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Promises and Challenges in India's Manufacturing Sector

Guest Editors

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Committed to examining diverse aspects of the changes taking place in our society, *Review of Development and Change* aims to encourage scholarship that perceives problems of development and social change in depth, documents them with care, interprets them with rigour and communicates the findings in a way that is accessible to readers from different backgrounds.

Infrastructural Development and Firm Efficiency in India (1999–2007)

Neha Hui, Subham Kailthya and **Uma Kambhampati***

Abstract

In this paper, we examine the impact of macroeconomic conditions and firm characteristics on firm efficiency and output in the Indian manufacturing sector. We estimate stochastic frontier production functions for six different industries using level annual data for 1999–2007. Our results indicate that while frontier output showed an overall increase, efficiency levels remained largely stagnant during our study period. We find no positive impact of infrastructural improvements on firm efficiency. The results stay robust to using a synthetic index of macroeconomic variables. In almost all the cases, we find that infrastructural improvements in power generation capacity, electrification of railways, bank expansion or road construction are associated with a rise in frontier output (or production potential of firms) and a decline in firm efficiency (or the actual to potential output ratio). Our analysis suggests that the underlying reason for this puzzle might be a shifting out of production frontiers over time at a pace higher than the rate of increase in output, which is consistent with uneven utilisation of improvements in infrastructure amongst firms.

Keywords: *firm-efficiency, stochastic frontier model, time-varying efficiency, India*

1. Introduction

The 1990s and 2000s witnessed a period of very high economic growth in India. This led many pundits to argue that India would soon compete with China for top position in the world economy. Economic growth rate hovered around 6.6 per cent per annum during the 8th Five Year Plan (FYP, 1992–97), declined to 5.7 per

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cent per annum during the 9th FYP (1997–2002) before rising to 7.6 per cent per annum during the 10th FYP (2002–07). However, despite this growth experience, there have been fears that the high growth phase is unsustainable, some of which have been borne out in the light of the economy's recent slowdown.

Although the latest downturn in the domestic economy has been, in large part, related to one of the worst global recessions to hit the world economy, concerns regarding India's economic performance have focussed on two fronts: the lopsided service sector-driven growth and the underperformance of the manufacturing sector on the export front. The contribution of the manufacturing sector to India's GDP even at its peak in 1995 was only 17.3 per cent. In contrast, the service sector's contribution was 46.3 per cent for the same period. And despite many years of high growth, the manufacturing sector's contribution to GDP declined to 13.9 per cent in 2011. Banga and Das (2012) confirm these trends and find that the Indian manufacturing sector grew at an annual average rate of 5.4 per cent in the 1990s, lower than its annual average rate of 6 per cent in the 1980s. Even in the high growth period of 2000–07, manufacturing value-added contribution grew at an annual rate of 7.4 per cent. In fact, it has been the services sector that has outpaced the other sectors since 1991 and has seen its share increase from 44.5 per cent of GDP in 1990 to 56.4 per cent in 2011. The slower progress of the manufacturing sector has led to concerns about premature de-industrialisation in India. In view of this, the Indian government has set a target for the manufacturing sector to contribute 25 per cent of GDP by 2025 (Government of India, 2011a).

A second related concern often expressed regarding the Indian manufacturing sector is its underperformance on the export front. The structural reforms in 1991 reduced protection against foreign imports and devalued the currency – improving trade to GDP ratios from 11 per cent in 1995 to 24 per cent in 2007. Although India's share of global merchandise exports has improved in the last decade, it was only 1.3 per cent even in 2009 (up from 0.5 per cent in 1990) (Government of India, 2011b). Moreover, even though India's exports have been growing faster than the world average, manufacturing exports in India constitute 61.5 per cent of total merchandise exports. In comparison, China's manufacturing exports contribute 93 per cent of its total merchandise exports. India's share of world exports exceeded 10 per cent only in primary commodities like tea, spices, leather, rice and gems and jewellery (14.8 per cent). Within the manufacturing sector, the leading exporters were pharmaceuticals and chemicals (4.9 per cent), machinery and instruments (5.1 per cent), transport equipment (6.1 per cent) and garments (4.3 per cent) (Government of India, 2013).

