public sector. Privatization of a large segment of the economy, elimination of licensing requirements for industrial investment in most industries, and amendment of the Monopolies and Restrictive Trade Practices (MRTP) Act to remove barriers to entry and capacity expansion by large industrial houses prompted a more flexible and liberalized industrial structure. These new industrial policies were supplemented by trade liberalization measures. These measures included drastic depreciation of the Indian currency, removal of licensing and other physical controls on imports of capital and consumer goods, widening the scope of foreign direct investment, and lowering tariffs.

Historically, a major component of economic development and structural transformation has been the rapid growth of industrial productivity. Cost and price competitiveness of firms and industries depends heavily on productivity. This, in turn, determines the market share of the exports of these firms and industries in global markets. An important rationale for the economic reforms of 1991 was to deliberately shift toward an open economy in order to improve efficiency and productivity. Opening up the Indian economy to the international market led to the rapid emergence of a highly competitive environment. Indian manufacturing firms, which were heavily protected from foreign competition before the reforms, became subject to both internal and foreign competition. It was generally expected that a liberalized industrial policy regime, complemented by outward-oriented trade policies, and financial reforms, would automatically enhance the efficiency and productivity of Indian manufacturing. The main objective of this paper is to compare the pre- and post-reform performance of Indian organized[1] manufacturing to assess the extent to which these objectives have been fulfilled.

Performance of the Indian manufacturing sector during the post-reform years has been a subject of a debate among empirical analysts over the last two decades. A large body of literature has assessed the performance of Indian manufacturing industries in terms of total factor productivity growth. However, there is no clear consensus on how the aggregate manufacturing sector has actually performed in the post-reform years. The existing literature in this area can be classified into two categories. One set of studies shows that productivity improved in the manufacturing sector in the post-reform years (Trivedi, Prakash, and Sinate (2000); Unel (2003); Topalova (2004); and Milner, Vencappa, and Wright (2007)). But another set of studies finds evidence of decline in total factor productivity in the post-reform period (Goldar and Kumari (2003); Das (2004); Goldar (2004); Trivedi (2004); and Das and Kalita (2009)).

The economic reforms of 1991 left much greater scope for state-level initiatives to improve the performance of the manufacturing in a state by reducing the degree of central government control in many areas. While reforms were implemented effectively at the central government level, there has been considerable variation in the speed and extent of reforms across states (Mukherjee and Ray (2005)). Even though there exists a large body of literature examining manufacturing productivity growth at the national level, studies dealing with productivity growth at regional levels have been rather few. Aghion, Burgess, Redding, and Zilibotti (2003) argue that the states with a better investment climate experienced higher productivity growth in manufacturing. Veeramani and Goldar (2004) investigates the influence of institutional and political factors on the levels of total factor productivity and reveals that the states fostering a better investment climate grew faster than others during the post-reform years. Ray (2002), Trivedi (2004), Kumar (2004), and Trivedi, Lakshmanan, Jain, and Gupta (2011) also find strong evidence of an interstate difference in total factor productivity growth in the post-reform period[2].

Given the regional heterogeneity of India's vast economy, state level performance of the manufacturing sector deserves much closer attention than it has received. It is particularly important to study the variation in performance across states to identify those which are mostly responsible for driving the outcomes at the national level. With this objective, this paper evaluates the pre- and post-reform performance of Indian manufacturing at the regional level in terms of changes in total factor productivity over time.

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[1] The organized manufacturing sector includes all factories covered under sections 2m (i) and 2m (ii) of the 1948 Indian Factories Act (IFA) which refers to factories employing 10 or more workers and using power, or those employing 20 or more workers but not using power on any day of the preceding 12 months.

[2] Mitra and Ural (2008) examine the impact of reforms on manufacturing productivity. However, their study uses labor productivity as a measure of manufacturing productivity.

With the exception of Trivedi et al. (2011), studies exploring regional variation in productivity growth in India's manufacturing sector only cover the period up to 2001-02. Because the reform process was initially slow and took time to be properly put into operation, it is important to extend the sample period to capture the full effect of the reform on manufacturing performance. Therefore, using state level data over an extended sample period, spanning 1970-71 to 2007-08, this study examines whether the manufacturing sector in different Indian states has experienced faster growth in total factor productivity during the post-reform period.

Most of the studies estimating total factor productivity growth in Indian manufacturing adopt either growth accounting or econometric techniques. However, these methodologies implicitly assume that a firm is operating on its production frontier. Total factor productivity change, or the Solow residual thus obtained, is synonymous with the index of pure technical change. Such an interpretation rests on several restrictive assumptions, including constant returns to scale and marginal cost pricing (Hulten (2001)). Besides, the Solow residual is not pure technical change. It is a residual and can include scale effect and change in technical efficiency. It is not that these alternative measures do not capture these other sources of productivity change but it is that they do not split them out. Decomposition of the change in productivity into its likely sources is important because it can identify the other factors responsible for productivity changes over time. Thus, along with estimating changes in productivity, this study also provides estimates of different components of total factor productivity change. Departing from the common practice in the literature, the Malmquist Index of total factor productivity for the manufacturing sector in each of the major Indian states is constructed using the non-parametric method of Data Envelopment Analysis (DEA). The Malmquist Productivity Index, introduced by Caves, Christensen, and Diewert (1982), and operationalized by Färe, Grosskopf, Lindgren, and Roos (1992) (FGLR) to measure productivity change, is a normative measure based on a reference technology underlying observed input output data. In this study, the DEA measures of the Malmquist Index of productivity, the Solow residuals or total factor productivity change do not require the strong assumptions (mentioned above) about the production technology and can be decomposed into relevant components.

The empirical results show that, at the national level, post-reform estimates of total factor productivity growth exceed the pre-reform estimates. However, some states that registered improvement in total factor productivity in the pre-reform period (between 1970-71 and 1990-91) experienced a slowdown in productivity growth, or even a decline in productivity, after the reforms. In addition, leading industrial states such as Maharashtra and Tamilnadu grew at a slower rate than "lagging states" such as Assam and Orissa. The decomposition of the Malmquist productivity index shows that both before and after the reforms, technological progress was the most important component of the manufacturing growth process in different Indian states.

