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Efficiency dynamics and sustainability of the Indian IT-ITeS industry: An empirical investigation using DEA

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Abstract Efficiency considerations of the Indian IT-ITeS industry have come to the forefront especially with slowdown in the US and other major industrialised economies. Using the DEA technique, this paper argues that the key to sustainability rests on the operational efficiency of the players. Primary data for this study has been collected from STP Kolkata for a period of 15 years. The results reveal that (technical) efficiency varies across industry segments and increases with greater global orientation of the unit. The study prescribes segment-specific policies for sustainability of the industry instead of a uniform policy that has been the usual practice.

The Indian IT-ITeS industry has been successful in positioning itself as one of the most favoured outsourcing destinations, especially since the beginning of the 21st century. However, in recent times, issues concerning sustainability of the industry have come to the forefront. The outbreak of the sub-prime crisis that has engulfed major industrialised nations, notably the US (India's major trading partner) has resulted in lower offshore outsourcing. This is coupled with rising wage inflation that is eroding cost arbitrage; stiff competition from various low-cost destinations like Ireland, China, Philippines, and Vietnam that is eating into India's share in the offshore outsourcing pie; lack of product innovation leading to specialisation in services (and not products) and thereby lower earnings; and exchange rate vulnerabilities resulting in uncertain export realisations.

In view of these developments, efficiency considerations have assumed prominence, since sustainability of this industry rests on the operational efficiency of its players. As a result, identification of possible determinants of efficiency is of prime importance, both for industry participants and policymakers. However, this important aspect of efficiency considerations in the context of the Indian IT-ITeS industry has remained unexamined, primarily due to the paucity of granular data.

In this study, an attempt has been made to measure efficiency and thereby identify the possible determinants of efficiency, by incorporating Data Envelopment Analysis

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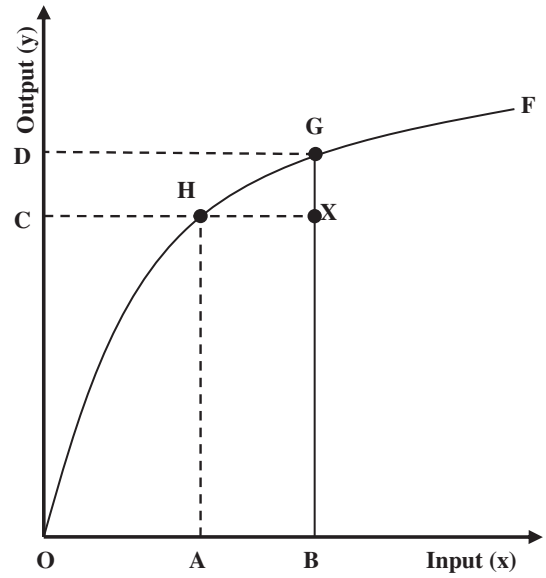
(DEA). The novelty of the technique is that it enables measurement of (comparative) efficiencies of the units without any information regarding the product and input prices. The data for this purpose has been collected from STP Kolkata, one of the nodal centres of its parent body Software Technology Parks of India (STPI). The data set considers the entire population (census) for the period of 15 years, Fiscal Year 1993 to Fiscal Year 2007 (FY93—FY07). The analysis carried out in this study is subject to the structure of the data set and its limitations.

We begin by exploring the theoretical underpinnings of the DEA technique in the next section, wherein the concept of the DEA is introduced using the simplest possible case of a firm that uses a single input to produce a single output. The graphical technique is then employed in order to measure the efficiencies and in the process, visualise the difference between the input- and output-oriented measures of technical efficiency. The single input-single output case is then generalised to account for multiple inputs-multiple outputs using the linear programming (LP) technique. The third section explores the nature and structure of the data set which has been collected solely from STP Kolkata. In the fourth section, we apply the DEA technique to the IT-ITeS industry in order to measure the efficiencies of the operating units and account for the variability in efficiencies across various segments of the industry. Concluding observations are made in the fifth section, including policy prescriptions.

Data envelopment analysis: theoretical considerations

In its purest form, DEA measures relative efficiencies of decision making units (DMUs) using multiple inputs in order to produce multiple outputs. These DMUs must be homogeneous entities in the sense that they must use the same set of resources for producing their output. For obvious reasons, proper identification of the inputs and outputs is crucial before incorporating DEA. The inputs must take into consideration all the resources that influence the output. On the other hand, the outputs must reflect all the possible outcomes that can be used to assess the efficiency of each DMU (Thanassoulis, 2001). When we talk of relative efficiencies, it implies that these efficiencies are compared with the efficient DMU (or DMUs). In our case, these DMUs are the firms that operate in the industry.

The novelty of the DEA technique is that it enables us to measure the efficiencies of the DMUs without any information regarding the product and input prices. This form of efficiency in the terminology of the DEA literature is known as "technical efficiency". Depending on whether output augmentation or input conservation is more important, two related measures of technical efficiency have been devised, namely technical output efficiency and technical input efficiency. The distinction between the two is illustrated in Fig. 1. It represents the simplest possible case wherein a single output is produced using a single input. The curve OF is the locus of maximum levels of output attainable from the given set of inputs. In other words, OF represents the efficient frontier. Given the frontier, DEA



Output-oriented technical efficiency: OC/OD
Input-oriented technical efficiency: OA/OB

Figure 1 Technical efficiencies.

provides an efficiency score between zero and one, with a score of one assigned to those DMUs that are on the frontier. The DMUs that are on the frontier either produce maximum output given the input levels or use minimum inputs to produce given level of output. In the former case, a DMU is said to be "output efficient" and in the latter it is said to be "input efficient".

A representative DMU operating at X might have been operating at G so as to produce maximum output level OD, given its input level OB. On the other hand, it could have operated at H, by using the minimum possible input OA, for the given output level OC. Thus the DMU is not Pareto efficient for it can produce more output from a given input level, or use less input for producing a given output level. Hence, output efficiency can be defined as the ratio of actual output attainable from the given input to the maximum attainable output from that input, i.e. OC/OD. Conversely, input efficiency can be defined as the ratio of the minimum input required for a given level of output to the actual input required to produce that level of output i.e. OA/OB. Thus, the concerned DMUs may have different efficiency scores depending on the type of efficiency being considered.

