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Does the Presence of Surplus Labor Hinder Production in Indian Manufacturing?

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Abstract

Input congestion occurs at a given input bundle when the assumption of free disposability of inputs does not hold and an increase in input leads to a decline in output. In this paper we employ the nonparametric method of Data Envelopment Analysis (DEA) to examine the question on input congestion with respect to labor, using state level data from the Annual Survey of Industries for the period 1986-87 through 1999-2000. When the standard assumption of strong disposability is relaxed for the labor inputs, the nonparametric analysis of state-level data from Indian manufacturing shows considerable measure of labor input congestion. While in selected states congestion comes from non-production workers as well, the principal source of labor congestion is production labor. There is no evidence that the problem of labor congestion has become less severe during the post-Reform years. It appears that market forces without any major institutional changes in enforcement of labor discipline cannot eliminate congestion.

DOES THE PRESENCE OF SURPLUS LABOR HINDER PRODUCTION IN INDIAN MANUFACTURING?

1. Introduction

The popular perception in India is that there is a significant measure of disguised unemployment in the nation's industrial labor force and that firms can easily downsize the employment level without any loss of output. In a recent nonparametric analysis of state-level input and output data from the total manufacturing sector, Ray and Bhattacharya (2003) found evidence of the presence of surplus labor in a number of states in most of the years during the period 1986-87 through 1999-2000. In their paper, it was assumed, however, that even though the surplus labor did not contribute to production and was effectively idle, it did not create any hindrance to production thereby reducing the level of output. This is, in deed, consistent with the standard assumption that marginal productivity of labor (or any other input) does not actually become negative. In specific situations, however, beyond a certain level any further increase in an input may actually be detrimental for production and reduce the level of output. For example, in agriculture, increase in the use of chemical fertilizers only holding land, labor, and other inputs constant, increases output. But when pushed beyond a certain limit it can cause crop damage. This phenomenon is known as input congestion. It may appear counter-intuitive that a firm might incur additional wage costs to hire surplus labor when that results in a loss of output due to congestion. It should be remembered, however, that militant trade unionism in Indian industries poses a tangible threat of serious labor unrest triggered by layoffs that could result in costs exceeding the benefits from downsizing. Moreover, in a labor surplus economy like India there is considerable political and social pressure to create employment[1]. This makes the firms additionally reluctant to reduce employment.

In this paper we employ the nonparametric method of Data Envelopment Analysis (DEA) to examine the question of input congestion with respect to labor using state level data from the Annual Survey of Industries for the period 1986-87 through 1999-2000. In this sense, the present paper extends the previous study by Ray and Bhattacharya. Specifically, we seek to answer the following questions.

- Is there any evidence that the presence of surplus labor reduces output? If so, what is the extent of output lost?
- Which are the states where labor congestion is evident?
- Is there any noticeable change in the incidence of input congestion after the introduction of the Economic Reforms in 1991?
- Does congestion, where present, come from both production and non-production labor?

The rest of the paper is organized as follows. In section 2 we present the theoretical background and explain the concept of weak (rather than strong) disposability of inputs and its implication for input congestion. Section 3 presents the nonparametric DEA methodology and the relevant mathematical programming models. Section 4 reports the models specified and variables used for this study. The empirical analysis is reported in section 5. Section 6 summarizes the main conclusions of this study.

2. The Theoretical Background

2.1 The Production Technology

Consider the production technology in an industry producing m outputs from n inputs. If an input bundle $x=(x_1, x_2, ..., x_n)$ can produce an output bundle $y = (y_1, y_2, ..., y_m)$, then the input-output combination (x, y) is a feasible production plan or a production possibility. The production technology can be characterized by the production possibility set

$$T = \{(x, y): y \text{ can be produced from } x\}. \quad (1)$$

In the single output case, the production possibility set is typically specified as

$$T = \{(x,y): f(x) \geq y \geq 0\}. \quad (2)$$

The function $y = f(x)$ is known as the production function and the set

$$G = \{(x,y): f(x) = y\} \quad (3)$$

is the graph of the technology. In the multiple-input, multiple-output case,

$$T = \{(x,y): F(x,y) \leq 1\} \quad (4)$$

where, $F(x,y) = 1$ is the production correspondence.

Usually, the following regularity conditions are imposed on the production technology.

(a) The production possibility set is convex. That is, if a pair of input-output bundles (x^1, y^1) and (x^2, y^2) are both feasible, then the pair $(\lambda x^1+(1-\lambda)x^2, \lambda y^1+(1-\lambda)y^2)$ is also feasible for any $0 \leq \lambda \leq 1$. In the single output parametric case, this is always true for any concave production function. Thus, (x^1, y^1) and $(x^2, y^2) \in T$ together implies that

for any $0 \leq \lambda \leq 1$, $(\lambda x^1+(1-\lambda)x^2, \lambda y^1+(1-\lambda)y^2) \in T$.

(b) Output is freely disposable. Thus, if (x^0, y^0) is feasible, and if $y^1 \leq y^0$, then (x^0, y^1) is also feasible. That is, $(x^0, y^0) \in T$ and $y^1 \leq y^0$ together implies that $(x^0, y^1) \in T$.

(c) Input is freely disposable. Thus, if (x^0, y^0) is feasible, and if $x^1 \geq x^0$, then (x^1, y^0) is also feasible. Hence, $(x^0, y^0) \in T$ and $x^1 \geq x^0$ together implies that $(x^1, y^0) \in T$.

A possible alternative characterization of the technology is in terms of input requirement sets.

The input requirement set for a specific output bundle y^0 consists of all input bundles that can produce y^0 and can be specified as

$$V(y^0) = \{ x: (x, y^0) \in T \} . \qquad (5)$$

The following properties of the input requirement sets follow from the properties (a)-(c) of the production possibility set.

(i) For any output bundle y, the set $V(y)$ is convex. It may be noted that convexity of the production possibility set is sufficient but not necessary for convexity of the input requirement set.

(ii) If $x \in V(y^0)$ and $y^1 \leq y^0$, then $x \in V(y^1)$. This follows from free disposability of outputs.

(iii) If $x^0 \in V(y)$ and $x^1 \geq x^0$, then $x^1 \in V(y)$. This follows from free disposability of inputs.

Input congestion occurs at a given input bundle when the assumption of free disposability of inputs does not hold. Formally, *input congestion* can be defined as a situation where an increase in input leads to a decline in output or, conversely, a decrease in any input leads to an increase in output. In the context of a standard production function, this amounts to negative marginal productivity of an input.

2.2 Some Parametric Examples

Example 1: Input Freely Disposable

Suppose that the production function

$$f(x) = 4\sqrt{x} \qquad (6a)$$

defines the production possibility set

$$T = \{(x, y) : y \leq 4\sqrt{x}\} \qquad (6b)$$

in the single input, single output case. The corresponding input requirement set is

$$V(y) = \{x : x \geq \tfrac{y^2}{16}\}.$$

In Figure 1, the area below the curve *OA* shows the production possibility set. The input requirement set for the output level $y_0 = 3$ is the segment of the horizontal axis to the right of the point *B* and can be formally defined as