The rest of the paper is organized as follows. Section 2 presents the theoretical background for measurement and decomposition of the total factor productivity change into three components: technical change, technical efficiency change, and scale efficiency change. The non-parametric technique used to construct and decompose the Malmquist Index of total factor productivity is briefly discussed in section 3. Section 4 describes the data and explains how the different components of the Malmquist productivity index have been measured using DEA. Empirical findings are reported in section 5 and section 6 concludes.

2. Measurement and Decomposition of the Total Factor Productivity Change

Analysis of productivity change can use either a parametric method or the non-parametric index number approach. Theoretically productivity of a firm is measured by the quantity of output produced per unit of input. In the single input, single output case it is simply the average productivity of the input - measured as a ratio of the firm's output and input quantities - is easy to compute. In most situations, however, we encounter multiple inputs and outputs, in which case some economically meaningful aggregation of inputs and outputs is necessary.[3] Further Total factor productivity change can be decomposed into three factors showing technical change, efficiency change, and returns to scale effects.

The parametric approach – primal or dual – involves an explicit specification of the production or cost function, which is then estimated by appropriate econometric techniques (see Denny, Fuss, and Waverman (1981), Nishimizu and Page (1982), and Bauer (1990) for details) to measure and decomposes the productivity change of a production unit.

In this paper we adopt the non-parametric (primal) approach to measure total factor productivity change. In the non-parametric approach, productivity index is used to measure productivity change. Figure 1 illustrates the measurement of productivity index and decomposition of it into above mentioned three components for a single input-single output case.

If in period t a firm produces output Y_0^t (point A) from input X_0^t, its productivity is

$$\pi_t = \frac{Y_0^t}{X_0^t} = \left(\frac{AX_0^t}{OX_0^t}\right). \qquad (1)$$

Similarly, in period $t+1$, when output Y_0^{t+1} (point B) is produced from input X_0^{t+1}, the productivity is

$$\pi_{t+1} = \frac{Y_0^{t+1}}{X_0^{t+1}} = \left(\frac{BX_0^{t+1}}{OX_0^{t+1}}\right) \quad . \qquad (2)$$

The productivity change in period $t+1$, with period t as the base is measured by

$$\pi_{t+1|t} = \frac{\pi_{t+1}}{\pi_t} = \frac{\left(\frac{BX_0^{t+1}}{OX_0^{t+1}}\right)}{\left(\frac{AX_0^t}{OX_0^t}\right)}. \qquad (3)$$

Now, suppose that the production function is $Y^{t^*} = f^t\left(X^t\right)$ in period t and $Y^{t+1^*} = f^{t+1}\left(X^{t+1}\right)$ in period $t+1$. Because each observed input-output bundle is by definition feasible in the relevant period, $f^t\left(X^t\right) \geq Y_0^t$ and $f^{t+1}\left(X^{t+1}\right) \geq Y_0^{t+1}$. Thus the productivity index, as defined in (3), can be rewritten and decomposed as

[3] When multiple inputs and/or multiple outputs are involved, one must replace the simple ratios of the output and input quantities by ratio of quantity indexes of output and input (see Ray (2004, p. 279-295) for details).

$$\pi_{t+1|t} = \frac{\pi_{t+1}}{\pi_t} = \frac{\left(\dfrac{BX_0^{t+1}}{OX_0^{t+1}}\right)}{\left(\dfrac{AX_0^t}{OX_0^t}\right)}$$

$$= \frac{\left(\dfrac{BX_0^{t+1}}{FX_0^{t+1}}\right)}{\left(\dfrac{AX_0^t}{CX_0^t}\right)} \times \frac{\left(\dfrac{FX_0^{t+1}}{OX_0^{t+1}}\right)}{\left(\dfrac{CX_0^t}{OX_0^t}\right)}$$

$$= \frac{\left(\dfrac{BX_0^{t+1}}{FX_0^{t+1}}\right)}{\left(\dfrac{AX_0^t}{CX_0^t}\right)} \left(\frac{DX_0^t}{CX_0^t}\right) \frac{\left(\dfrac{FX_0^{t+1}}{OX_0^{t+1}}\right)}{\left(\dfrac{DX_0^t}{OX_0^t}\right)}$$

$$= \left[\frac{\left(\dfrac{y_0^{t+1}}{f^{t+1}\left(x^{t+1}\right)}\right)}{\left(\dfrac{y_0^t}{f^t\left(x^t\right)}\right)}\right] \times \left[\frac{f^{t+1}\left(x^t\right)}{f^t\left(x^t\right)}\right] \times \left[\frac{\left(\dfrac{f^{t+1}\left(x^{t+1}\right)}{x^{t+1}}\right)}{\left(\dfrac{f^{t+1}\left(x^t\right)}{x^t}\right)}\right]$$

$$= TEC \times TC \times SEC. \tag{4}$$

The first component in this expression (TEC) is the ratio of the technical efficiencies of the firm in two periods and captures the contribution of technical efficiency change over time. The second term (TC) shows how the maximum producible output from input X_0^t changes between period t and $t+1$ and captures the autonomous shift in the production function due to technical change. Finally the last term (SEC) identifies the returns to scale effect over time.

3. Non Parametric Estimation of Productivity Index

This paper adopts the non-parametric method of Data Envelopment Analysis (DEA) introduced by Charnes, Cooper and Rhodes (1978) (CCR) and further generalized for variable returns to scale technology by Banker, Charnes and Cooper (1984) (BCC), in order to measure and decompose the Malmquist index of total factor productivity.

The major advantage of using DEA is that, unlike in the parametric approach, there is no need to specify any explicit functional form for the production function (e.g., Cobb-Douglas or Translog) and mathematical programming techniques can be used to get point-wise estimates of the production function. In fact, DEA allows one to construct the production possibility set from observed input-output bundles on the basis of the following four assumptions:

a. all observed input-output combinations are feasible;

b. the production possibility set is convex;
c. inputs are freely disposable; and
d. outputs are freely disposable.