The graphical analysis presented above considers the simplest possible case where a DMU uses a single input to produce a single output. Using the LP technique, the graphical analysis can be easily generalised to account for multiple DMUs, each using multiple inputs to produce multiple outputs. In the generalised version, we make the following specifications:

- There are N DMUs to be evaluated, producing m outputs from n inputs
- A representative DMU, say t, uses the input bundle $x^t = (x_{1t}, x_{2t}, \ldots, x_{nt})$ to produce the output bundle $y^t = (y_{1t}, y_{2t}, \ldots, y_{mt})$

- Each DMU has at least one positive input and one positive output value i.e. $x_{it} \geq 0$ ($i = 1,2,\ldots,n$) and $y_{rt} \geq 0$ ($r = 1,2,\ldots,m$)
- Let $u^t = (u_{1t}, u_{2t},\ldots,u_{nt})$ be the shadow price of inputs and $v^t = (v_{1t}, v_{2t},\ldots,v_{mt})$ be the shadow price of outputs.[1]

Using these specifications, we can measure the average productivity of the DMU t as

$$\mathrm{AP}_t = \frac{\sum v_{rt} y_{rt}}{\sum u_{it} x_{it}} = \frac{v^{t'} y^t}{u^{t'} x^t}; \quad (r = 1,2,\ldots,m;\ i = 1,2,\ldots,n).$$

There are numerous combinations of shadow price vectors (u^t, v^t) and we choose the one that maximises AP_t, subject to two constraints which are noted below:

$$\text{(i)}\ u_{it} \geq 0; \quad (i = 1,2,\ldots,n); \quad v_{rt} \geq 0; \quad (r = 1,2,\ldots,m),$$

$$\text{(ii)}\ \mathrm{AP}_j = \frac{\sum v_{rt} y_{rj}}{\sum u_{it} x_{ij}} = \frac{v^{t'} y^j}{u^{t'} x^j} \leq 1; \quad (j = 1,2,\ldots,t,\ldots,N).$$

The first constraint implies that the shadow prices must be non-negative, though zero prices are admissible for individual inputs and outputs. The second constraint implies that shadow prices have to be such that when aggregation is done using these prices, no DMU's input—output bundle results in average productivity greater than unity (Ray, 2004).[2]

This is a standard linear programming problem (LPP) and we state the problem as

$$\begin{aligned}
&\text{Max } Z = v^{t'} y^t / u^{t'} x^t \\
&\text{s.t. } v^{t'} y^j / u^{t'} x^j \leq 1 \\
&u_{it} \geq 0; \quad v_{rt} \geq 0 \quad (i = 1,2,\ldots,n;\ r = 1,2,\ldots,m).
\end{aligned}$$

However, the problem with this LPP formulation is that it has infinite number of solutions. To avoid this problem, Charnes and Cooper (1962)[3] proposed a transformation in which the shadow price vectors (u^t, v^t) are normalised to form a new set of shadow price vectors (μ^t, γ^t), by imposing a constraint $\mu^{t'} x^t = 1$.

The transformed LPP may be stated as

$$\begin{aligned}
&\text{Max } Z' = \gamma^{t'} y^t \\
&\text{s.t. } \gamma^{t'} y^j - \mu^{t'} x^j \leq 1; \quad (j = 1,2,\ldots,t,\ldots,N) \\
&\mu^{t'} x^t = 1 \\
&\mu^t \geq 0; \quad \gamma^t \geq 0.
\end{aligned}$$

The dual of this problem is

$$\begin{aligned}
&\text{Min } \theta \\
&\text{s.t. } \sum \lambda_j x^j \leq \theta x^t \\
&\sum \lambda_j y^j \geq y^t \\
&\lambda_j \geq 0 \quad (j = 1,2,\ldots,t,\ldots,N).
\end{aligned}$$

The optimal solution of this problem may be represented as $(\theta^*; \lambda_i^*, \lambda_2^*, \ldots, \lambda_N^*)$.

Let (x^{t*}, y^t) be the efficient input-oriented radial projection of (x^t, y^t) on to the envelopment frontier, where $x^{t*} = \theta^* x^t$.

Hence, the input-oriented measure of technical efficiency under constant returns to scale (CRS) may be denoted as $\mathrm{TE}_I^C\ (x^t, y^t) = \theta^*$

The output-oriented measure of technical efficiency is obtained from the solution of the following LPP:

$$\begin{aligned}
&\text{Max } \phi \\
&\text{s.t. } \sum \lambda_j x^j \leq x^t \\
&\sum \lambda_j y^j \geq \phi y^t \\
&\lambda_j \geq 0 \quad (j = 1,2,\ldots,t,\ldots,N).
\end{aligned}$$

The optimal solution of this problem may be represented as $(\phi^*; \lambda_i^*, \lambda_2^*, \ldots, \lambda_N^*)$.

Let (x^t, y^{t*}) be the efficient input-oriented radial projection of (x^t, y^t) on to the envelopment frontier, where $y^{t*} = \phi^* y^t$.

Hence, the output-oriented measure of technical efficiency under CRS may be denoted as

$$\mathrm{TE}_O^C(x^t, y^t) = 1/\phi^*.$$

Under CRS, both the output and the input-oriented measures of technical efficiencies are one and the same, i.e. $\theta^* = 1/\phi^*$.

The LPPs thus formulated to measure the efficiency scores under CRS can be easily modified to take into account the case for variable returns to scale (VRS) as well by imposing an additional constraint $\sum \lambda_j = 1$ ($j = 1,2,\ldots t,\ldots,N$).