$$V(y = 3) = x : x \geq \tfrac{9}{16}\}.$$

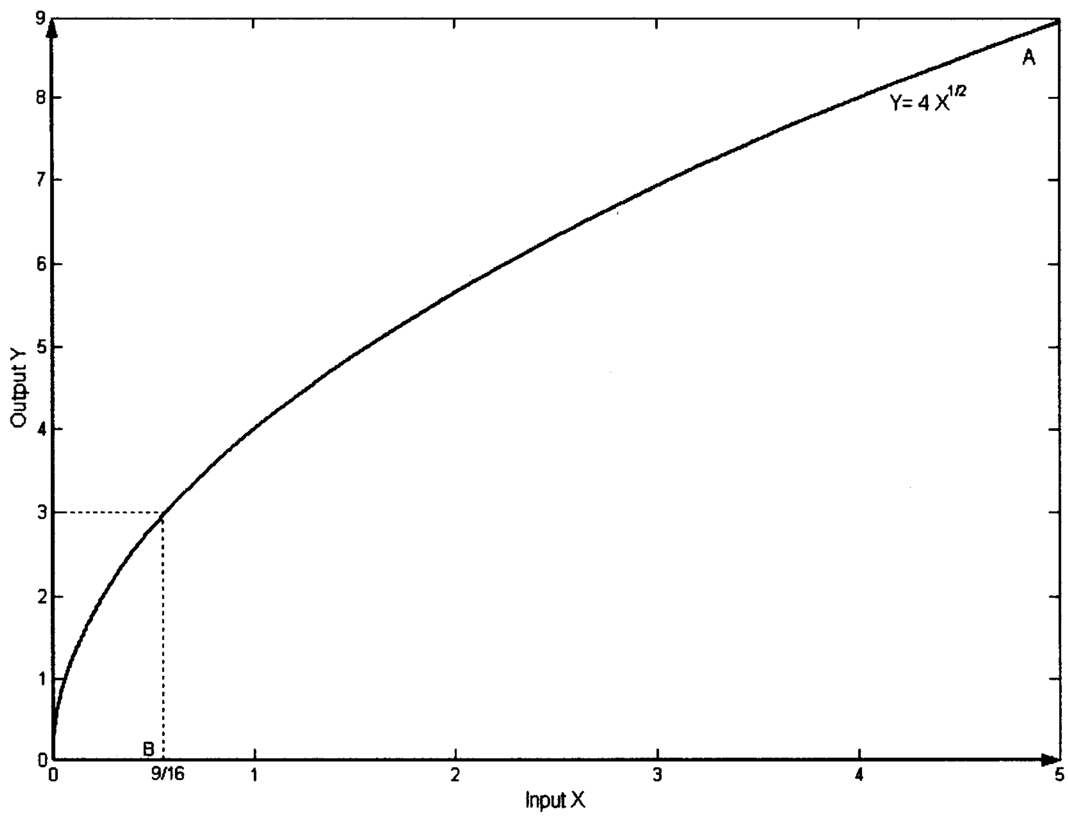


Figure 1

In this example, all of the properties (i)-(iii) are satisfied. In particular, for any increase in the input beyond $x=\frac{9}{16}$, the maximum output producible remains at least as high as $y= 3$. Thus, free disposability of input, clearly, holds.

Example 2: Input Congestion

Now consider the production function

$$f(x) = 4\sqrt{x} - x;\ 0 \le x \le 16. \qquad (7)$$

Note that in this case, $f'(x) = \frac{2}{\sqrt{x}} - 1$ and while output increases with x over the range $0 \le x \le 4$, for $x>4$, any increase in input causes the output to decline. Thus, input congestion is present in the region $x>4$. The production function is shown by the line *OA* in Figure 2. The input requirement set for output $y=3$ is

$$V(y = 3) = \{x : 1 \le x \le 9\}.$$

This is shown by the segment *BC* on the horizontal axis. While the input requirement set is convex, it does not satisfy free disposability of input. If x is increased beyond 9, the output $y=3$ is no longer producible. Note that if a firm that is using $x=9$ units of input could dispose of 5 units, the maximum producible output would increase to $y=4$. One would expect that *if the firm could do so at no cost,* it would, in deed, reduce input to increase output. Indeed, if the firm is constrained to operate at input level beyond $x=4$, it is experiencing input congestion.

The simple intuition behind this assumption of free disposability of inputs is that if an increase in the quantity of any input leads to a decline in output, the additional input quantity can be left idle at no cost. In many practical situations, however, this may not be true. For example, in farming, although irrigation has a positive marginal impact on output, excessive rain or flooding does lead to crop damage. One needs to use additional labor and capital equipment to pump out the unwanted water from the field. One cannot simply let the floodwater remain on the ground without lowering output. Here the negative marginal productivity of water has to be neutralized by additional application of labor and capital inputs. Similarly, any excessive increase in the number of workers inside a coalmine creates obstruction for the workers already employed and reduces production. In business firms, increase in the workforce can create problems of communication and coordination and hinder production.

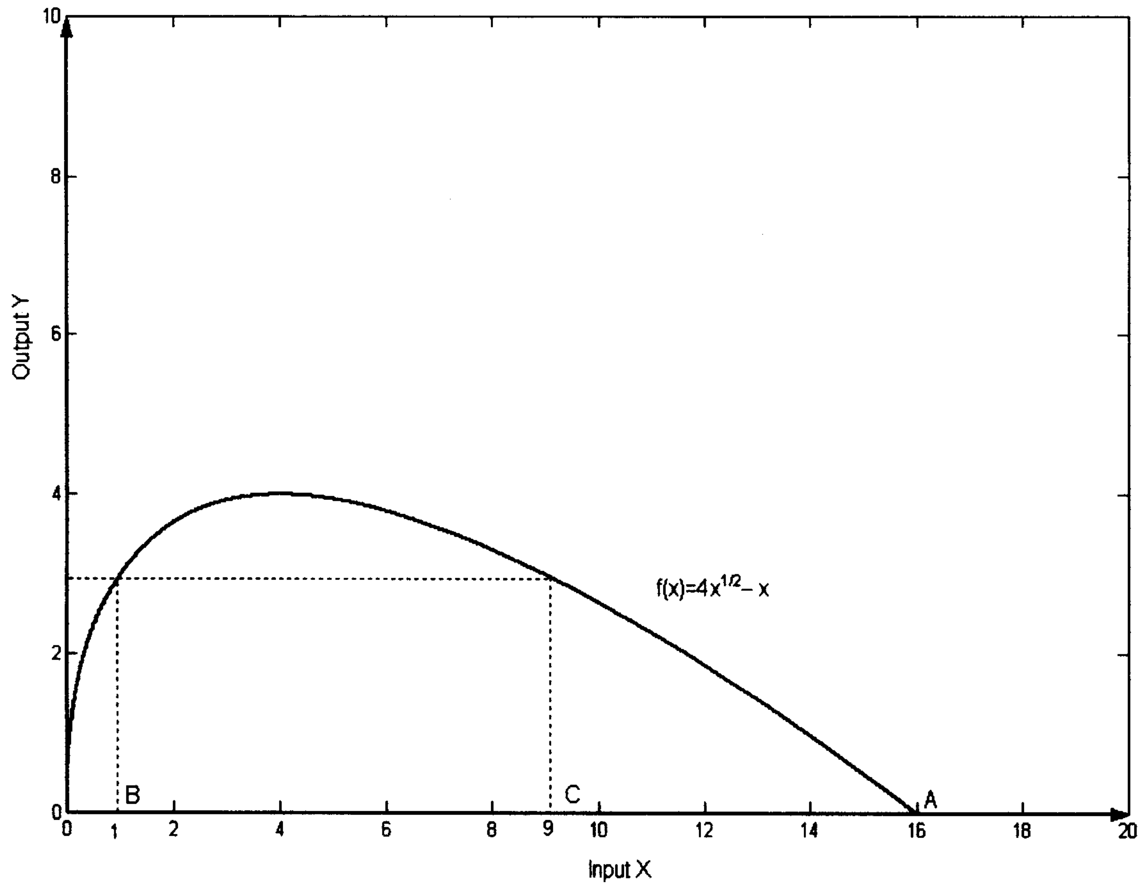


Figure 2

Example 3: Free Disposability in the 2-input case

The example shown in Figure 1b is a case of *non-disposability*. This can be contrasted with two other situations exhibiting (a) strong (or free) and (b) weak disposability. First, consider a two-input 1-output Leontief production technology with the production function

$$f(x_1, x_2) = min\ \{2x_1, x_2\}. \qquad (8)$$

Here, for any given quantity of input x_1, any increase in x_2 beyond $2x_1$ leads to no additional output and the incremental quantity of this input effectively lies idle. It does not, however, cause the output to *fall*. This is an example of strong or free disposability. Similarly, any amount of the input x_1 beyond $\frac{1}{2}x_2$ is also strongly disposable.

Example 4: Congestion of 1 input in the 2-input case

Next consider the example

$$f(x_1, x_2) = 4\sqrt{x_1 x_2} - x_2; x_1 \geq x_2. \qquad (9)$$

In this case, the maximum producible output is monotonically increasing in x_1. Thus input x_1 is strongly disposable. But the marginal productivity of input x_2 becomes negative for $x_2 > 4x_1$. Thus, input x_2 is not strongly disposable.

Example 5: Weak Disposability and Congestion in the 2-input Case

For an example of weak disposability, consider the production function

$$f(x_1, x_2) = 4\sqrt{x_1 x_2} - x_1 - x_2 \qquad (10)$$

where the function is defined for values of the two inputs satisfying $f(x_1, x_2) \geq 0$. As can be easily verified, the marginal productivity of each input becomes negative beyond a certain point. Thus, neither x_1 nor x_2 is freely disposable. However, if both inputs are increased by the same proportion, the output increases and by free disposability of output, the proportionately scaled up input bundle can always produce the previous lower level of output. This is an example of weak disposability of inputs. We may now define weak disposability formally. The technology exhibits weak disposability if $x^1 \in V(y)$ implies that $x^2 = \beta x^1 \in V(y)$ for $\beta > 1$. Two things may be noted. First, the technology may show weak disposability with respect to only a sub-vector of inputs and strong disposability for the remaining inputs. Second, and more important, weak disposability is a multiple input concept. With respect to a single input, weak and strong disposability become synonymous. For a single input, if it is at all disposable, it must be strongly disposable.