Now, consider an industry producing one output y^t from one input x^t in period *t*. The input-output bundle $\left(x^t, y^t\right)$ is considered as feasible if the output y^t can be produced from the input x^t. Let $\left(x_j^t, y_j^t\right)$ represent the input-output bundle of firm j; and suppose that input-output data are observed for n firms. Then, based on the above assumptions, in period *t*, the production possibility set showing a variable returns to scale (VRS) technology is[4]

$$T_v^t = \left\{ (x, y) : x \geq \sum_{j=1}^{n} \lambda_j x_j^t ; y \leq \sum_{j=1}^{n} \lambda_j y_j^t ; \sum_{j=1}^{n} \lambda_j = 1; \lambda_j \geq 0; (j = 1,2,3,.....,n) \right\}. \qquad (5)$$

Under the constant returns to scale (CRS) assumption, if any (x, y) is feasible, so is the bundle (kx, ky) for any $k > 0$. The production possibility set then becomes

$$T_c^t = \left\{ (x, y) : x \geq \sum_{j=1}^{n} \lambda_j x_j^t ; y \leq \sum_{j=1}^{n} \lambda_j y_j^t ; \lambda_j \geq 0; (j = 1,2,3,.....,n) \right\}. \qquad (6)$$

One can measure the output-oriented technical efficiency $TE^t\left(x_s^t, y_s^t\right)$ of a firm s in period t by comparing its actual output y_s^t with the maximum producible quantity from its observed input x_s^t Therefore, the output-oriented technical efficiency of firm s in period t is

$TE^t\left(x_s^t, y_s^t\right) = \left(\dfrac{1}{\theta_s^*}\right)$; where, $\theta_s^* = \max \theta : \left(x_s^t, \theta y_s^t\right) \in T^t$ and T^t is the period t production possibility set[5].

An alternative characterization of technical efficiency in terms of the Shephard Distance Function is $D^t\left(x_s^t, y_s^t\right) = \min \lambda : \left(x_s^t, \dfrac{1}{\lambda} y_s^t\right) \in T^t$. It can be seen that $\lambda = \dfrac{1}{\theta_s^*}$.

Caves et al. (1982) define the Malmquist Productivity Index as the ratio of the period t and period $t+1$ output-oriented Shephard distance functions pertaining to a certain benchmark technology. Equivalently, the Malmquist Index of total factor productivity of the firm s is[6]

$$M_c\left(x_s^t, y_s^t; x_s^{t+1}, y_s^{t+1}\right) = \left[\frac{TE_c^{\,t+1}\left(x_s^{t+1}, y_s^{t+1}\right)}{TE_c^{\,t+1}\left(x_s^t, y_s^t\right)} \cdot \frac{TE_c^{\,t}\left(x_s^{t+1}, y_s^{t+1}\right)}{TE_c^{\,t}\left(x_s^t, y_s^t\right)} \right]^{\frac{1}{2}}. \qquad (7)$$

[4] In DEA, the production possibility frontier for any particular period, constructed on the basis of that period's production possibility set is known as the contemporaneous frontier.
[5] Farell (1957) formulated a linear programming model to estimate the output-oriented technical efficiency of a firm with observed input–output bundle with reference to a benchmark technology.
[6] For a detailed intuitive explanation of the Malmquist Productivity Index, see Ray (2004, p. 279-295).

The standard non-parametric DEA model used to estimate the period t output-oriented technical efficiency of a firm s , relative to contemporaneous CRS frontier is

$$\theta_s^* = \text{Max } \theta \tag{8}$$

subject to
$$\sum_{j=1}^{n} \lambda_j y_j^t \geq \theta y_s^t;$$
$$\sum_{j=1}^{n} \lambda_j x_j^t \leq x_s^t;$$
$$\lambda_j \geq 0 \,; \left(j = 1,2,3,\ldots n \right);$$
and,
$$TE_c^t \left(x_s^t , y_s^t \right) = \left(\frac{1}{\theta_s^*} \right).$$

By imposing the additional restriction $\sum_{j=1}^{n} \lambda_j = 1$ in this DEA model, period t output- oriented technical efficiency, $TE_v^t \left(x_s^t , y_s^t \right)$, of a firm s with reference to a contemporaneous VRS frontier can be estimated.

Färe et al. (1992) (FGLR) decompose the Malmquist Productivity Index into technical change (TC) and technical efficiency change (TEC) components using the CRS frontier as the benchmark. However, assumption of global CRS is a restrictive assumption about the underlying technology, and the FGLR decomposition is not particularly meaningful when CRS does not hold everywhere. Färe, Grosskopf, Norris, and Zhang (1994) (FGNZ) offer an extended decomposition to accommodate variable returns to scale and isolate specific contributions of technical efficiency change (TEC), technical change (TC), and scale efficiency change (SEC) towards the overall productivity change. According to Ray and Desli (1997), this decomposition uses CRS and VRS within the same decomposition and raises a problem of internal consistency. They offer a modified decomposition using the VRS frontier as a benchmark. In that decomposition, scale efficiency change is obtained by considering both the constant returns to scale technology and the variable returns to scale technology. However, estimating cross-period efficiency scores[7] under a VRS technology may result in linear programming infeasibilities for some observations.[8]

The Biennial Malmquist Index introduced by Pastor, Asmild, and Lovell (2011) provides the same decomposition and avoids the infeasibility problem associated with the Ray-Desli decomposition of the Malmquist Index. Instead of using a contemporaneous production possibility frontier, they estimate the technical efficiency of a production unit with reference to a biennial production possibility frontier. The reference technology set T^B is defined as the convex hull of pooled data from both periods t and $t+1$ (a simple graphical illustration of the biennial production possibility frontier, for single output-single input case, is given in the appendix to this paper).

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[7] Cross-period efficiency score is measured by comparing actual output of a firm in period t with the maximum producible output from period $t+1$ input set.

[8] For details see Ray and Mukherjee (1996).