The modified LPPs may be written as

$$\begin{aligned}
&\text{Min } \theta \\
&\text{s.t. } \sum \lambda_j x^j \leq \theta x^t \\
&\sum \lambda_j y^j \geq y^t \\
&\sum \lambda_j = 1 \\
&\lambda_j \geq 0 \quad (j = 1,2,\ldots t,\ldots,N).
\end{aligned}$$

The optimal solution of this problem may be represented as $(\theta^*; \lambda_i^*, \lambda_2^*, \ldots, \lambda_N^*)$.

$$\begin{aligned}
&\mathrm{TE}_I^V(x^t, y^t) = \theta^* \\
&\text{Max } \phi \\
&\text{s.t. } \sum \lambda_j x^j \leq x^t \\
&\sum \lambda_j y^j \geq \phi y^t \\
&\sum \lambda_j = 1 \\
&\lambda_j \geq 0 \quad (j = 1,2,\ldots t,\ldots,N).
\end{aligned}$$

[1] We have taken into consideration shadow prices of inputs and outputs in order to measure the average productivity since we do not have any information regarding product or input prices.

[2] These two assumptions follow directly from the definition of efficiency in the DEA literature, wherein efficiency scores vary between zero and one. Violation of these assumptions would imply that efficiency scores cannot be computed in cases involving multiple inputs and multiple outputs. In other words, these two constraints enable us to compute efficiency scores using LPP for multiple DMUs, producing multiple outputs using multiple inputs.

[3] The Charnes—Cooper transformation: in this transformation, we replace the shadow price vectors (u^t, v^t) by a new set of vectors (μ^t, γ^t), where
$\mu_{it} = (u_{it}/\sum u_{it} x_{it};\ i = 1,2,\ldots,n)$; and
$\gamma_{rt} = (v_{rt}/\sum u_{it} x_{it};\ i = 1,2,\ldots,n;\ r = 1,2,\ldots,m)$.
By imposing the restriction $\sum \mu_{it} x_{it} = 1$ ($i = 1,2,\ldots,n$), the LPP may be restated as
$\text{Max } Z' = \gamma^{t'} y^t$
$\text{s.t. } \gamma^{t'} y^j - \mu^{t'} x^j \leq 1$; ($j = 1,2,\ldots,t,\ldots,N$)
$\mu^{t'} x^t = 1$
$\mu^t \geq 0$; $\gamma^t \geq 0$.

The optimal solution of this problem may be represented as $(\phi^*; \lambda_i^*, \lambda_2^*, \ldots, \lambda_N^*)$.

$TE_O^V(x^t, y^t) = 1/\phi^*$.

Under VRS, $TE_I^V(x^t, y^t) = \theta^* \neq TE_O^V(x^t, y^t) = 1/\phi^*$. They will equal if $\theta^* = 1 = 1/\phi^*$, i.e. when the observed input—output bundle lies on the envelopment frontier. In other words, when the observed input—output bundle lies on the envelopment frontier, the efficiency scores (both under input- and output-oriented measures) would be the same, irrespective of whether we are assuming CRS or VRS. This is because of the fact that the output level of the DMU which lies on the efficient frontier, cannot be raised without raising the input level, nor can the input level be lowered without lowering the output level (Ray, 2004; Thanassoulis, 2001). This would apply if we assume CRS. In all other cases, the efficiency scores obtained under VRS are greater than or equal to those obtained under CRS.

There are several distinct advantages of the DEA technique:

- It is non-parametric.
- It uses linear programming techniques to calculate the efficiency.
- It is independent of the units of measurement.
- It does not require any specified set of assumptions.
- Being non-statistical in nature, it produces no standard errors and leaves no room for hypothesis testing.
- It enables comparative analysis by providing relative efficiency score of each DMU.

The DEA technique has been widely used in empirical research towards performance evaluation of manufacturing and service operations, given its novelty in computation of efficiency scores in the absence of complete information of prices (Briec, Dervaux, & Leleu, 2007; Charnes, Cooper, Lewin, & Seiford, 1994; Fare, Grosskopf, & Li, 1992; Li & Ng, 1995).

Data description

Data for this study has been collected solely from the statutory reports submitted by the registered units in prescribed formats to STP Kolkata.[4] These include annual performance report-cum auditor's certificate, monthly, and quarterly performance reports.

A major part of our data has been collected from the performance details furnished by the member units in their auditor's certificate at the end of each financial year.[5] The auditor's certificate provides the following information:

1. The date of STP approval: It corresponds to the date in which the letter of permission (LoP) is issued by the STP to its member units.[6] Only after the LoP is issued, can the member units start their commercial operation.
2. The capital goods (CG) limit that is approved by the STP: While applying for STP registration, units are required to specify their projected imports for their tenure of five years. The projected imports for a five-year term give their CG limit, subject to STP approval. Units, whose imports cross the approved CG limit, do not get any import duty relief for the additional imports. However, the units can enhance their CG limit by writing to STP, subject to STP approval.
3. Performance: The performance of the member units is outlined in terms of the export earnings, which can fall into seven broad categories, namely software application (SA), product development (PD), embedded software (ES), business process outsourcing (BPO), call centre (CC), medical transcription (MT) and other IT-enabled services (Other ITeS). Specification of the exact domain of export earnings has enabled us to classify the units in accordance with the products or services they are offering.[7] In addition to the exports, units can also venture into sales in the domestic market as indicated by the actual domestic tariff area (DTA) sales executed by the units.
4. Components of cost: The costs incurred by the units as reported in their auditor's certificate fall in three broad categories. These include
   i. Cost for import of capital goods: Capital goods are imported either through direct purchase or on loan or lease basis. Firms import capital goods for infrastructural purposes which include computers, computer related accessories, furniture and fixtures, networking and telecommunication equipment, air conditioning systems, and security systems. The provision of 100% duty free imports is one of the chief attractions for registration with STP.
   a. Cost towards other foreign exchange outflow (other FE outflow): This includes foreign exchange outflow (other than the imports of capital goods) which a single unit normally incurs for a variety of purposes such as import of spares and consumables, repatriation of dividends and profits to foreign collaborators, royalty, lump sum know-how fee, design and drawing fee, payment for training of Indian technicians abroad, payment to foreign technicians, commission on export, and foreign travel.