2.3 Some Nonparametric Examples

In all the examples above, the production function is explicitly specified and the appropriateness of all conclusions drawn about the production technology depends on the validity of the production function itself. In the nonparametric approach to production analysis, one only relies on the general assumptions (a) through (c) made above and constructs a production possibility set and the corresponding family of input requirement sets from a sample of observed input-output bundles.

Example 6. Nonparametric Example of Input Congestion

Consider, for example, the input-output data from 5 firms shown in Exhibit 1.

Firm	A	B	C	D	E
input	3	5	8	10	16
output	5	7	20	12	16

Exhibit 1.

The points A through E show the input-output bundles of the individual firms in Figure 3. Because these output quantities are actually produced from the corresponding input quantities by the individual firms, these input-output bundles are all feasible. Thus, all of these points lie in the production possibility set. Next, by convexity, all points in the closed area ACE are feasible. Further, by free disposability of outputs, all points directly below this area are also in the production possibility set.

Thus, if one assumes only convexity and free disposability of output but not free disposability of input, an approximation to the underlying production possibility set would be the closed area $FACEG$. The upper boundary ACE is the corresponding production frontier or the graph of the technology. Any input-output bundle that lies below the frontier is technically inefficient. Thus, points B and D are technically inefficient. The efficient projection of B onto the frontier is the point H where 11 units of the output are produced from 5 units of the input. Thus the technical efficiency of the firm B is

$$TE(B) = \frac{7}{11}.$$

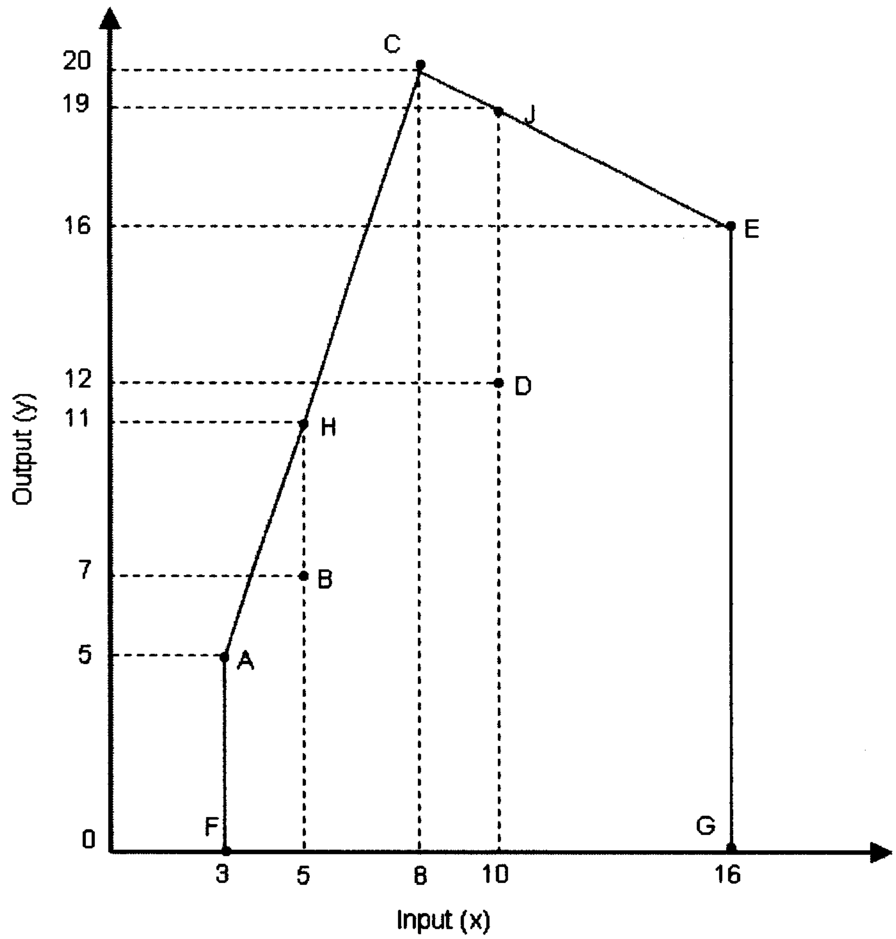


Figure 3

The efficient projection of D is the point J where 19 units of the output is produced from 10 units of the input. Thus the technical efficiency of the firm D is

$$TE(D) = \tfrac{12}{19}.$$

Note that unlike the point H, point J is on the downward sloping segment of the frontier and firm D could produce 20 units rather than 19 units of output, if it could reduce its input from 10 to 8 units. Thus, a measure of the incidence of input congestion at the input level of firm D is its congestion efficiency

$$CE(D) = \tfrac{19}{20}.$$

Note that once the point B is projected on to the frontier, there is no room for increasing output further by lowering the level of the input used. Thus, while the firm B is technically inefficient, it does not suffer from input congestion, however. Finally, consider the firm E. It already lies on the frontier and is, therefore technically efficient. It is possible, however, to increase output from *16* to 20 if it can reduce its input from 16 to 8. Thus, a measure of its congestion efficiency is

$$CE(E) = \tfrac{16}{20}.$$

Note that firm E is technically efficient in the sense that it does produce the maximum output possible from its existing input level. But it exhibits input congestion that results in a loss of output by 20%.

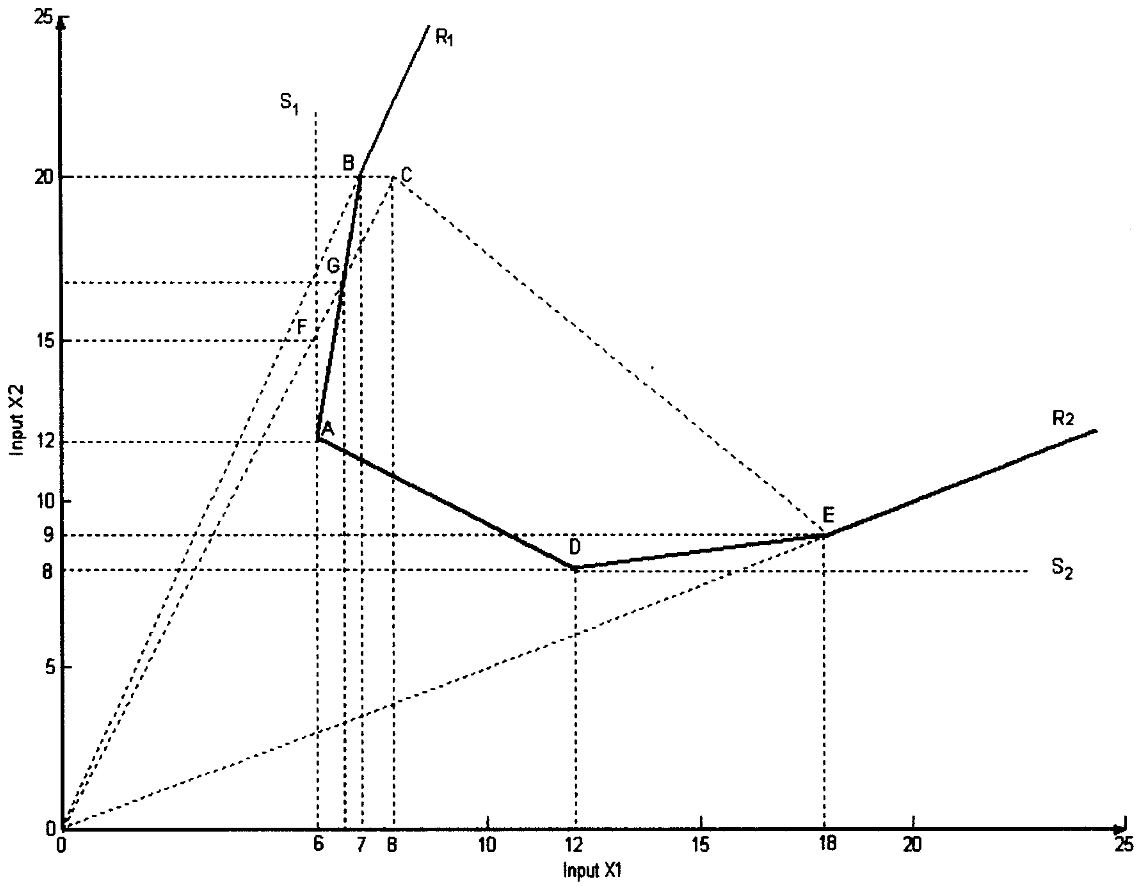
Example 7: Nonparametric Example of Weak Disposability and Congestion