Using the output-oriented technical efficiency scores with reference to a CRS biennial frontier, the Biennial Malmquist Productivity Index of the firm s producing a single output from multiple inputs is measured as[9]

$$M_c^{\,B}\left(x_s^t, y_s^t; x_s^{t+1}, y_s^{t+1}\right) = \frac{TE_c^{\,B}\left(x_s^{t+1}, y_s^{t+1}\right)}{TE_c^{\,B}\left(x_s^t, y_s^t\right)}. \tag{9}$$

The decomposition of this Biennial Malmquist productivity index is

$$M_c^{\,B}\left(x_s^{\,t}, y_s^{\,t}; x_s^{\,t+1}, y_s^{\,t+1}\right) = TEC \times TC \times SC\,; \tag{10}$$

where,

$$TEC = \frac{TE_v^{\,t+1}\left(x_s^{\,t+1}, y_s^{\,t+1}\right)}{TE_v^{\,t}\left(x_s^{\,t}, y_s^{\,t}\right)},$$

$$TC = \frac{TE_v^{\,B}\left(x_s^{\,t+1}, y_s^{\,t+1}\right) / TE_v^{\,t+1}\left(x_s^{\,t+1}, y_s^{\,t+1}\right)}{TE_v^{\,B}\left(x_s^{\,t}, y_s^{\,t}\right) / TE_v^{\,t}\left(x_s^{\,t}, y_s^{\,t}\right)}, \text{ and}$$

$$SEC = \frac{TE_c^{\,B}\left(x_s^{\,t+1}, y_s^{\,t+1}\right) / TE_v^{\,B}\left(x_s^{\,t+1}, y_s^{\,t+1}\right)}{TE_c^{\,B}\left(x_s^{\,t}, y_s^{\,t}\right) / TE_v^{\,B}\left(x_s^{\,t}, y_s^{\,t}\right)}.$$

The appropriate DEA model to estimate period t output-oriented technical efficiency $TE_c^B\left(x_s^t, y_s^t\right)$ of firm s, with reference to a CRS biennial production possibility set is

$$\phi_s^* = \text{Max } \phi \tag{11}$$

subject to $$\sum_{k=t,t+1} \sum_{j=1}^{n_k} \lambda_j^k y_j^k \geq \phi y_s^t;$$

$$\sum_{k=t,t+1} \sum_{j=1}^{n_k} \lambda_j^k x_j^k \leq x_s^t;$$

$$\lambda_j^k \geq 0;$$

where n_k is the number of observed firms in period k and $TE_c^B\left(x_s^t, y_s^t\right) = \left(\dfrac{1}{\phi_s^*}\right)$.

Period t output-oriented technical efficiency $TE_v^B\left(x_s^t, y_s^t\right)$ of firm s, with reference to a biennial VRS frontier, can be estimated by the following DEA model:

$$\varphi_s^* = \text{Max } \varphi \tag{12}$$

9 Since the Biennial Malmquist Index of productivity uses the biennial CRS production possibility set, which includes the period *t* and *t+1* sets, one need not to calculate a "geometric mean" of two productivity indexes while measuring it.

subject to $\sum_{k=t,t+1} \sum_{j=1}^{n_k} \lambda_j^k y_j^k \geq \varphi y_s^t;$

$$\sum_{k=t,t+1} \sum_{j=1}^{n_k} \lambda_j^k x_j^k \leq x_s^t;$$

$$\sum_{k=t,t+1} \sum_{j=1}^{n_k} \lambda_j^k = 1;$$

$$\lambda_j^k \geq 0;$$

where n_k is the number of observed firms in period k and $TE_v^B\left(x_s^t, y_s^t\right) = \left(\frac{1}{\varphi_s^*}\right)$.

4. Data and Empirical Application

This study uses state level input-output data from the Indian manufacturing sector for the years 1970-71 through 2007-08. The basic data come from the Annual Survey of Industries (ASI) reported by the Government of India. Following the existing literature, the period up to 1991-92 is treated as the pre-reform regime and the subsequent period in the sample is regarded as post-reform. This study covers twenty Indian states. These states together account for 91% of the total manufacturing output, and 93% of the total employment in the manufacturing in 2007-08.

For the empirical analysis a single-output, five-input production technology for the manufacturing industry in India is specified. The inputs used are: (i) production workers, (ii) non-production workers, (iii) capital, (iv) raw materials, and (v) energy. Output is measured by the gross value of manufacturing production in the state. In the Indian context, it was Rao (1996a) who first addressed the question of whether productivity should be measured by gross output or real value-added. As long as material inputs are separable from the other factors, it does not matter which of the two measures is used to estimate productivity. Because no information on inter-state variation in manufacturing output and non-labor input prices is available, appropriate all-India wholesale price indexes (WPI), with 1981-82 as the base year, are used as deflators for all states in any particular year. WPI series with base 1970-71, 1981-82, and 1993-94 are available for the relevant periods. The 1970-71 and 1993-94 series have been arithmetically brought to a common base year, *i.e.*, 1981-82.

The nominal value of gross output has been converted into real output by using the wholesale price index for manufacturing products as a deflator. Values of non-labor inputs in current prices have been deflated by their respective wholesale price indexes to make them comparable measure of quantities across years.

Material input for total manufacturing is measured by the cost of materials deflated by the industrial raw materials wholesale price index. The energy input is measured by the expenditure on fuels deflated by the wholesale price index of Fuel, Power and Lubricants.

Measuring capital input is especially problematic. It may be treated either as stock measured by the book value of fixed assets or as a flow measured by the sum of rent, repairs, and depreciation expenses. The former is vulnerable for two reasons. First, the book value may correlate poorly with the physical stock of machinery and equipment. Second, the capacity may not be fully utilized. The flow measure, on the other hand, may be questioned on the ground that the depreciation charges in the financial accounts may be unrelated to actual tear and wear of the hardware (Ray, (2002)). Alternatively, in Trivedi (2004), Trivedi et al. (2011) and several other studies, perpetual inventory method is used to construct a capital stock series from annual investment data. That does not address the question of capacity utilization, however. In this study, capital is measured as a stock by the book value of fixed assets deflated by a composite wholesale price index (see Appendix B for the method used to construct the composite piece index) of machinery and transport equipment.

Labor inputs – both production and non-production workers – are measured by the number of persons employed.

The input-output data reported in the ASI for individual states are aggregates over all firms in the state covered by the Survey. This aggregation poses a serious technical problem in applying DEA. Even though, the actual input-output quantities of the individual firms are all feasible bundles, the total input-output bundle – the sum of those feasible bundles – is neither observed nor a weighted average of feasible observations. Assumptions of constant returns to scale along with convexity of the production possibility set would ensure the feasibility of these aggregate input-output bundles. Nevertheless, using a reference technology showing CRS throughout the production process does not allow decomposition of the Malmquist productivity index into all of its components.