[4] The Software Technology Parks (STPs) were established as an autonomous society by Government of India on 5th June 1991 to promote exports of software and services. Since its inception, the parent body STPI has set up a number of centres or nodal offices in various parts of India. Presently, there are 52 nodal centres in the country. STP Kolkata is one such nodal wing and is administered by West Bengal Electronics Industry Development Corporation (WEBEL) under the powers delegated by STPI for implementing the scheme in the state of West Bengal. Among 52 nodal centres, STP Kolkata happens to be the sixth largest STP in terms of exports, the first being STP Bangalore (STPI Annual Report, 2010—2011).

[5] In this connection, it is important to state that the units that are non-operational do not submit their auditor's certificate for they do not have any performance. Thus, the units that do not furnish their auditor's certificate are deemed to be non-operational.

[6] Unless and until the STP issues the LoP, the units cannot operate under the purview of the STP scheme.

[7] In this connection, it needs to be mentioned that there are some units that have multiple segments, though the number of such units is few.

Table 1 Export-obligation of member units.

Period of registration	Export-obligation
Before 1st April 1999	• 1.5 × (Annual wage bill to be achieved on annual basis) + 1.5 × (value of imports to be achieved over a period of 4 years).
After 1st April 1999	• NEEP = 20% for the units registered with effect from 1st April 1999 • Exports to be achieved in 5 years: USD 250,000 or 5 × (value of imports), whichever is higher.
Between 1st April 2001—31st March 2003	• NEEP = 10% for the units registered with effect from 01/04/2001 • Exports to be achieved in 5 years: USD 250,000 or 3 × (value of imports), whichever is higher.
After 31st March 2003	• The unit shall be a positive net foreign exchange earner (in 5 years), i.e. NFE = $(A - B) > 0$.

Note: NEEP: net exports earning potential.
NEEP = $((A - B) \times 100)/A$; where A = exports and B = total FE outflow.

b. Amount of interest to be paid on external commercial borrowing/deferred payment credit etc.

In practice, these costs are firm-specific and are incurred for upgrading the existing capabilities. As a result, a higher other FE outflow essentially signifies the maturity and increased global orientation of the firm.

ii. Cost for meeting the monthly salaries (i.e. wage bill) of the employees: The wage bill component was present in the auditor's certificate for the period FY93—FY04. However, since FY05 the auditor's certificate did not have the wage bill component since it no longer played a role towards computation of the export-obligation of the units.

A brief account of the export-obligation[8] that the units are required to fulfil in order to avail the benefits of the STP scheme is outlined in Table 1.

Thus, the units that obtained STP registration prior to 1st April 1999 had to furnish their wage bill for computation of export-obligation. The wage bill factor was not taken into account for those units that entered after 1st April 1999. However, the format of the auditor's certificate remained unchanged till FY04 and as a result all the units furnished their wage bill. Since FY05, the wage bill component was extracted from the monthly performance reports as thereafter it no longer found a place in the auditor's certificate.

5. Investment: Member units are also required to furnish their investment figures in their auditor's certificate. There are three sources of investment, namely foreign investment, NRI investment, and Indian investment.
6. Employment: Employment has never been taken into consideration for computation of the export-obligation of the member units. As a result, units were not required to furnish employment data in their auditor's certificate. Employment figures, instead, were extracted from the monthly performance reports. Average monthly employment in a given year was considered as employment for the said year.
7. Capital stock: Capital stock figures were not available for the years FY93—FY04 and they were incorporated in the auditor's certificate only in FY05. As a result, capital stock was estimated using import and investment figures as the firms built up their capital stock either through import of capital goods or through investment or both. The discounted sum of domestic and imported capital adjusted for appreciation and depreciation was used to compute the capital stock as enumerated by the formulae given below

$$K_i^t = \left[I_i^t + M_i^t\right] + \left[I_i^{t-1}(1-\delta)(1+(\rho-P)) + M_i^{t-1}(1-\gamma)(1+(\rho-P))\right] + \left[I_i^{t-2}(1-\delta)^2(1+(\rho-P))^2 + M_i^{t-2}(1-\gamma)^2(1+(\rho-P))^2\right] + \left[I_i^{t-3}(1-\delta)^3(1+(\rho-P))^3 + M_i^{t-3}(1-\gamma)^3(1+(\rho-P))^3\right] + \cdots\cdots.$$

where

K_i^t = capital stock of the i-th firm in period t
I_i^t = investment of the i-th firm in period t
M_i^t = imports of capital goods of the i-th firm in period t
ρ = weighted average of interest rates of central government securities for the respective years
P: consumer price index (urban non-manual employee) (CPI UNME) for Kolkata for the respective years
δ = depreciation on investment which is taken as 15%
γ = depreciation on imports of capital goods which is taken as 60%[9]

Incorporation of DEA

In order to incorporate DEA into the industry, we have considered employment and capital stock as inputs[10] and total revenue[11] as output. Considering the fact that the industry is

[8] The export-obligation of the member units has been revised from time to time and the structure of the annual performance report-cum-auditor's certificate has been revised in order to calculate the export-obligation.

[9] Specified by Ministry of Information Technology, GOI.

[10] The measurement of capital stock and employment has been outlined in the third section.

[11] Consideration of a composite score to represent output is an interesting avenue for further research in this area.

Table 2 Industry concentration.

FY	No. of players	C_5	SA	PD	ES	BPO	CC	MT	Other ITeS
FY97	17	95.79	5	—	—	—	—	—	—
FY98	24	74.31	5	—	—	—	—	—	—
FY99	29	66.37	5	—	—	—	—	—	—
FY00	51	59.88	4	1	—	—	—	—	—
FY01	68	61.60	5	—	—	—	—	—	—
FY02	77	70.96	5	—	—	—	—	—	—
FY03	99	71.75	5	—	—	—	—	—	—
FY04	104	74.20	5	—	—	—	—	—	—
FY05	123	77.04	5	—	—	—	—	—	—
FY06	144	76.18	5	—	—	—	—	—	—
FY07	167	70.20	5	—	—	—	—	—	—

C_5: five firm concentration ratio.
SA: software application; PD: product development; ES: embedded software; BPO: business process outsourcing; CC; call centre; MT: medical transcription; other ITeS: other IT-enabled services.

highly concentrated, with Top-5 firms accounting for over 70% of industry earnings consistently since FY02 (Table 2), we have run the DEA exercise in two phases (Tables 3–6).[12]

In phase I, we took into consideration *All* the firms that were in operation since FY97[13] and in phase II, we eliminated the Top-5 firms[14] for each financial year and only considered the *Rest* before running the DEA exercise. The DEA exercise was carried out separately for each financial year. Thus, for each financial year, we had two different sets of efficiency scores – one that considered *All* the firms for a given financial year and the one that considered only the firms in the *Rest* category.[15] For efficiency measurement, we have considered the output-oriented measure of technical efficiency. We have assumed VRS to make the analysis more general.