For an example of weak disposability, we consider a two-input, one-output case. Suppose that output is freely disposable while inputs are only weakly disposable. Consider, for a simple example, a two-input, one-output case. Suppose that output is freely disposable while inputs are only weakly disposable. Exhibit 2 below shows the input quantities of 6 hypothetical firms each producing 12 units of the output:

Firm	A	B	C	D	E
input 1	6	7	8	12	18
input 2	12	20	20	8	9

Exhibit 2

Points A through E in Figure 4 show the input bundles of the firms.. Because all input bundles produce 12 units of the output, they all lie in the input requirement set for $y = 12$. By convexity, all points in the closed



Input X2
Input X1
25
20
15
12
10
9
8
5
0
0
6
7
8
10
12
15
18
20
25
R1
R2
S1
S2
A
B
C
D
E
F
G

Figure 4

area $A BCED$ also lie inside $V(y = 12)$. By weak disposability of inputs all radial expansion of points in this area also lie in the input requirement set of the specified output level. Thus the truncated cone represented by the area $R_1 BADER_2$ is the weak disposal input requirement set for $y = 12$. If, on the other hand, inputs were assumed to be strongly rather than weakly disposable, the usual free disposal convex hull shown by the area to the right of S_1ADS_2 would be the relevant input requirement set.

Now consider the input-oriented technical efficiency of Firm C. If free disposability is assumed, its radial projection onto the free-disposability isoquant is the point $F\ (x_1= 6,\ x_2=15)$ and the measure of efficiency is $\theta = \frac{3}{4}$. On the other hand, if only weak rather than strong (or free) disposability is assumed, the relevant projection is the point $G\ (x_1 = 6\frac{6}{11},\ x_2 = 16\frac{4}{11})$ on the weak-disposability isoquant. In that case, the technical efficiency will be $\theta_W = \frac{9}{11}$. It may be noted that at this point the isoquant is upward sloping and the marginal productivity of x_2 is negative. This corresponds to a negative shadow price for this input.

Färe, Grosskopf, and Lovell[2] (1994) attribute the difference between the two isoquants to input congestion and measure congestion efficiency[3] of a firm as:

$$\psi = \frac{\theta}{\theta_W}. \qquad (11)$$

In the present example, the congestion efficiency of firm C is

$$\psi_C = \tfrac{11}{12}.$$

3. The DEA Methodology

Except in the 1-input 1-output case, one cannot construct the production possibility set geometrically as shown in the simple example above and must use the mathematical programming approach of Data Envelopment Analysis (DEA) introduced by Charnes, Cooper, and Rhoades (CCR) (1978) and further generalized by Banker, Charnes, and Cooper (BCC) (1984).

3.1 Strong Disposability of All Inputs

The output-oriented model for measuring the technical efficiency of firm k under the assumption of variable returns to scale and strong disposability of inputs is the BCC DEA model:

$$\max \ \varphi$$

subject to

$$\sum_{1}^{N} \lambda_j y_{rj} \geq \varphi y_{rk}; (r = 1,2,\ldots,m);$$

$$\sum_{1}^{N} \lambda_j x_{ij} \leq x_{ik}; (i = 1,2,\ldots,n); \qquad (12)$$

$$\sum_{1}^{N} \lambda_j = 1;$$

$$\lambda_j \geq 0; (j = 1,2,\ldots,N); \quad \varphi \text{ free.}$$

Technical efficiency of firm k is measured by the inverse of the optimal value of φ. Note that an implication of the strong disposability assumption is that there can be slacks in individual inputs at the optimal solution without any effect on the level of efficiency.

3.2 Weak Disposability of All Inputs

If, on the other hand, inputs are assumed to be only weakly disposable, the appropriate DEA model is:

$$\max \ \varphi_W$$

subject to

$$\sum_{1}^{N} \lambda_j y_{rj} \geq \varphi_W y_{rk}; (r = 1,2,\ldots,m);$$

$$\sum_{1}^{N} \lambda_j x_{ij} = \alpha x_{ik}; (i = 1,2,\ldots,n); \qquad (13)$$

$$\sum_{1}^{N} \lambda_j = 1;$$

$$\lambda_j \geq 0; (j = 1,2,\ldots,N); \quad \alpha \leq 1; \quad \varphi_W \text{ free.}$$

3.3 Weak Disposability of Some Inputs

Next suppose that only a subset of inputs *(x^A)* is considered to be weakly disposable while the remaining inputs *(x^B)* are treated as strongly disposable, the model needs to be modified as follows:

$$\max \ \varphi_W^A$$

subject to

$$\sum_{1}^{N} \lambda_j y_{rj} \geq \varphi_W^A y_{rk}; (r = 1,2,\ldots,m);$$

$$\sum_{1}^{N} \lambda_j x^A{}_{ij} = \alpha x^A{}_{ik}; (i = 1,2,\ldots,n_1);$$

$$\sum_{1}^{N} \lambda_j x^B{}_{ij} \le x^B{}_{ik}; (i = 1,2,\ldots,n_2); \tag{14}$$

$$\sum_{1}^{N} \lambda_j = 1;$$

$$\lambda_j \ge 0; (j = 1,2,\ldots,N); \;\; \alpha \le 1; \;\; \varphi_W^A \text{ free.}$$

A measure of congestion efficiency of the inputs x^A is

$$\psi^A = \frac{\varphi}{\varphi_W^A}. \tag{15}$$

As noted before, if x^A has only one element, α must be set equal to unity.

4. The Application to Indian Manufacturing

4.1 The DEA Models

We conceptualize a single-output, 5-input production technology for the total manufacturing sector in India. Output *(y)* is measured by the gross value of production consisting of the value of shipments and change in the inventories of finished goods. The inputs include (i) production workers, (L_1) (ii) non-production workers (L_2), (iii) capital *(K)*, (iv) fuels *(F)*, and (v) materials *(M)*. The objective of the study is to determine whether the two different kinds of labor input (L_1 and L_2) together or individually lead to input congestion. For this we consider a number of alternative DEA models.

The first is a radial output-oriented BCC-DEA model assuming strong disposability of all inputs:

$$\max \varphi$$

subject to

$$\sum_j \lambda_j y_j \ge \varphi y^0 \quad \text{(output)}$$

$$\sum_j \lambda_j L_{1j} \le L_{10} \quad \text{(production labor);}$$

$$\sum_j \lambda_j L_{2j} \le L_{20} \quad \text{(non-production labor);} \tag{16}$$

$$\sum_j \lambda_j K_j \le K_0 \quad \text{(capital);}$$

$$\sum_j \lambda_j F_j \le F_0 \quad \text{(fuels)}$$

$$\sum_j \lambda_j M_j \le M_0 \quad \text{(materials)}$$

$$\sum_j \lambda_j = 1; \; \lambda_j \ge 0; (j = 1,2,\ldots,N).$$

When the optimal value φ^* is greater than unity, the difference $(\varphi^* - 1)$ shows that the proportion by which the output of the firm under investigation can be increased without increasing any input and keeping some inputs partially idle when appropriate. Being an output-oriented approach this does not penalize the firm for wasting inputs.

Next, we restrict the sub-vector of labor inputs to be weakly disposable while the non-labor inputs are assumed to be strongly disposable. The corresponding DEA model is:

$$
\begin{aligned}
&\max \ \varphi_W^{12} \\
&\text{subject to} \\
&\sum_1 \lambda_j y_j \geq \varphi_W^{12} y_0; \quad \text{(output)} \\
&\sum_j \lambda_j L_{1j} = \alpha L_{10} \quad \text{(production labor);} \\
&\sum_j \lambda_j L_{2j} = \alpha L_{20} \quad \text{(non-production labor);} \qquad (17) \\
&\sum_j \lambda_j K_j \leq K_0 \quad \text{(capital);} \\
&\sum_j \lambda_j F_j \leq F_0 \quad \text{(fuels)} \\
&\sum_j \lambda_j M_j \leq M_0 \quad \text{(materials)} \\
&\sum_1 \lambda_j = 1; \ \alpha \leq 1; \\
&\lambda_j \geq 0; (j = 1,2,\ldots,N); \varphi \text{ free.}
\end{aligned}
$$

If, for any specific firm, the optimal value of φ exceeds the optimal value of φ_W^{12}, the two labor inputs together cause congestion. The measure of labor congestion efficiency is

$$\psi^{12} = \frac{\varphi_w^{12}}{\varphi}.$$

Viewed differently, the difference $(\varphi - \varphi_W^{12})$ measures the potential increase in the output that cannot be realized because it is not possible to keep one kind of labor idle without keeping the other kind of labor idle as well.