Against this background, a number of studies have analysed the productivity and efficiency of Indian manufacturing firms in recent years. We add to this literature by estimating the efficiency of firms operating in India at a disaggregated industry level for six manufacturing industries between 1999 and 2007. We explore the trends in efficiency over time, analysing in particular whether Indian manufacturing firms have gained or lost in efficiency terms. Second, we identify the firm-specific characteristics and macroeconomic determinants of three aspects of performance – firm efficiency, frontier output (or the maximum potential production given a fixed input bundle) and growth in the observed output of firms. Efficiency in our analysis is defined as the ratio of observed output to potential output so that a firm that produces the maximum possible level of output is considered to be fully efficient and any deviation from the maximum possible production captures the degree of inefficiency. Efficiency, of course, is dynamic and responds not only to the strategic decisions made by the firms themselves, but also to the environment in which the firms function. Thus, factors external to the firm such as public investments in transport network, electrification, etc. are all likely to influence firm efficiency, although the impact is expected to vary across firms.

Our paper makes two main contributions to the literature. First, we not only analyse the factors that affect firm efficiency, as many others have done before, but we also examine the determinants of frontier output and the growth of firms. Since output is predicted as an outcome of capital, labour and materials, factors that influence frontier output are those that might cause the extensive growth of firms. By analysing the factors influencing both efficiency (derived from the systematic residual) and frontier output (the output predicted by only the inputs), we are able to consider the factors influencing both the location of the frontier and also the distance of each firm from this frontier. Second, we consider the effect of infrastructural development and broader macroeconomic changes on industrial performance. Many studies have argued that infrastructural and macroeconomic constraints have resulted in capacity underutilisation in the Indian industry. If this is true, then improvements in infrastructure and a weak currency in post-liberalisation India might be expected to have a positive impact on firm efficiency.

India's investment in infrastructure has grown significantly in recent years. Since 1991, power generation and transport infrastructure have improved dramatically. The installed plant capacity for power generation doubled from 82,400 MW in 1992 to 168,000 MW in 2007 (to a massive 243,000 MW by 2014). Similarly, the electrification of railways gathered momentum. Having taken 40 years to grow from 400 km in 1950 to 10,000 km in 1990/91, it doubled in the next two decades to 21,000 km by 2012/13. Similarly, the network of national highways grew in length from 19,800 km in 1950 to 34,000 km in 1990/91 and more than doubled to 70,500 km by 2008/9. Such improvements in physical infrastructure reduce constraints on growth by making it easier to transport goods across the country and by opening up a wider market. In addition, the Indian financial sector has also witnessed visible growth through, for instance, greater financial coverage that channels savings to productive investment. How have these economy-wide developments affected the production and efficiency of Indian manufacturing firms? We address this question in Sections 4 and 5.

Our results indicate that, contrary to initial expectations, infrastructural developments and a weaker currency have not helped to increase the efficiency of firms. However, these developments have significantly increased frontier output and growth in actual output of firms during this period. Thus, our results allow us to conclude that while macroeconomic developments have helped firms to increase the level of capital (K), labour (L) and raw materials (M) that they can employ to raise output, they have failed to increase the efficiency with which these inputs are employed.

Our paper is organised as follows: In the next section, we review some of the extant literature studying the productivity and efficiency of Indian industries, which helps identify potential candidate variables for our empirical analysis. Section 3 outlines our estimation methodology. Section 4 describes the data set and the econometric specification used in estimating firm efficiency, frontier output and growth in actual output and identifies firm-specific and macroeconomic factors explaining differences across firms. Section 5 presents the results from our analysis; Section 6 concludes.

2. Literature Review

There is a large and long-standing literature on productivity growth in Indian manufacturing. Much of this has concentrated on measuring the average productivity in Indian industries and to some extent on analysing the causes of poor productivity. Trivedi et al. (2011) contend, after a review of the existing literature, that total factor productivity growth (TFPG) in Indian manufacturing decelerated after the reforms of 1991. However, their conclusion remains contentious because it is often argued that productivity trends cannot be generalised across sectors. Kathuria et al. (2013), for instance, argue that looking at average TFPG is meaningless because TFP varied significantly across the formal and informal sectors. Sivadasan (2006) distinguished between industries that were de-licensed and those that were not. He found increased productivity in the former, as well as in those affected by the liberalisation of foreign direct investment (FDI) liberalisation (which saw an increase in productivity from 18 to 23 per cent). In addition, studies have differed in their methodology, the period of analysis as well as the sample of industries analysed. So, it is not surprising that their results also are different. The OECD (2007), for instance, found an increase in TFPG in manufacturing from less than 0.5 per cent per annum during the 1990s to 2.5 per cent per annum between 2000 and 2005. Virmani and Hashim (2011), on the other hand, found that TFPG decreased from 0.61 per cent per annum in the 1980s to 0.25 per cent per annum in the 1990s and then increased to 1.4 per cent per annum in the 2000s.