Fig. 2 illustrates the variability in technical output efficiencies across the various segments over the years on an average considering all the firms. It appears that over the years, technical output efficiency has exhibited a decline on an average. Though there is some variability in efficiency scores across various segments over the years on the whole, the IT-enabled units (namely call centres, medical transcription centres and BPO units) have witnessed lower efficiency scores on an average as compared to their software development counterparts. The picture is no different when we eliminate the Top-5 firms in each financial year (Fig. 3).

A graphical analysis gives us only an initial perception about the variability in efficiency scores across the various segments over the years. A regression analysis would substantiate this variability and infer exactly the extent of variability across various segments.

Model

We have constructed two regression models with the twin objectives of substantiating the variability in efficiency scores across the various segments (Model I) and identifying the possible determinants of efficiency (Model II).

In order to measure the variability in efficiency scores across the various segments of the industry, we have used intercept dummies in Model I. Since the industry has been broadly classified into seven segments, we have used six dummies, with software application as the base or reference category.[16] Hence all product-wise comparisons are made with reference to this category. For the purposes of regression, the pooling technique has been adopted.

The six dummies that we have used for facilitating comparisons across various segments are defined below:

$$D_2^{PD} = 1, \quad \text{if the firm is a product development unit}$$
$$= 0, \quad \text{otherwise}$$
$$D_3^{ES} = 1, \quad \text{if the firm is an embedded software unit}$$
$$= 0, \quad \text{otherwise}$$
$$D_4^{BPO} = 1, \quad \text{if the firm is a BPO unit}$$
$$= 0, \quad \text{otherwise}$$
$$D_5^{CC} = 1, \quad \text{if the firm is a call centre unit}$$
$$= 0, \quad \text{otherwise}$$
$$D_6^{MT} = 1, \quad \text{if the firm a medical transcription unit}$$
$$= 0, \quad \text{otherwise}$$
$$D_7^{\text{Other ITeS}} = 1, \quad \text{if the firm is an other ITeS unit}$$
$$= 0, \quad \text{otherwise.}$$

[12] The five firm concentration ratio (C_5) reveals that Top-5 players have accounted for 70% of the industry revenues consistently since FY02. Segment-wise break-up of the Top-5 firms reveals that they are invariably engaged in software development and not ITeS.

[13] We have not considered the years FY93 to FY96, since the number of operating firms for the said period was extremely low.

[14] We have eliminated the Top-5 firms for each financial year since the efficiency rankings of the *Rest* of the firms would be grossly underestimated in their presence, considering the fact that DEA is a comparative measure of efficiency. Further, it would enable us to figure out the extent variability in efficiency scores across the seven segments in their absence in a much better way.

[15] The *Rest* category comprises all the firms for a given financial year barring the Top-5 firms of that year.

[16] Software application has been used as the reference category for two reasons:
(a) Software application units were there since inception.
(b) Majority of the units are engaged in software application.

Table 3 Descriptive statistics for output efficiency scores under VRS-*All*.

Output efficiency under VRS-*All*	*N*	Mean		Standard deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	S.E.	Statistic	Statistic	Statistic	S.E.	Statistic	S.E.
SA	514	0.31	0.01	0.31	0.10	1.14	0.11	0.12	0.22
PD	84	0.37	0.04	0.34	0.12	0.77	0.26	−0.80	0.52
ES	21	0.18	0.03	0.15	0.02	1.31	0.50	1.67	0.97
BPO	56	0.18	0.03	0.25	0.06	2.26	0.32	4.63	0.63
CC	67	0.09	0.01	0.12	0.01	3.52	0.29	16.67	0.58
MT	62	0.10	0.03	0.21	0.04	3.94	0.30	15.00	0.60
Other ITeS	99	0.25	0.03	0.27	0.07	1.79	0.24	2.56	0.48
All	903	0.27	0.01	0.30	0.09	1.40	0.08	0.85	0.16

VRS: variable returns to scale.
SA: software application; PD: product development; ES: embedded software; BPO: business process outsourcing; CC; call centre; MT: medical transcription,; Other ITeS: other IT-enabled services.

Model I

$$Y_i = \beta_1 + \beta_2\left(D_2^{PD}\right) + \beta_3\left(D_3^{ES}\right) + \beta_4\left(D_4^{BPO}\right) + \beta_5\left(D_5^{CC}\right) + \beta_6\left(D_6^{MT}\right) + \beta_7\left(D_7^{\text{Other ITeS}}\right) + \beta_8(\text{time}) + u_i$$

Analysis and interpretation

The regression results obtained in Models IA and IB are similar in more ways than one.

- All the coefficients have expected signs and significance.
- Technical output efficiency under VRS has declined on an average over the years, though this decline is not statistically significant.
- Software application and product development units are comparatively efficient.
- Call centres, BPO and medical transcription units have significantly lower technical efficiency scores among all the other segments.

The basic reason for this decline in technical efficiency over the years, under VRS irrespective of whether we are considering *All* firms or only the firms in the *Rest* category is that DEA is a comparative measure of efficiency. As more firms enter the industry, competition increases, thereby reducing the gap between "technically efficient" and "technically inefficient" firms. As a result, average efficiency as a whole falls.