Finally, we consider the case where, only one of the labor inputs (but not the other) is strongly disposable like the non-labor inputs. This implies of course that the remaining input is not disposable at all and must be used to the fullest extent even if it causes output to decline. The relevant DEA model is

$$
\begin{aligned}
&\max\ \varphi_W^k \\
&\text{subject to} \\
&\sum_j \lambda_j y_j \geq \varphi_W^k y_0; \quad \text{(output)} \\
&\sum_j \lambda_j L_{kj} = L_{k0} \quad (\text{k=1 or 2}); \\
&\sum_j \lambda_j L_{rj} \leq L_{r0}\ (\text{r=1 or 2; r} \neq \text{k}); \\
&\sum_j \lambda_j K_j \leq K_0 \quad \text{(capital)}; \\
&\sum_j \lambda_j F_j \leq F_0 \quad \text{(fuels)} \\
&\sum_j \lambda_j M_j \leq M_0 \quad \text{(materials)} \\
&\sum_j \lambda_j = 1;\ \alpha \leq 1; \\
&\lambda_j \geq 0; (j = 1,2,\ldots,N); \varphi_W^k \text{ free.}
\end{aligned}
\tag{18}
$$

A measure of congestion efficiency in this case is

$$
\psi^k = \frac{\varphi_w^k}{\varphi}. \tag{19}
$$

Again, the difference $(\varphi - \varphi_W^k)$ reflects the potential increase in output that is not realizable due to non-disposability of the specific type of labor input (production or non-production labor).

4.2 Data Construction

In this paper, we examine state-level data from India for the years 1986-87 through 1999-2000. The period up to 1990-91 is regarded as "pre-reform" and the subsequent period in the sample is regarded as "post-reform". The data for different states come from the Annual Survey of Industries (ASI) for the relevant years. In light of inter-state differences in the output-mix, use of gross value to measure output may appear problematic. However, as shown in Ray (2002), under the assumption of identical output prices for different kinds of manufactured products across the nation, the value of aggregate output in manufacturing can serve as a quantity index of output.

Labor inputs - both production and non-production workers - are measured by numbers of persons employed. The energy input was measured by expenses on fuels deflated by the fuel, power, and lubricant price index with 1981-82 as the base year. Similarly, the material input was measured by the cost of materials deflated by the industrial raw materials price index.

Measuring the 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 on two counts. 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 wear and tear of the hardware. People have, in some cases, used a perpetual inventory method to construct a capital stock series from annual investment data. That does not address the question of capacity utilization, however. In this paper, capital was measured as stock by the book value of fixed assets deflated by the price index of new capital equipment with 1981-82 as the base. This, clearly, is an imperfect measure. But, to the extent that the true capital input is distorted in a uniform manner for all states, their relative performance should not be affected seriously by this shortcoming.

A more serious problem that applies to all non-labor inputs is that no information on inter-state variation on prices was available. It was necessary, therefore, to apply the all-India price indexes as deflators for all states in any individual year.

5. The Empirical Findings

5.1 Detecting the Presence of Labor Congestion

Table 1a reports the optimal values of φ from the DEA LP problems (16) for the pre-Reform (1986-91) years. During the first period, 9 states, namely, Andhra Pradesh (AP), Bihar (BI), Himachal Pradesh (HP), Maharashtra (MH), Andaman & Nicobar (AN), Chandigarh (CH), Delhi (DE), and Goa (GO), were technically efficient in all the years. Among the remaining 13 states, Haryana (HA), Punjab (PU), Rajasthan (RA), Uttar Pradesh (UP), and West Bengal (WB) had average efficiency of less than 95% while Pondicherry (PO) and Orissa (OR) had efficiency lower than 97.5%.

Table 2a reports the optimal values of φ_W^{12} from the problem (17) where the labor inputs are treated as weakly disposable while the other inputs are strongly disposable. As explained before, $\varphi \geq \varphi_W^{12}$ by construction and a positive difference between the two shows the potential increase in output that remains unrealizable due to labor congestion. For example, consider the case of West Bengal (WB) and Kerala (KE) in the year 1986-87. Table 1a shows that when all inputs are treated as strongly disposable, eliminating technical inefficiency would increase the output by 3.20% in Kerala (KE) and by 2.55% in West Bengal. But, if the labor inputs are regarded as weakly disposable, no increase in the output would be possible. This is an evidence of labor congestion. By contrast, in the case of Haryana (HA) in the same year, the potential increase in output remains the same (by 9.15%) even when the labor inputs are treated as only weakly disposable. Thus, there is no evidence of labor congestion in this case. In fact, in 15 cases we find technical inefficiency but do not find labor congestion. They are

Haryana (HA),Orissa (OR), Punjab (PU) and Tamilnadu (TN) in 1986-87;

Orissa (OR), Punjab (PU), Rajasthan (RA), and Uttar Pradesh (UP) in 1987-88;

Gujarat (GU), Haryana (HA), Punjab (PU), and Uttar Pradesh (UP) in 1989-90; and

Punjab (PU), Tamilnadu (TN), and Uttar Pradesh (UP) in 1990-91.

States that are technically efficient under strong disposability of inputs are by definition also efficient under weak disposability and have no input congestion. During the pre-Reform years only one state, namely Gujarat (GU) showed no congestion in any year even though it showed some technical inefficiency during 1989-90. On the other hand, West Bengal (WB) and Pondicherry (PO) exhibited labor congestion in 4 out of the 5 pre-Reform years in our study.

Table 3a shows the levels of congestion efficiency for the individual years prior to the Reforms. In 5 states, namely Kerala (KE), Madhya Pradesh (MP), Uttar Pradesh (UP), West Bengal (WB), and Pondicherry (PO), the average level of congestion efficiency was less than 0.99. In specific cases, e.g. Madhya Pradesh (MP) in 1990-91, Kerala (KE) and Uttar Pradesh (UP) in 1986-87, and Assam (AS) and Kerala (KE) in 1988-89 congestion efficiency was less than 0.97.

The optimal values of φ for the post-Reform years (1991-2000) are reported in Table 1b. During this period, only 4 states (Bihar (BI), Chandigarh (CH), Delhi (DE), and Goa (GO)) were technically efficient in each year. All of these states were efficient in the pre-Reform years as well. Among the remaining states, only 5 (Haryana (HA), Madhya Pradesh (MP), Orissa (OR), Rajasthan (RA), and Pondicherry (PO)) had higher average efficiency in the post-Reform years than during the pre-Reform period. In Punjab (PU) and West Bengal (WB) average efficiency fell even below 90%. Even Maharashtra (MH) widely acclaimed as the leader in manufacturing showed evidence of technical inefficiency in the last 4 of the 9 years during the post-Reform period.

Table 3b shows the levels of congestion efficiency of the states during the different post-Reform years. In 3 states, namely Assam (AS), West Bengal (WB), and Pondicherry (PO), annual average level of congestion efficiency was below 96% and only barely above this mark in Kerala (KE). Among the other states, Andhra Pradesh (AP), Himachal Pradesh (HP), Jammu & Kashmir (JK), Karnataka (KA), Tamilnadu (TN), and Andaman and Nicobar (AN) had average congestion efficiency less than 0.99.

From the above discussion following broad conclusions emerge:

- Output-oriented technical efficiency has , on average, been lower during the post-Reform years for an overwhelming majority of the states.
- There has been an aggravation rather than a mitigation of the problem of labor input congestion in Indian manufacturing. Many more states show congestion in the second period than in the pre-Reform years.
- In a number of cases, congestion accounts for about 4% of the output lost due to inefficiency.
- In general, states that showed significant labor congestion in the pre-Reform years, continued to do so (often to a greater extent) in the post-Reform years as well. In fact, they were joined by other states that showed no congestion before.

5.2 Identifying Congestion by the Type of Labor Input

When two inputs are found to be only weakly disposable, it does not necessarily follow that both the inputs create congestion. Consider the following case. In farming, employing too many workers in a given plot of land creates overcrowding and congestion leading to a decline in the output. If, however, farm size and employment both increase together, output does not fall. In this sense, the land-labor pair is weakly disposable. If, however, only land is increased without any increase in employment, the additional area can be laid idle and the output level would remain unchanged. Thus, land itself is strongly disposable even though labor and land are together weakly disposable. On the other hand, there are situations where each of two inputs by itself can create congestion. For example, growing greenhouse tomatoes requires both moisture and heat. Increasing heat without moisture would cause the plants to dry up leading to crop damage. On the other hand, increasing moisture without increasing heat might cause mould and reduce output. Thus, either of the two inputs, if increased in isolation, can create congestion. In this section we examine whether only one or both types of labor inputs create congestion.