One possible solution is to use the average input-output bundle for any state as a feasible combination and to use as a basis for constructing the non parametric production possibility frontier (Ray (2002), Ray (2009)). Accordingly, state level input-output quantity data for an "*average*" firm is constructed by dividing the state level total values of output and inputs by the number of establishments (factories) in the state[10]. Using the contemporaneous CRS and VRS frontiers (as defined before), the corresponding biennial frontiers for every pair of adjacent years within the chosen sample period are constructed from input-output data for these *average* firms.[11] In this case the sample period covers 37 years and there is a series of 36 overlapping biennial frontiers for each pair-wise comparison of adjacent years. With reference to the associated biennial production possibility set we solve model (11) and (12) to estimate output-oriented technical efficiency scores for each year for all states under CRS and VRS assumptions, respectively. It should be noted that for some states no data were available for specific years. We exclude the states for those years and conducted the entire empirical work with an unbalanced panel.[12] We measure the yearly Biennial Malmquist Index of total factor productivity using the

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[10]The average input-output bundle is an equally weighted average of the unobserved input-output bundles of the individual firms from a state, and by convexity assumption each of these bundles is feasible. Let $\left(X^t, Y^t\right)$ represent the aggregate input-output bundle for a state. Assuming that there are *n* individual firms in this state, let $\left(x_s^t, y_s^t\right)$ represent the input-output bundle of firm $s\left(s=1,2,.....,n\right)$. Hence, $X^t = \sum_{f=1}^{n} x_s^t$ and $Y^t = \sum_{f=1}^{n} x_s^t$. We know that the firm-level input-output pairs, although not individually reported are all feasible. Hence by the convexity assumption the average input-output bundle $(\frac{1}{n}\sum_{f=1}^{n} x_s^t, \frac{1}{n}\sum_{f=1}^{n} y_s^t)$ will always be feasible.

[11] The only exception was the year 1972-73, during which no survey was conducted.

[12] An unbalanced panel dataset is better than a panel dataset in this regard because working with the latter requires excluding those *states* for which we have data for other years. This exclusion could lead to

efficiency scores obtained by solving model (11) only for those states with data available in adjacent years. To estimate the technical efficiency change and the technical change component of the productivity index we also solve model (8) with additional restriction (as mentioned in the previous section) necessary to measure output-oriented technical efficiency for each of the sample years under the VRS technology.

5. Empirical Findings

Indian manufacturing has been a major component of Indian industry for years. The average share of the organized manufacturing sector in India's GDP increased from about 13 % during 1970-75 to 15.1% in 2002-07. In the year 2009-10, it rose to 16.1%. Among the individual states, Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Maharashtra, Tamil Nadu and West Bengal account for the major share of organized manufacturing output and employment during this period over the years 1970-71 through 2007-08. However, the annual shares in output and employment continuously declined in Bihar and West Bengal. Labor disputes along with the successive closure of industrial units (partially due to labor unrest) during the 1980s in West Bengal likely played a role. However, it should be noted the development of a strong unorganized manufacturing sector in West Bengal also played an important role in the decline in this state's organized manufacturing sector. The separation of the state Jharkhand (which includes the major metal industry) from Bihar in 2000-01, was partly responsible for the observed deterioration in Bihar. Up until 2000-01, Bihar's shares of India's manufacturing output and employment were close to 5%. Since then Bihar's shares fell to less than 1% per year. Among the other leading industrial states, manufacturing industries in Andhra Pradesh and Haryana gained significant importance over these years, while Maharashtra, renowned for having major textile mills and containing Mumbai (Bombay) - the financial capital of India - experienced continuous decline. Still Maharashtra ranked at the top in the year 2007-08. At the same time Gujarat which had always been recognized as a major industrial state retained its contribution toward manufacturing output and employment in a consistent manner.

Table 1 shows the average annual rates of change in total factor productivity before and after the economic reforms, as well as for the entire sample period, within each region and for the nation. Over the pre-reform period Indian manufacturing productivity grew 1.064% per year, increasing to 2.737% per year over the post-reform years. State level estimates reveal a considerable variation – measured by the coefficient of variation - in the rates of total factor productivity change across states both before and after the reform. However, this variation diminished in the post-reform years showing a sign of convergence in productivity growth experience in this period.

During the entire sample period all the states reported here showed positive total factor productivity growth, and for most of the states the growth accelerated during the post-reform years. Andhra Pradesh, Chandigarh, Punjab, and West Bengal showed remarkable improvement and switched from productivity decline to productivity growth after the reform. Also, Haryana and Rajasthan, which registered annual growth rates of 1.481% and 1.584%, respectively, over the pre-reform years, improved their growth rates considerably and grew by more than 3.5% after the reform. The "lagging industrial states" such as Assam and Orissa grew faster after the reform than Maharashtra and Tamilnadu, the commonly perceived leading industrial states. Only one state, Pondicheri, experienced a change from a productivity increase to a decline after the reform.

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conceptual problem in constructing the production possibility frontier because there is likelihood for the input output bundle(s) for the excluded state(s) for a particular year to lie on the frontier if not excluded from the dataset.

For Bihar, Delhi, Goa, and Madhya Pradesh productivity growth continued after the reform but at a lower rate than before. Thus, the overall evidence from a pre- and post-reform comparison of manufacturing productivity growth reveals an improvement in the rate of change in productivity at the national and regional levels.

Tables 2 and 3 show the estimates of different components of the Malmquist Index of total factor productivity for the individual states and for India in the pre-and post-reform periods, respectively. Entries in column TEC show average annual changes in the level of technical efficiency over time for each state, a value greater than unity for this component implies that a state experienced improvement in technical efficiency over the period. Similarly, an entry with value greater (less) than unity in column TC reflects technological progress (regress) in a state over time. The change in scale efficiency over time for each state is reported in column SECI, with a value exceeding one again signaling an improvement in scale efficiency.