The IT-ITeS industry at STP Kolkata, in the formative years, consisted of software application and product development units only. It was FY00 that witnessed the birth of the ITeS sector, with the entry of call centres, BPO and medical transcription units and the non-software development firms grew in subsequent years. In FY00 around 70% of the firms in the industry were software application firms and their share declined steadily to around 47% in FY07. Moreover, the average exports of ITeS units picked up since FY03. Thus, it is not only in terms of numbers but also in terms of revenue earning capacity that the non-software development firms have gained in importance over the years.

The growth of the industry was characterised by increasing prominence of non-software development units with firms competing against each other to enhance their

Table 4 Descriptive statistics for output efficiency scores under VRS-*Rest*.

Output efficiency under VRS-*Rest*	*N*	Mean		Standard deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	S.E.	Statistic	Statistic	Statistic	S.E.	Statistic	S.E.
SA	461	0.35	0.02	0.33	0.11	0.82	0.11	−0.57	0.23
PD	83	0.44	0.04	0.35	0.13	0.46	0.26	−1.24	0.52
ES	21	0.23	0.04	0.16	0.03	0.65	0.50	−0.15	0.97
BPO	55	0.22	0.03	0.25	0.07	1.95	0.32	3.53	0.63
CC	67	0.15	0.02	0.19	0.04	2.14	0.29	4.77	0.58
MT	62	0.12	0.03	0.21	0.04	3.76	0.30	14.01	0.60
Other ITeS	99	0.32	0.03	0.31	0.09	1.22	0.24	0.41	0.48
All	848	0.31	0.01	0.32	0.10	1.07	0.08	−0.06	0.17

VRS: variable returns to scale.
SA: software application; PD: product development; ES: embedded software; BPO: business process outsourcing; CC; call centre; MT: medical transcription,; Other ITeS: other IT-enabled services.

competitive standing in the international market. Thus over the years, the industry witnessed a transformation with the emergence of a handful of big or "technically efficient" players and a large number of small and mid-sized or "technically inefficient" players manifested in lower efficiency scores on an average.

In order to trace the factors accounting for variability in efficiency scores in the various segments, we need to revisit the components that have been used for the computation of the efficiency scores. While total revenue has been used as output, capital stock and employment have been used as input. On the output front, the software development units, such as software application and product development have produced a much higher output as compared to their counterparts in the ITeS segment, comprising call centres, medical transcription, BPO and other ITeS units. This is understandable, considering the nature and volume of projects and the size of the units. The large size of the firms enables them to enjoy the economies of scale, and diversity of projects over the years has enabled them to enjoy the economies of scope. In contrast, the ITeS segment comprises firms that are either mid-sized or small players. In a bid to sustain themselves in the industry in the face of dominance of industry majors, the mid-sized players are venturing into various niche service lines instead of being end-to-end service providers.

These players do not have the requisite resources (both human and physical) to undertake projects that encompass the entire value-chain. Instead, dedicated focus on niche areas has enabled them to develop their "areas of excellence" and thereby strategically differentiate themselves from the rest.[17] While this strategic differentiation empowers them to sustain themselves in the industry, it results in lower revenue realisation as compared to their software development counterparts. The service offerings of their software development counterparts on the other hand, encompass the entire value-chain of IT resulting in higher revenue realisation. This lower revenue realisation given the input usage is manifested in terms of lower efficiency scores for the ITeS segment.

Further, software development entails core activity as compared to IT-enabled services which are non-strategic or non-core in nature.[18] These services are labour-intensive primarily involving back office operations and are usually outsourced from the user organisation, often to a third party (third party outsourcing) or in some cases a subsidiary of its own (captive BPO) using software as a means of production and the Internet as a transporting medium (Aranya, 2008; Coward, 2002; Joshi, 2011; Rajeev & Vani, 2007). This distinction is manifested in terms of the variability in revenue realisations.

With regard to the inputs, the ITeS segment tends to absorb more labour as it is less demanding in terms of skill. We highlight the differences between the two segments,

Table 5 Regression results — Model I.

Model	N	Adj. R^2	F stat	Y_i	Regressors							
					Constant	D_2^{PD}	D_3^{ES}	D_4^{BPO}	D_5^{CC}	D_6^{MT}	$D_7^{Other\ ITeS}$	Year
IA	903	0.069	10.609**	$(ovrs\_te)^{ALL}$	0.327	0.068	−0.127	−0.120	−0.217	−0.205	−0.051	−0.002
					(7.385)	(1.977)*	(−1.967)*	(−2.900)**	(−5.654)**	(−5.257)**	(−1.590)	(−0.453)
IB	848	0.073	10.573**	$(ovrs\_te)^{REST}$	0.337	0.085	−0.120	−0.125	−0.230	−0.234	−0.027	−0.004
					(15.870)	(2.344)*	(−1.775)@	(−2.860)**	(−5.091)**	(−5.686)**	(−0.811)	(−0.990)

Notes:
1. Figures in the parenthesis are t-values.
**Denotes significant at 1% level.
*Denotes significant at 5% level.
@Denotes significant at 10% level.
2. The dummy variables simply point out the differences, if any, but they do not suggest the reasons for the differences (Gujarati, 2004: p. 301). In other words, dummy variables do not explain the variability in the dependent variable; they simply capture the differences with respect to the base or reference category, if they exist. This results in low values of adjusted R^2 in models involving dummy variables as explanatory variables. Nevertheless, these models do not lose their statistical significance provided the F statistic is significant.

[17] If strategic differentiation is not forthcoming, then players are left with no other option but to deliver more features, quality and client-specific calibrations for less in order to retain their clientele.
[18] The distinction between core and non-core activity is from the point of view of the client, which may be IT firms or may involve a broader range of sectors such as banking, telecom, travel and tourism wherein IT is deployed (Coward, 2002).

Table 6 Regression results — Model II.