We solve two alternative versions of the DEA LP problem (18) for each state and each year. In one, production labor *(L_1)* is treated as non-disposable while all other inputs are strongly disposable. In the other, non-production labor *(L_2)* alone is non-disposable. Comparing the optimal value of the objective function obtained from LP (18) with the corresponding value obtained in LP (16) one gets the measure of congestion efficiency of the specific kind of labor. Tables 4a and 5a show the levels of congestion efficiency of the individual states during the pre-Reform years for production and non-production labor, respectively. In 1986-87 Kerala (KE) and Uttar Pradesh (UP) show congestion of L_1 but not of L_2 while Jammu and Kashmir (JK) and West Bengal (WB) show a slight measure of congestion of both kinds of labor. In 1987-88 the only state showing any noticeable degree of congestion was Pondicehrry (PO) in respect of non-production workers. In each of the 3 following years, West Bengal (WB) showed significant labor congestion for both production and non-production workers. In fact, by 1990-91, the levels of congestion efficiency in West Bengal had fallen below 0.90. While there was no consistent pattern, in general, congestion, when found, was more pronounced in respect of production workers although in 1990-91 the incidence of labor congestion was higher in respect of non-production workers.

Tables 4b and 5b show the state-wise congestion measures for production and non-production workers for the post-Reform years. During this period, there is clear evidence that production labor is the primary source of congestion. In numerous instances, there is significant congestion in production labor alongside no (or at least not a significant degree of) congestion in non-production labor. This is true of West Bengal (WB) in 1991-92 through 1996-97 (and to a certain extent in 1997-98), Pondicherry (PO) in 1991-92 and 1993-94 through 1995-96, Kerala (KE) in 1993-94, 1997-98 and 1998-99, and Assam (AS) in 1993-94 through 1996-97, 1998-99, and 1999-2000. In the cases of Haryana (HA) and Madhya Pradesh (MP), the opposite is true. Haryana (HA) shows a much greater degree of labor congestion for non-production workers than for production workers in most of the post-Reform years in our sample. Madhya Pradesh

(MP) shows a greater degree of congestion for non-production workers than for production workers in 1998-99. But, in general, production workers appear to be the source of labor congestion.

We can find indirect support for our conclusion from Ray and Bhattacharya (2003) who found that if one wanted to minimize either total employment or the total wage cost without either reducing the level of output or increasing any non-labor input, in most cases one would need to reduce the employment of production workers much more than the employment of non-production workers. In fact, in a number of cases, employment of non-production workers would actually have to be *increased* to accomplish the *maximum reduction in total employment*. During the pre-Reform years, on average, West Bengal (WB) would have to reduce production labor by 42.4% and non-production labor by 32.1%. In Kerala (KE) , on the other hand, while production labor would have to be reduced by 24.3%, non-production labor would actually have to be increased by 0.9%.During the post-Reform years, 5 of the 22 states (Andhra Pradesh (AP), Assam (AS), Bihar (BI), Kerala (KE), and Tamilnadu (TN)) would need to increase non-production labor. At the other end, 5 states (Haryana (HA), Karnataka (KA), Punjab (PU), West Bengal (WB), and Pondicherry (PO)) would need to reduce non-production labor by more than 10%. By contrast, 13 of the 22 states would need to reduce employment of production labor by more than 10%. In fact, West Bengal (WB) and Kerala (KE) would need to reduce the employment of production labor by 58% and 45% respectively. Assam (AS) and Punjab (PU) would have to lower production labor by over 35%. Overall, it is evident that there is a much greater measure of surplus among the production workers than among the non-production workers. Here we go a step further to show that the presence of surplus labor among non-production workers is much less detrimental to production than labor surplus among production workers.

A possible intuitive interpretation of labor congestion coming from production workers is the following. Non-production workers (often described as *employees*) include managers as well as administrative and white-collar employees. It is reasonable to argue that for an efficient functioning of the production process there is an optimal ratio of production to non-production workers. This, of course, may vary across states. But if only the number of white-collar workers is reduced while the number of production workers remains unchanged, insufficient monitoring by the managerial personnel on the one hand and inadequate logistical support from the overhead facilities (like stores, transportation, or accounting) on the other would create frequent disruption. Also the under-occupied workers may create distraction for other workers as well causing the output to go down. Interestingly, the reverse is not the case. If the number of production workers is reduced but the number of non-production workers is unchanged, while there may be idle workers in this category, there is no evidence that this would cause a decline in output. In that sense, a surplus of white-collar employees does not hinder production even though it affects cost efficiency.

Among the individual states, West Bengal (WB) presents an interesting picture. When the two kinds of labor input are treated as (jointly) weakly disposable, there is only a limited evidence of congestion in the pre-Reform years. During the same period, however, when only one kind of labor is treated as non-disposable and the other as freely disposable, congestion is found to be much more pronounced. The annual average level of congestion efficiency is below 95% and both production and non-production workers are found to create congestion. In fact, during the pre-Reform years West Bengal (WB) is the only state exhibiting any significant measure of labor congestion. The picture is quite different after the Reforms. During this second sub-period of our study, there appears to be a lesser degree of congestion caused by non-production workers. On the other hand, congestion from production workers seems to have worsened with average congestion efficiency falling to just above 90%. Three other states, namely Assam (AS), Kerala (KE), and Pondicherry (PO), also show considerable measure of congestion of production labor (with average annual levels of congestion efficiency around 0.96). At the same time, two states (Haryana (HA) and Jammu and Kashmir (JK)) show considerable measure of congestion of non-production workers. Labor congestion in West Bengal (WB) and Kerala (KE) may be ascribed, at least in part to labor militancy fostered by Left-front governments. Similarly, political unrest and deteriorating law and order conditions appear to have caused the congestion in Assam (AS) and Jammu and Kashmir (JK). But the persistent phenomenon of labor congestion in Pondicherry (PO) and Haryana (HA) is rather puzzling.

6. Summary

When the standard assumption of strong disposability is relaxed for the labor inputs, the evidence from the nonparametric analysis of state-level data from Indian manufacturing shows considerable measure of labor input congestion. While in selected states congestion comes from non-production workers as well, the principal source of labor congestion is production labor. There is no evidence that the problem of labor congestion has become less severe during the post-Reform years. It appears that market forces without any major institutional changes in enforcement of labor discipline cannot eliminate congestion.

A note of caution would be in order. Our findings are based on an analysis of the total manufacturing sector and may hide variation across industries within manufacturing. A more detailed sector-by-sector analysis of the question of labor congestion in manufacturing would be a logical extension of this line of research.

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Endnotes:

[1] Using a different approach Cooper, Deng, Gu, Li, and Thrall (2001) found that an "iron rice bowl" policy instituted shortly after the revolution resulted in congestion that led to bankruptcy in the textile industry and near bankruptcy in other industries. See also Brockett, Cooper, Shin, and Wang (1998).
[2] See also Färe and Grosskopf (1983).
[3] For an input-oriented empirical application see Färe, Grosskopf, and Logan (1983).

Table 1a: Optimal values of ϕ: Pre-Reform years.

Obs.	Name	Φ8687	Φ8788	Φ8889	Φ8990	Φ9091	MeanΦ
1	AP	1	1	1	1	1	1
2	AS	1	1	1.03679	1	1	1.007358
3	BI	1	1	1	1	1	1
4	GU	1	1	1	1.02466	1	1.004932
5	HA	1.09146	1.0846	1.09466	1.10285	1.0878	1.092274
6	HP	1	1	1	1	1	1
7	JK	1.00149	1	1.00576	1.00371	1	1.002192
8	KA	1	1	1	1	1.03446	1.006892
9	KE	1.03196	1	1.038	1	1.01115	1.016222
10	MP	1	1	1	1.00842	1.07644	1.016972
11	MH	1	1	1	1	1	1
12	OR	1.0147	1.05089	1	1	1.07933	1.028984
13	PU	1.06675	1.09283	1.1203	1.05133	1.14789	1.09582
14	RA	1	1.07462	1.08043	1.09445	1.11345	1.07259
15	TN	1.00832	1.02422	1.01061	1	1.02435	1.0135
16	UP	1.03939	1.05997	1.07618	1.0498	1.09696	1.06446
17	WB	1.02553	1	1.07114	1.09347	1.12589	1.063206
18	AN	1	1	1	1	1	1
19	CH	1	1	1	1	1	1
20	DE	1	1	1	1	1	1
21	GO	1	1	1	1	1	1
22	PO	1	1.03844	1.05221	1.08567	1.08362	1.051988

Table 2a: Optimal values of ϕ under joint weak-disposability of labor inputs: Pre-Reform years.