Analysing firm-level efficiency, Kambhampati (2003, 2006) found that the 1991 reforms had a significant impact on efficiency levels in Indian manufacturing. In addition, the sources of finance for firms were significant correlates of efficiency levels between 1986 and 1998 (Kambhampati, 2006). Driffield and Kambhampati (2003), analysing the efficiency of firms in manufacturing between 1987 and 1994, also found that efficiency increased in the post-reform period in five out of the six sectors that they considered. Analysing why these reforms might have helped improve productivity levels, Chand and Sen (2002) conclude that the improvement in productivity has been brought about by trade liberalisation, which has increased access to imported intermediate goods rather than from domestic deregulation. Topalova (2004) too finds that the trade liberalisation reforms have been more effective than domestic deregulation in increasing productivity since 1991. Testing other effects of input tariff liberalisation in the 1991 reforms, Goldberg et al. (2008) find that it contributed to domestic product growth both by decreasing production costs incurred by domestic producers and also by relaxing the technological constraints these producers are faced with via access to new imported input varieties that were not available before liberalisation. Dougherty et al. (2009), however, argue that the increased labour productivity was caused by capital deepening rather than improvement in TFP.

Testing whether the post-1991 growth of firms came from more efficient use of resources or increased use of factor inputs, especially capital, Ray (2014) found that between 1991 and 2001, the change in technical efficiency declined in textiles, aluminium, metal products, plastics, steel, cables, electrical equipment, fertilizers, electronics and telecom. In addition, he found that technical change has declined in all the industries, leading to the conclusion that it has been dragging down TFPG in all the sectors. Bhaumik and Kumbhakar (2008) used plant-level data from 1989-90 and 2000-01 and found that while there was an increase in the productivity of factor inputs during the 1990s, most of the growth in value-added output is explained by growth in the use of factor inputs. More specifically, they found that median technical efficiency declined in all but one of the industries between the two years, and change in technical efficiency explains a very small proportion of the change in gross value-added output. Trivedi et al. (2011) argue that though productivity, efficiency and competitiveness are indicators of performance, these need not move in tandem with each other. 'Productivity' is an absolute measure of performance that can be estimated independently for a decision-making unit, whereas, 'efficiency' entails comparison with a peer group (Ray, 2004).

In the context of marketisation, de-regulation or trade reforms, Tybout and Westbrook (1995) have suggested that a link exists between the lowering of trade barriers and increase in competition, which would lead to increased productivity. They found that the exit of inefficient firms, cheaper intermediates and competition from imports stimulated increases in productivity and the effect was strongest in the more open industries. Tybout (2000), reviewing the literature on trade liberalisation and efficiency across developing countries, concludes that the improvement in efficiency is probably due to intra-plant improvement and unrelated to internal or external scale economies.

Goldar and Mitra (2008) consider productivity in both the manufacturing and services sector in the Indian economy. They find that TFP growth was faster in the services sector than in manufacturing in the post-1980 period though they conclude that, despite this, the secondary sector has provided the motor for growth. Banga and Goldar (2004) found that the contribution of services input to output growth in manufacturing was approximately 1 per cent in the 1980s and approximately 25 per cent in the 1990s.

Turning to the impact of infrastructure on total factor productivity and efficiency in Indian manufacturing, Mitra et al. (2012) found that between 1994 and 2008, a 1 per cent increase in the index of infrastructure was associated with a 0.32 per cent increase in total factor productivity (TFP) growth in manufacturing and 0.17 per cent with respect to technical efficiency (TE). In an earlier study, Mitra et al (2002) considered the effect of infrastructure on the manufacturing sector's TFP and TE for different states in India and found a positive relationship. While they find no significant impact of road and rail network density on the industrial efficiency of states, electricity consumption, the number of vehicles per inhabitant and the postal system density are found to play an important role. Mitra et al. also included financial infrastructure variables (number of bank branches but also size of loans and deposits) and primary and secondary education as factors determining efficiency. In the following section, we describe our estimation methodology.