Comparison of Tables 2 and 3 shows that at the national level productivity growth was mostly driven by technological progress both before and after the reform, with a slight improvement in the rate of technological progress during post-reform years. While at the national level, Indian manufacturing firms were not able to achieve better utilization of factors of production, use of superior technology pushed them to be on higher growth path after the reforms. This is confirmed by observed technological progress and decline in technical efficiency during this period. At the regional level, over the pre-reform period only three states, Chandigarh, Pondicheri and Punjab, showed technological regress. Gujarat, Haryana, Punjab, and West Bengal showed decline in technical efficiency during these years. Scale efficiency decreased in Andhra Pradesh, Assam, Delhi, Himachal Pradesh, Karnataka, Madhya Pradesh, Rajasthan, Uttar Pradesh, and West Bengal. Over the post-reform years all states showed technological progress, while most of the states experienced decline in technical efficiency. Chandigarh, Himachal Pradesh, Kerala, Maharashtra, Madhya Pradesh, Pondicheri, Rajasthan, Tamilnadu, and Uttar Pradesh registered deterioration in scale efficiency during this period. Therefore, both before and after the reform, technological progress was mainly responsible for net productivity change in most of the states.

Underlying growth accounting or econometric techniques used to estimate total factor productivity change is the assumption of constant returns to scale in the production technology. This often implies that total factor productivity growth is synonymous with technical change and that productivity growth (decline) always signifies technological progress (regress). This empirical study provides evidence to the contrary. For Indian manufacturing, we find evidence of productivity growth even in the presence of technological regress. For Pondicheri, we find that even though the state was experiencing technological regress, it showed productivity growth driven by improvement in technical efficiency and scale efficiency during the pre-reform period. On the other hand, there is also an example of productivity decline in the presence of technological progress. During the pre-reform period West Bengal showed technological progress but experienced productivity decline due to reduction in technical and scale efficiency. Over the post-reform years, productivity growth of West Bengal was mostly driven by technological progress. Pondicheri also showed technological progress and improvement in technical efficiency, but due to deterioration in scale efficiency it registered a decline in productivity during this period. Therefore, it is safe to conclude that not only use of better technology but also efficient utilization of inputs and use of optimal scale size play important roles in accelerating the total factor productivity in Indian manufacturing.

6. Conclusion

The Indian Economic Reform, initiated in the wake of a severe foreign exchange crisis in 1991, and its impact on manufacturing productivity have been an important area of research among empirical analysts. This paper provides new evidence on productivity change in Indian manufacturing using state level input-output data from the Annual Survey of Industries over an extended sample period from 1970-71 through 2007-08. The non-parametric method of Data Envelopment Analysis is used to construct and decompose the Malmquist Index of total factor productivity for each of the major Indian states and the country as a whole. The results show that at the national level, manufacturing productivity grew faster during the post-reform period. At the individual level, most states enjoyed faster productivity growth after the reform, but some states experienced a slowdown in productivity growth or even a productivity decline after the reforms. There was considerable variation in productivity growth rates across states over the sample years. However, this variation diminished during the post-reform years suggesting that there has been a tendency for the states to converge in terms of productivity change after the reforms. The decomposition of total factor productivity change shows that both before and after the reforms, technological progress was the major source of improvement in manufacturing productivity at the national level as well as for most of the states. Contrary to the popular notion that technological progress leads to productivity growth, we find evidence of productivity decline (growth) even in the presence of technological progress (regress) at the regional level.

Nevertheless, one needs to be careful in interpreting the empirical findings of this paper. Even though there is ample evidence of acceleration of productivity growth rate in most states during the post-reform years, such improvement in productivity growth can be related to economic reforms only if a statistically significant impact is found in a regression model that controls for other economic and demographic factors. That would constitute a logical extension of this analysis.

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Appendix A: Construction of the Biennial Production Possibility Frontier

Figure A.1 provides an illustration of the biennial production possibility frontier and measure of output-oriented technical efficiency with reference to it for a firm, producing a single output from a single input, observed in two time periods *t* and *t+1* (point A and B respectively). The VRS frontiers for period t and $t+1$ are indicated by $K_0L_0M_0$- extension and $K_1L_1M_1$- extension respectively. The rays through origin OP_0 and OP_1 represent the CRS frontiers for period t and period $t+1$ respectively. The biennial VRS frontier is indicated by the broken line $K_1L_1DFM_0$- extension and the biennial CRS frontier in this case coincides with that of period $t+1$. Output-oriented technical efficiency of the firm with reference to CRS biennial frontier in period t is $TE_c^{\,B}(x^t, y^t) = \left(A_tX^t / QX^t\right)$ and that for period $t+1$ is $TE_c^{\,B}(x^{t+1}, y^{t+1}) = \left(A_{t+1}X^{t+1} / RX^{t+1}\right)$. Similarly with reference to the VRS biennial frontier, $TE_v^{\,B}(x^t, y^t) = \left(AX^t / DX^t\right)$ and $TE_v^{\,B}(x^{t+1}, y^{t+1}) = \left(A_{t+1}X^{t+1} / FX^{t+1}\right)$ show the levels of technical efficiency for the firm in period t and $t+1$, respectively.

Therefore, the Biennial Malmquist productivity index is

$$M_c^{\,B}(x^t, y^t; x^{t+1}, y^{t+1}) = \frac{\left(A_{t+1}X^{t+1} / RX^{t+1}\right)}{\left(A_tX^t / QX^t\right)} \ .$$

The decomposition of this Malmquist productivity index is

$$M_c^{\,B}(x^t, y^t; x^{t+1}, y^{t+1}) = \frac{\left(A_{t+1}X^{t+1} / EX^{t+1}\right)}{\left(A_tX^t / CX^t\right)} \times \frac{\left(A_{t+1}X^{t+1} / FX^{t+1}\right) / \left(A_{t+1}X^{t+1} / EX^{t+1}\right)}{\left(A_tX^t / DX^t\right) / \left(A_tX^t / CX^t\right)}$$

$$\times \frac{\left(A_{t+1}X^{t+1} / RX^{t+1}\right) / \left(A_{t+1}X^{t+1} / FX^{t+1}\right)}{\left(A_tX^t / QX^t\right) / \left(A_tX^t / DX^t\right)}$$

where, $TEC = \dfrac{\left(A_{t+1}X^{t+1} / EX^{t+1}\right)}{\left(A_tX^t / CX^t\right)}$,

$$TC = \frac{\left(A_{t+1}X^{t+1} / FX^{t+1}\right) / \left(A_{t+1}X^{t+1} / EX^{t+1}\right)}{\left(A_tX^t / DX^t\right) / \left(A_tX^t / CX^t\right)}, \text{ and}$$

$$SEC = \frac{\left(A_{t+1}X^{t+1} / RX^{t+1}\right) / \left(A_{t+1}X^{t+1} / FX^{t+1}\right)}{\left(A_tX^t / QX^t\right) / \left(A_tX^t / DX^t\right)}$$

Appendix B: Construction of Composite Wholesale Price Index

Described below a general formulation used in this paper to construct a composite price index of an input *x* from the whole sale price indexes of N inputs of the same category as *x*.