Obs.	Name	Φ128687	Φ128788	Φ128889	Φ128990	Φ129091	MeanΦ12
1	AP	1	1	1	1	1	1
2	AS	1	1	1	1	1	1
3	BI	1	1	1	1	1	1
4	GU	1	1	1	1.02466	1	1.004932
5	HA	1.09146	1.08451	1.09359	1.10285	1.08777	1.092036
6	HP	1	1	1	1	1	1
7	JK	1	1	1.0016	1	1	1.00032
8	KA	1	1	1	1	1.03165	1.00633
9	KE	1	1	1.0015	1	1	1.0003
10	MP	1	1	1	1	1	1
11	MH	1	1	1	1	1	1
12	OR	1.0147	1.05089	1	1	1.05592	1.024302
13	PU	1.06675	1.09283	1.11861	1.05133	1.14789	1.095482
14	RA	1	1.07462	1.07732	1.09261	1.11203	1.071316
15	TN	1.00832	1.02418	1	1	1.02435	1.01137
16	UP	1	1.05997	1.05951	1.0498	1.09696	1.053248
17	WB	1	1	1.05906	1.08993	1.10434	1.050666
18	AN	1	1	1	1	1	1
19	CH	1	1	1	1	1	1
20	DE	1	1	1	1	1	1
21	GO	1	1	1	1	1	1
22	PO	1	1.0276	1.02608	1.07672	1.05215	1.03651

Table 3a: Congestion efficiency under joint weak-disposability of labor inputs: Pre-Reform years.

Obs.	Name	ψ128687	ψ128788	ψ128889	ψ128990	ψ129091	Meanψ12
1	AP	1	1	1	1	1	1
2	AS	1	1	0.96452	1	1	0.9929
3	BI	1	1	1	1	1	1
4	GU	1	1	1	1	1	1
5	HA	1	0.99992	0.99902	1	0.99997	0.99978
6	HP	1	1	1	1	1	1
7	JK	0.99851	1	0.99586	0.9963	1	0.99814
8	KA	1	1	1	1	0.99728	0.99946
9	KE	0.96903	1	0.96484	1	0.98897	0.98457
10	MP	1	1	1	0.99165	0.92899	0.98413
11	MH	1	1	1	1	1	1
12	OR	1	1	1	1	0.97831	0.99566
13	PU	1	1	0.99849	1	1	0.9997
14	RA	1	1	0.99712	0.99832	0.99872	0.99883
15	TN	1	0.99996	0.9895	1	1	0.99789
16	UP	0.9621	1	0.98451	1	1	0.98932
17	WB	0.97511	1	0.98872	0.99676	0.98086	0.98829
18	AN	1	1	1	1	1	1
19	CH	1	1	1	1	1	1
20	DE	1	1	1	1	1	1
21	GO	1	1	1	1	1	1
22	PO	1	0.98956	0.97517	0.99176	0.97096	0.98549

Table 4a: Congestion efficiency of production labor: Pre-Reform years

Obs	name	ψ18687	ψ18788	ψ18889	ψ18990	ψ19091	Meanψ1
1	AP	1	1	1	1	1	1
2	AS	1	1	0.96452	1	1	0.9929
3	BI	1	1	1	1	1	1
4	GU	1	1	1	1	1	1
5	HA	1	0.99992	0.99829	1	0.99983	0.99961
6	HP	1	1	1	1	1	1
7	JK	0.99851	1	0.99427	0.9963	1	0.99782
8	KA	1	1	1	1	1	1
9	KE	0.96903	1	0.96419	1	0.98897	0.98444
10	MP	1	1	1	0.99165	1	0.99833
11	MH	1	1	1	1	1	1
12	OR	1	1	1	1	1	1
13	PU	1	1	0.99849	1	1	0.9997
14	RA	1	1	1	1	1	1
15	TN	1	0.99996	0.9895	1	1	0.99789
16	UP	0.9621	1	0.98451	1	1	0.98932
17	WB	0.97511	1	0.93358	0.91452	0.88819	0.94228
18	AN	1	1	1	1	1	1
19	CH	1	1	1	1	1	1
20	DE	1	1	1	1	1	1
21	GO	1	1	1	1	1	1
22	PO	1	1	0.97517	0.98706	0.92283	0.97701

Table 5a: Congestion efficiency of non-production labor: Pre-Reform years

Obs	name	ψ28687	ψ28788	ψ28889	ψ28990	ψ29091	Meanψ2
1	AP	1	1	1	1	1	1
2	AS	1	1	1	1	1	1
3	BI	1	1	1	1	1	1
4	GU	1	1	1	1	1	1
5	HA	1	1	1	1	0.9865	0.9973
6	HP	1	1	1	1	1	1
7	JK	0.99851	1	0.99427	0.9963	1	0.99782
8	KA	1	1	1	1	0.96669	0.99334
9	KE	1	1	1	1	1	1
10	MP	1	1	1	0.99165	0.92899	0.98413
11	MH	1	1	1	1	1	1
12	OR	1	1	1	1	0.97831	0.99566
13	PU	1	1	1	1	1	1
14	RA	1	1	0.99712	0.99832	0.99872	0.99883
15	TN	1	1	1	1	1	1
16	UP	1	1	1	1	1	1
17	WB	0.97511	1	0.93358	0.91452	0.88819	0.94228
18	AN	1	1	1	1	1	1
19	CH	1	1	1	1	1	1
20	DE	1	1	1	1	1	1
21	GO	1	1	1	1	1	1
22	PO	1	0.96298	1	0.97635	0.98061	0.98399

Table 1b: Optimal values of ϕ: Post-Reform years.

Obs	name	Φ9192	Φ9293	Φ9394	Φ9495	Φ9596	Φ9697	Φ9798	Φ9899	Φ9900	MeanΦ
1	AP	1	1	1	1	1	1	1	1.29084	1.15637	1.04969
2	AS	1	1	1.05678	1.05583	1.0176	1.09566	1	1.06498	1.17869	1.0521711
3	BI	1	1	1	1	1	1	1	1	1	1
4	GU	1.0477	1	1.07283	1.01713	1.02896	1.00243	1	1.04751	1.07548	1.0324489
5	HA	1.07341	1.09305	1.13764	1.0349	1.03264	1.16547	1.1069	1	1	1.0715567
6	HP	1	1	1	1	1	1	1.11829	1	1.06519	1.0203867
7	JK	1	1	1	1	1	1	1	1.1105	1.22138	1.0368756
8	KA	1	1.06567	1.05979	1.01769	1	1.05381	1.12295	1.05677	1.11733	1.05489
9	KE	1.00264	1	1.08391	1	1.02526	1	1.1538	1.1138	1	1.0421567
10	MP	1.06942	1	1	1	1	1	1	1.05669	1.00672	1.0147589
11	MH	1	1	1	1	1	1.00894	1.01162	1.0254	1.02339	1.0077056
12	OR	1	1	1.0643	1	1	1	1	1	1	1.0071444
13	PU	1.1076	1.11293	1.24333	1.1478	1.1546	1.1163	1.34626	1.01044	1.07053	1.1455322
14	RA	1.0166	1.01472	1.11155	1	1.0071	1	1.07864	1.18267	1	1.0456978
15	TN	1	1	1.00534	1	1	1.00488	1	1.09782	1.05774	1.01842
16	UP	1	1.04424	1.08609	1.01631	1.05434	1.01241	1.12162	1.19972	1.20433	1.0821178
17	WB	1.08584	1.06737	1.15805	1.06289	1.08496	1.10959	1.28286	1.1391	1.22981	1.1356078
18	AN	1	1	1.0003	1	1	1	1	1.18041	1	1.0200789
19	CH	1	1	1	1	1	1	1	1	1	1
20	DE	1	1	1	1	1	1	1	1	1	1
21	GO	1	1	1	1	1	1	1	1	1	1
22	PO	1.06027	1.03506	1.07382	1.10307	1.1548	1.02268	1	1	1	1.0499667

Table 2b: Optimal values of ϕ under joint weak disposability of labor inputs: Post-Reform years.