Model	N	Adj. R^2	F stat	Y_i	Regressors		
					Constant	Share of other FE outflow	NFE
IIA	903	0.101	34.862**	$(\text{ovrs\_te})^{ALL}$	0.219	0.265	1.223
					(19.415)	(5.937)**	(7.685)**
IIB	848	0.195	103.775**	$(\text{ovrs\_te})^{REST}$	0.227	0.287	0.0002
					(18.841)	(6.110)**	(12.927)**

Notes:
1. Figures in the parenthesis are t-values.
**Denotes significant at 1% level.
2. In empirical studies involving cross-sectional data with several observations, one generally obtains low values of adjusted R^2 because of the diversity of the cross-sectional units (Gujarati, 2004: p. 260). In such cases, the significance F statistic may be considered to find out whether the model has the overall statistical significance.

namely software development and ITeS with regard to the skill component in alignment with Coward (2002). Firstly, software development entails in-depth knowledge of computer programming languages, networks and software programmes in contrast to ITeS. Coward (2002) puts it aptly when he says, "employees need to know how to use computers, but not understand how they work". Secondly, from an educational perspective, software development requires people with either a background in computer science or advanced technical training. For ITeS, elementary computer training with a proficiency in the English language is sufficient. Thirdly, software development is much more communication intensive involving an iterative process of building, checking, revising, and testing in contrast to ITeS, wherein, once the process is established, there is less need for project communications. Fourthly, while cost considerations are one of the major drivers of outsourcing software development and ITeS projects, the quality of service often becomes a critical factor in case of software development as compared to ITeS. More specifically, for outsourcing software development work, very few companies would opt for the lowest cost provider. Instead, they would look at "highest value" entailing cost with quality of service. In contrast, for ITeS, especially those that do not require spoken language proficiency, the cost factor assumes prominence. Only for language-based IT-enabled services like call centres, cost savings are weighed against the quality of the customer interaction.

With regard to the capital stock, firms build up their capital stock either through imports or investment or both. A study of the trajectory of imports at STP Kolkata reveals that ITeS units have tended to import on a much higher scale on an average towards establishment of their initial set up at least in the formative years as compared to software development units which have maintained steady imports throughout. On the other hand, segment-wise break-up of investment reveals that since FY01 there has been significant increase in investment in the ITeS segments, though the software application segment retained its leadership both in absolute and relative terms. The increase in investment in ITeS segments has been most prominent in call centres, followed by BPOs and medical transcription units. As a result, output generation vis-a-vis input usage on an average has been far greater for the software development units as compared to their ITeS counterparts.

Finally, it needs to be mentioned that output efficiency essentially implies production of the maximum possible output with a given level of inputs. For software application or product development firms, the marginal cost of reproduction of their product is almost nil which implies that the average cost of production falls drastically with the rise in output ensuring a higher output efficiency. Further, much of their revenues come from maintenance or upgradation of their existing products and/or services in which resource utilisation is virtually negligible as compared to revenue realisation (Cusumano, 2003). In this connection, it is worthwhile mentioning that since maintenance tends to be resource (labour) intensive, much of the outsourcing work comes to India.[19] Indian firms have executed many such projects (e.g. the Y2K projects) that have not only yielded lucrative revenues for Indian firms but have also absorbed labour, which is abundant in India (Athreye, 2005; Dongier & Sudan, 2009; Krishnan & Vallabhaneni, 2010).

In contrast, call centres, BPO and medical transcription units use more resources in delivering their services in comparison to other segments. That makes them significantly less efficient.

Identifying possible determinants of efficiency

Having thus determined the efficiency scores and accounted for their variability across the various segments, we have also attempted to find out the factors that significantly influence the efficiency scores. Model II does this.

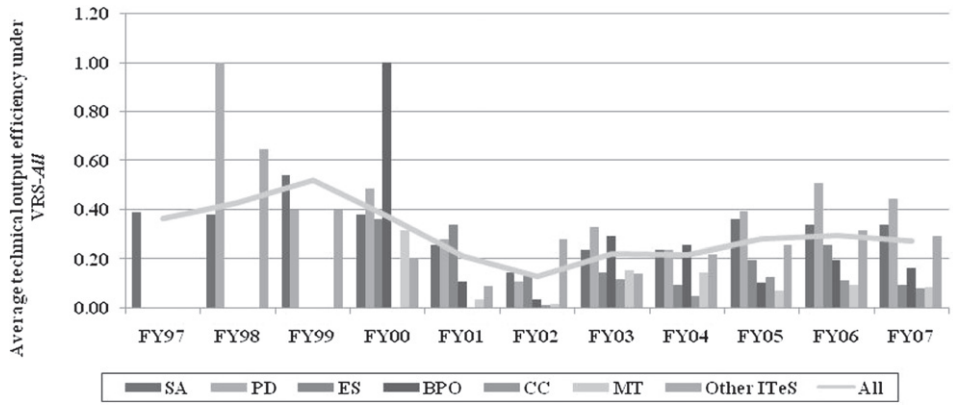
Model II

$$(\text{ovrs\_te})_i = \beta_1 + \beta_2(\text{net\_fe}) + \beta_3(\text{sh\_other fe\_out/tc}) + u_i,$$

Where

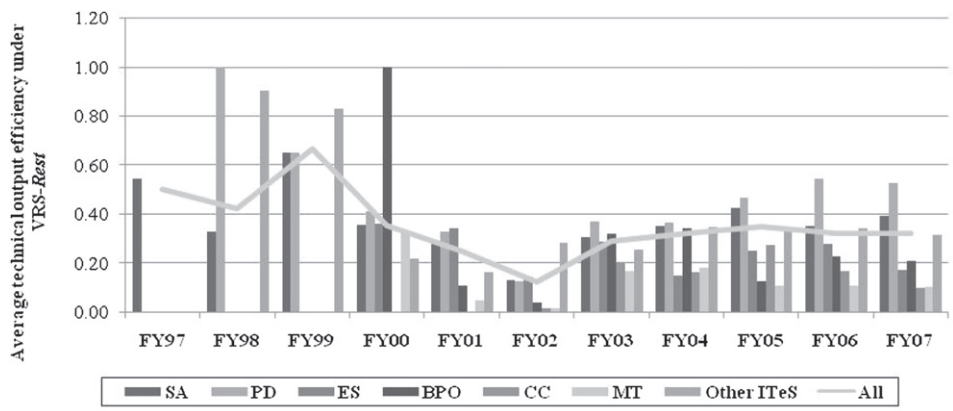
$(\text{ovrs\_te})_i$ = technical output efficiency under VRS of the i-th DMU
net_fe = net foreign exchange earnings
sh_other fe_out = other FE outflow/total cost

[19] We are thankful to the reviewer for pointing this out. This is corroborated by the fact that India happened to be the largest recipient of global sourcing in the IT sector, accounting for 55% of the addressable global sourcing market in 2010, an increase from 51% in 2009 (Information Technology Annual Report, 2010—2011, Ministry of Communications and Information Technology, Government of India).