Let W_i is the weight for *i*th input used to construct the Whole Price Index of it.

Therefore, $s_i = \dfrac{W_i}{\sum_{j=1}^{N} W_j}$. (B1)

Weighted WPI of *i*th input in year *t* is $wpi_{it} = (WPI_{it} \times s_i)$. (B2)

Therefore composite price index of input *x* in period *t* is (B3)

$$WPI_{xt} = \sum_{i=1}^{N} wpi_{it} = \sum_{i=1}^{N} \left(WPI_{it} \times \frac{W_i}{\sum_{j=1}^{N} W_j} \right)$$

Tables

Table 1
Average Annual Rates of Total Factor Productivity Change in Total Manufacturing Sector (State-Wise)

States	Pre-Reform (1970-1991)	Post-Reform (1992-2007)	All Years (1970-2007)
Andhra Pradesh	-0.068	3.202	1.372
Assam	1.256	3.322	2.169
Bihar	2.495	2.155	2.344
Chandigarh	-0.642	3.012	0.966
Delhi	1.890	1.559	1.743
Goa	2.322	2.028	2.191
Gujarat	0.896	3.609	2.093
Haryana	1.481	4.322	2.734
Himachal Pradesh	0.839	2.583	1.611
Karnataka	1.086	2.771	1.831
Kerala	0.872	4.315	2.388
Madhya Pradesh	2.138	1.014	1.637
Maharashtra	0.943	2.244	1.519
Orissa	0.758	3.243	1.855
Pondicheri	0.985	-0.515	0.315
Punjab	-0.253	2.287	0.868
Rajasthan	1.584	3.580	2.467
Tamil Nadu	1.400	2.878	2.054
Uttar Pradesh	1.530	2.820	2.101
West Bengal	-0.240	2.736	1.072
All India	1.064	2.737	1.986
Coefficient of Variation (CV)	0.790	0.418	0.462

Table 2
Decomposition of Malmquist Productivity Index for
Total Manufacturing Sector (Pre-Reform)

States	TECI	TCI	SECI	MPI
Andhra Pradesh	1.005	1.009	0.985	0.999
Assam	1.005	1.013	0.994	1.013
Bihar	1.000	1.023	1.002	1.025
Chandigarh	1.000	0.991	1.002	0.994
Delhi	1.004	1.019	0.996	1.019
Goa	1.005	1.007	1.011	1.023
Gujarat	0.998	1.007	1.005	1.009
Haryana	0.996	1.010	1.009	1.015
Himachal Pradesh	1.000	1.013	0.995	1.008
Karnataka	1.000	1.014	0.997	1.011
Kerala	1.001	1.006	1.001	1.009
Madhya Pradesh	1.002	1.022	0.997	1.021
Maharashtra	1.000	1.006	1.003	1.009
Orissa	1.000	1.007	1.000	1.008
Pondicheri	1.001	0.998	1.011	1.010
Punjab	0.995	0.994	1.008	0.997
Rajasthan	1.002	1.015	0.999	1.016
Tamil Nadu	1.004	1.008	1.002	1.014
Uttar Pradesh	1.002	1.016	0.998	1.015
West Bengal	0.996	1.004	0.998	0.998
All India	1.001	1.009	1.001	1.010

Notes: TECI: Technical Efficiency Change Index (Annual Average)
TCI: Technical Change Index (Annual Average)
SECI: Scale Efficiency Change Index (Annual Average)
MPI: Malmquist Productivity Index (Annual Average)

Table 3
Decomposition of Malmquist Productivity Index for
Total Manufacturing Sector (Post-Reform)

States	TECI	TCI	SECI	MPI
Andhra Pradesh	0.991	1.032	1.009	1.032
Assam	0.998	1.034	1.001	1.033
Bihar	1.000	1.020	1.001	1.022
Chandigarh	1.000	1.031	0.999	1.030
Delhi	1.000	1.013	1.002	1.016
Goa	1.000	1.011	1.009	1.020
Gujarat	1.003	1.029	1.004	1.036
Haryana	1.002	1.022	1.019	1.043
Himachal Pradesh	1.000	1.032	0.994	1.026
Karnataka	1.000	1.025	1.003	1.028
Kerala	0.997	1.048	0.998	1.043
Madhya Pradesh	0.998	1.041	0.971	1.010
Maharashtra	1.000	1.030	0.993	1.022
Orissa	0.996	1.033	1.004	1.032
Pondicheri	1.004	1.018	0.973	0.995
Punjab	0.997	1.025	1.000	1.023
Rajasthan	0.988	1.051	0.998	1.036
Tamil Nadu	0.992	1.041	0.996	1.029
Uttar Pradesh	0.995	1.036	0.997	1.028
West Bengal	0.996	1.032	1.000	1.027
All India	0.999	1.028	1.000	1.027

Notes: TECI: Technical Efficiency Change Index (Annual Average)
TCI: Technical Change Index (Annual Average)
SECI: Scale Efficiency Change Index (Annual Average)
MPI: Malmquist Productivity Index (Annual Average)