Obs	name	Φ129192	Φ129293	Φ129394	Φ129495	Φ129596	Φ129697	Φ129798	Φ129899	Φ129900	MeanΦ12
1	AP	1	1	1	1	1	1	1	1.13823	1.01785	1.01734222
2	AS	1	1	1	1.00979	1	1	1	1	1.06368	1.00816333
3	BI	1	1	1	1	1	1	1	1	1	1
4	GU	1.0477	1	1.07283	1.01713	1.02896	1.00243	1	1.04028	1.05135	1.02896444
5	HA	1.07047	1.09193	1.12851	1.03436	1.02616	1.13704	1.0777	1	1	1.06290778
6	HP	1	1	1	1	1	1	1.04838	1	1.02802	1.00848889
7	JK	1	1	1	1	1	1	1	1.05481	1.09976	1.01717444
8	KA	1	1.0597	1.0591	1.00407	1	1.04628	1.10178	1.03059	1.06899	1.04116778
9	KE	1	1	1	1	1	1	1	1	1	1
10	MP	1.05414	1	1	1	1	1	1	1.05562	1.00381	1.01261889
11	MH	1	1	1	1	1	1.0072	1.00661	1	1.02132	1.00390333
12	OR	1	1	1.05414	1	1	1	1	1	1	1.00601556
13	PU	1.1076	1.11293	1.23311	1.13854	1.1546	1.10441	1.34626	1	1.06327	1.14008
14	RA	1.0166	1.00826	1.10341	1	1.0071	1	1.07864	1.1643	1	1.04203444
15	TN	1	1	1	1	1	1.00334	1	1.03253	1.02205	1.00643556
16	UP	1	1.04424	1.07391	1	1.05089	1.00658	1.12162	1.18659	1.15652	1.07115
17	WB	1.04302	1.02121	1.09404	1.03412	1.0459	1.09279	1.22199	1.07306	1.13453	1.08451778
18	AN	1	1	1	1	1	1	1	1	1	1
19	CH	1	1	1	1	1	1	1	1	1	1
20	DE	1	1	1	1	1	1	1	1	1	1
21	GO	1	1	1	1	1	1	1	1	1	1
22	PO	1	1	1.03046	1	1	1	1	1	1	1.00338444

Table 3b: Congestion efficiency under joint weak disposability of labor inputs: Post-Reform years

Obs	name	ψ129192	ψ129293	ψ129394	ψ129495	ψ129596	ψ129697	ψ129798	ψ129899	ψ129900	Meanψ12
1	AP	1	1	1	1	1	1	1	0.88177	0.88021	0.97355
2	AS	1	1	0.94627	0.95639	0.9827	0.91269	1	0.93898	0.90243	0.95994
3	BI	1	1	1	1	1	1	1	1	1	1
4	GU	1	1	1	1	1	1	1	0.9931	0.97756	0.99674
5	HA	0.99726	0.99898	0.99197	0.99948	0.99372	0.97561	0.97362	1	1	0.99229
6	HP	1	1	1	1	1	1	0.93748	1	0.9651	0.98918
7	JK	1	1	1	1	1	1	1	0.94985	0.90042	0.98336
8	KA	1	0.9944	0.99935	0.98662	1	0.99285	0.98115	0.97523	0.95674	0.98737
9	KE	0.99737	1	0.92259	1	0.97536	1	0.8667	0.89783	1	0.9622
10	MP	0.98571	1	1	1	1	1	1	0.99899	0.99711	0.99798
11	MH	1	1	1	1	1	0.99828	0.99505	0.97523	0.99798	0.99628
12	OR	1	1	0.99045	1	1	1	1	1	1	0.99894
13	PU	1	1	0.99178	0.99193	1	0.98935	1	0.98967	0.99322	0.99511
14	RA	1	0.99363	0.99268	1	1	1	1	0.98447	1	0.99675
15	TN	1	1	0.99469	1	1	0.99847	1	0.94053	0.96626	0.98888
16	UP	1	1	0.98879	0.98395	0.99673	0.99424	1	0.98906	0.9603	0.99034
17	WB	0.96057	0.95675	0.94473	0.97293	0.964	0.98486	0.95255	0.94202	0.92252	0.95566
18	AN	1	1	0.9997	1	1	1	1	0.84716	1	0.98298
19	CH	1	1	1	1	1	1	1	1	1	1
20	DE	1	1	1	1	1	1	1	1	1	1
21	GO	1	1	1	1	1	1	1	1	1	1
22	PO	0.94316	0.96613	0.95962	0.90656	0.86595	0.97782	1	1	1	0.95769

Table 4b: Congestion efficiency of production labor: Post-Reform years

Obs	name	ψ19192	ψ19293	ψ19394	ψ19495	ψ19596	ψ19697	ψ19798	ψ19899	ψ19900	Meanψ1
1	AP	1	1	1	1	1	1	1	0.88177	0.88021	0.97355
2	AS	1	1	0.94627	0.95639	0.9827	0.91269	1	0.93898	0.90243	0.95994
3	BI	1	1	1	1	1	1	1	1	1	1
4	GU	1	1	1	1	1	1	1	0.9931	0.97756	0.99674
5	HA	0.99315	0.97412	0.99245	0.99359	0.96839	0.90101	1	1	1	0.9803
6	HP	1	1	1	1	1	1	0.92921	1	0.9622	0.98794
7	JK	1	1	1	1	1	1	1	0.9005	0.84968	0.97224
8	KA	1	0.99914	0.99165	0.98662	1	0.99018	0.99468	0.94628	0.92921	0.98197
9	KE	0.99737	1	0.92259	1	0.97536	1	0.8667	0.89783	1	0.9622
10	MP	1	1	1	1	1	1	1	0.9728	0.99332	0.99624
11	MH	1	1	1	1	1	1	1	0.98814	0.98409	0.99691
12	OR	1	1	0.93958	1	1	1	1	1	1	0.99329
13	PU	1	1	1	0.99193	1	0.99963	1	0.98967	0.99322	0.99716
14	RA	1	1	1	1	1	1	1	0.98447	1	0.99827
15	TN	1	1	0.99469	1	1	0.99514	1	0.94053	0.96626	0.98851
16	UP	1	1	0.98879	0.98395	0.99673	0.99424	1	0.98768	0.9603	0.99019
17	WB	0.92095	0.93688	0.94473	0.96914	0.92169	0.90123	0.77951	0.87789	0.87087	0.90254
18	AN	1	1	0.9997	1	1	1	1	0.84716	1	0.98298
19	CH	1	1	1	1	1	1	1	1	1	1
20	DE	1	1	1	1	1	1	1	1	1	1
21	GO	1	1	1	1	1	1	1	1	1	1
22	PO	0.94316	0.96613	0.95962	0.90656	0.86595	0.97782	1	1	1	0.95769

Table 5b: Congestion efficiency of non-production labor: Post-Reform years

Obs	name	ψ29192	ψ29293	ψ29394	ψ29495	ψ29596	ψ29697	ψ29798	ψ29899	ψ29900	Meanψ2
1	AP	1	1	1	1	1	1	1	1	1	1
2	AS	1	1	1	1	0.99901	0.99399	1	1	1	0.99922
3	BI	1	1	1	1	1	1	1	1	1	1
4	GU	1	1	1	1	1	1	1	1	1	1
5	HA	0.99247	0.91487	0.9685	0.96628	0.96839	0.85802	0.92685	1	1	0.95504
6	HP	1	1	1	1	1	1	0.89422	1	1	0.98825
7	JK	1	1	1	1	1	1	1	0.9005	0.81875	0.9688
8	KA	1	0.9796	0.96976	1	1	0.98704	0.98115	0.98811	0.89642	0.97801
9	KE	1	1	1	1	1	1	1	1	1	1
10	MP	0.98571	1	1	1	1	1	1	0.94964	0.99332	0.99208
11	MH	1	1	1	1	1	0.99489	0.99505	0.97523	0.97714	0.99359
12	OR	1	1	1	1	1	1	1	1	1	1
13	PU	1	1	0.98375	0.99936	1	0.98878	1	1	1	0.99688
14	RA	1	0.99363	0.99194	1	1	1	1	1	1	0.9984
15	TN	1	1	1	1	1	0.99608	1	1	1	0.99956
16	UP	1	1	1	1	1	1	1	1	1	1
17	WB	0.99589	1	1	1	1	0.99891	0.96389	0.87789	0.81313	0.96108
18	AN	1	1	0.9997	1	1	1	1	0.89413	1	0.9882
19	CH	1	1	1	1	1	1	1	1	1	1
20	DE	1	1	1	1	1	1	1	1	1	1
21	GO	1	1	1	1	1	1	1	1	1	1
22	PO	1	0.96613	1	1	1	0.99879	1	1	1	0.9961