SA: software application; PD: product development; ES: embedded software; BPO: business process outsourcing; CC; call centre; MT: medical transcription; Other ITeS: other IT enabled services.

Figure 2 Average technical output efficiency under VRS-*All*. SA: software application; PD: product development; ES: embedded software; BPO: business process outsourcing; CC; call centre; MT: medical transcription; other ITeS: other IT-enabled services.



SA: software application; PD: product development; ES: embedded software; BPO: business process outsourcing; CC; call centre; MT: medical transcription; Other ITeS: other IT enabled services.

Figure 3 Average technical output efficiency under VRS-*Rest*. SA: software application; PD: product development; ES: embedded software; BPO: business process outsourcing; CC; call centre; MT: medical transcription; other ITeS: other IT-enabled services.

Interpretation

The regression results reveal that both Net Foreign Exchange (FE) Earnings and Share of Other FE Outflow in total cost are significant determinants of output efficiency. The determinants of Other FE Outflow outlined in the section "Data description" explain the international orientation of the unit, which is manifested in terms of higher exports. Once again, higher the exports higher the Net FE earnings and hence higher the efficiency.

The sign of these coefficients imply

- Higher the Net Foreign Exchange Earnings, higher the output efficiency
- Higher the Share of Other FE Outflow in total cost, higher the output efficiency.

Concluding observations

This study attempts to estimate the efficiency of the IT-ITeS industry drawing from the firm-level data collected from STP Kolkata with a view to highlight the heterogeneity inherent in the Indian IT-ITeS industry. The validity of the generalisation of the findings of the study of firms at STP Kolkata to the Indian IT-ITeS industry as a whole may be questioned, given the differential sizes and the number of players observed at the two levels. However, in this study, we have attempted such generalisation on account of the similarity in industry dynamics observed at the two levels. The similarity stems from (a) unrivalled export-orientation (b) industry structure which is pyramidal; (c) the service offerings that encompass the entire value-chain of IT; and (d) the dominance of software development units since inception and the birth of the ITeS sector in 1999—2000.

From the study the heterogeneity in the industry is apparent on two fronts. On the one hand, there are a few big players and a large number of smaller units. As a result, the industry remains highly concentrated, notwithstanding the entry of new players over the years. The big players are invariably involved in software development and due to the high switching costs involved in software development they tend to enjoy "repeat" clients. Their domination remains unabated since they tend to benefit from economies of scale and scope. On the other hand, the industry comprises

a diverse set of firms with significant differences among its various segments. From the data obtained from STP Kolkata, the industry was classified into seven broad segments in accordance with the product or services being offered. From the analysis it appears that all these are different spheres of activities. The heterogeneity among them is such that they could be considered different industries altogether (Coward, 2002). Whereas, the software development (namely, software application, product development and embedded software) units continue to be leading foreign exchange earners, ITeS units like call centres and BPOs seem to provide ample employment opportunities, albeit lower compensation. Hence, there is a trade-off between higher foreign exchange earnings and higher employment generation.

However, this inherent heterogeneity in the IT-ITeS industry has not been taken into account by the government or regulatory bodies while devising policies or measures to promote the industry, primarily due to paucity of granular data. The policy initiatives for the Indian IT-ITeS industry followed a structuralist model till the 1970s and a liberalised model thereafter, especially since 1984 with the initiation of the New Computer Policy (Heeks, 1996). Having realised the foreign exchange earning potential of the industry, the government began acting as a facilitator rather than a controller by the beginning of 1990s (Kapur, 2002). To curb infrastructural bottlenecks and enable offshore development of software and services, the government established software technology parks in 1991. Other measures included investing public money into building a high speed national telecommunications infrastructure, spreading the use of IT in government institutions, setting up venture capital funds and increased bank lending provisioning Indian firms to raise debt and equity in global capital markets, provisioning foreign institutional investment in Indian capital markets, increasing depreciation on computers and related accessories, and so on (Coward, 2002; Dutta, 2001; Kapur, 2002; Kapur & Ramamurti, 2001; Patibandla, Kapur, & Petersen, 2000).

The launch of the STP scheme in 1991 was beneficial to the industry as it provided single window clearance for a diverse set of activities (Arora & Bagde, 2010; Sarma & Krishna, 2010). However, there is no provision in the STP scheme to distinguish between big and small players and grant benefits in accordance with their size[20] or to distinguish between a software development unit and a call centre for example, as long as the concerned unit fulfils the minimum export-obligation.[21] As a result, the scheme has not been able to address this important (and neglected) issue of heterogeneity in the industry.

The Indian ITeS industry has been successful in cementing its footprint in the global market with a plethora of products and services; it is critical for the policymakers to take note of the inherent heterogeneity of the industry and devise suitable policies. This has assumed importance in the present times, given that the slowdown of the US economy in particular and major industrialised economies in general, has led to a reduced volume of outsourcing. Added to this is the industry's inability to penetrate newer geographies with considerable success, emerging competition from various low-cost destinations, wage inflation hitting the bottom-line growth, and exchange rate vulnerabilities resulting in uncertain export realisations. Segment-specific or size-specific policy is called for as this will instil competition and bring about all round development of the industry.

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[20] As a matter of fact, some of the industry majors have gone for multiple registrations with STP i.e. a player say A, have obtained three more registrations with STP in the name of A1, A2 and A3, just to reap the benefits offered by the STP scheme, which allows provision of 100% duty free imports. The STP scheme does not have any provision to keep a check on these activities.

[21] Employment has never been taken into consideration for computation of the export-obligation of the units. Hence, members have no incentive whatsoever to raise the level of employment.

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