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Figures

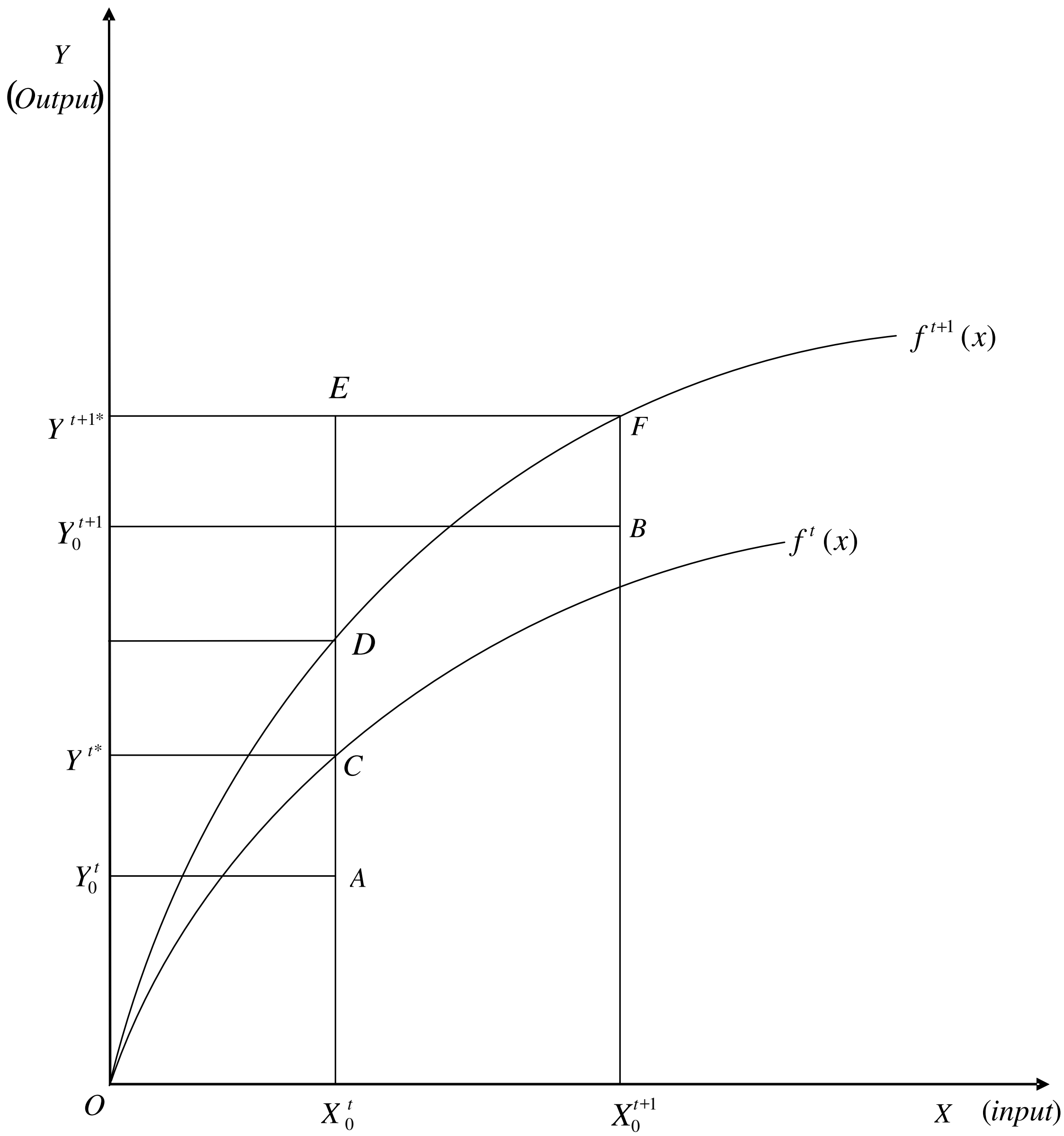

Figure 1: Decomposition of Productivity Index

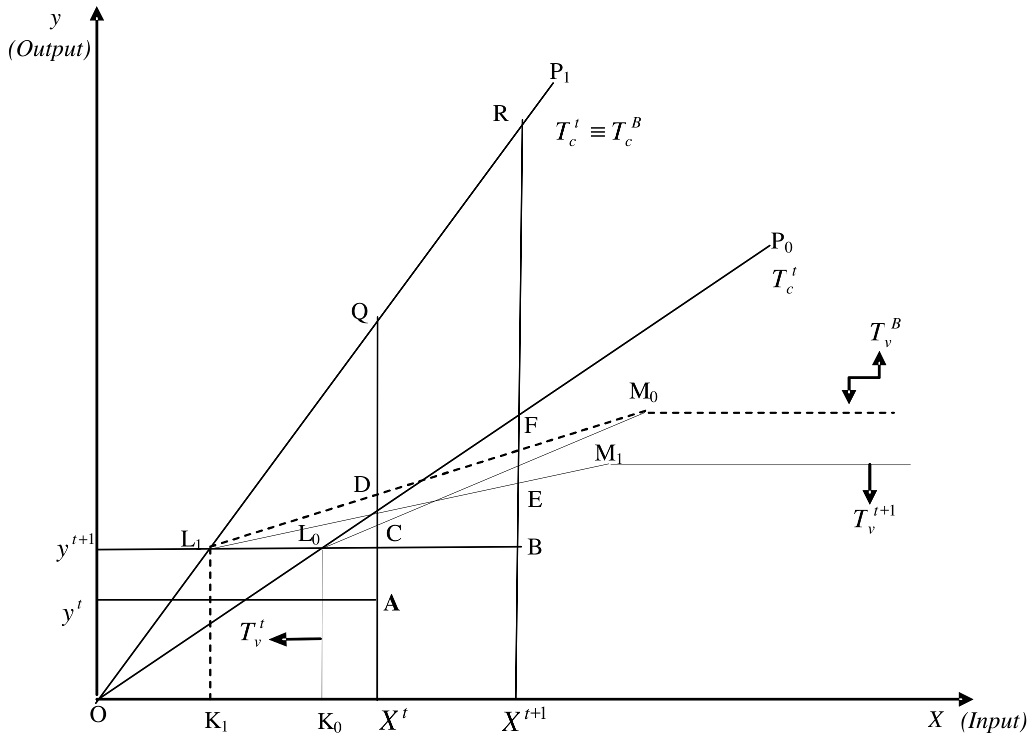

Figure A1: Biennial Production Possibility Frontier