3. Estimation Methodology

The production function frontier pioneered by Farrell (1957) defines the maximum possible output that a firm can produce with a given input bundle. This is the 'best-practice' frontier and inefficiency is measured as realised deviations from this frontier. One of the main drawbacks of this approach is that all deviations from the frontier are treated as inefficiency without taking into account the effect of exogenous shocks beyond the firm's control, measurement error or stochastic noise.

A better approach is to include two random terms: one that that accounts for the stochastic noise and another that measures inefficiency. In this methodology, the realised output is seen as bounded from above by the stochastic frontier (Schmidt and Sickles, 1984) and technical inefficiency is the amount by which a firm's actual output falls short of the efficiency frontier. This method of estimating a production function with a composite error term that comprised of not only a random noise term but also inefficiency was called the stochastic frontier approach and was first proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977). They specified a cross-sectional model in which output of a firm is a function of the inputs used, an inefficiency term and a stochastic noise term. In order to estimate the parameters from the likelihood function, strict assumptions on the independence of error terms with each other and with respect to the input variables as well as distributional assumptions are, however, necessary. Although cross-sectional estimates fulfilling the strict assumptions are unbiased, they remain non-consistent.

The restrictions imposed by using cross-sectional stochastic frontier models, namely strong distributional assumptions on error terms and inconsistent inefficiency estimates, may, however, be overcome by using panel data. By adding repeated observations over time for the same unit, panel data models yield consistent estimates of the inefficiency term and can do away with the need for distributional assumptions regarding the inefficiency term.

Panel data stochastic frontier models can treat inefficiency as either time-invariant or time-varying, a hypothesis that needs to be empirically tested. In a time-invariant model while the random term varies over units and time, the inefficiency error term varies only across units. In contrast, in a time-varying model, both the random error terms vary over units and time. Cornwell et al. (1990) were the first to propose a time-varying inefficiency effects stochastic frontier model as a generalisation of the Schmidt and Sickles (1984) model. Over the years, there have been many developments regarding the specification of the time-varying inefficiency term (see Murillo-Zamorano, 2004 for a survey on the developments of stochastic frontier modelling). The next section describes the nature and sources of the data set and specifies the stochastic frontier production function that we use in obtaining our results.

4. Data and Empirical Specification

4.1 Data

We use data on company-level profit and loss and balance sheet entries of large and medium, non-government, non-financial, public limited companies registered in India compiled by the Reserve Bank of India (RBI). The data relate to individual companies, which may be parts of much larger industrial houses, but are legally separate entities, independent in their day-to-day operations. These companies are assigned to 83 three-digit industries on the basis of majority of (>50%) output.[1] We use data for the period 1999–2007, the period after the classification of industries changed in the RBI data.

The RBI data comes from a purposive sample designed to adequately represent companies belonging to different industry groups and size classes. The sample size is relatively large both in terms of numbers and in terms of paid-up capital (accounting for nearly 65% of the total paid-up capital of the entire population of public limited companies). The size of the sample in terms of number of companies has been increasing over the years, and over 75 per cent of companies are retained from one year to the next.[2] For the purpose of our study, we focus on six industries within our sample – cotton textiles, jute, motor vehicles, chemicals, plastics and pharmaceuticals. The overall summary statistics of the variables used in the empirical models discussed in the paper are presented in Table 1. The summary statistics relating to firm-level variables grouped by industry is presented in Table A.2 in Appendix B.

Table 1 : *Overall summary statistics*

Variable	Mean	sd	Min	Max
Log(*Y*)	13.676	1.726	5.402	19.664
Log(*K*)	12.949	1.665	5.877	18.569
Log(*L*)	11.155	1.705	2.205	16.541
Log(*M*)	13.040	1.809	3.534	19.265
Loans from:				
BANK	0.673	9.279	0.000	497.113
IFI	0.285	9.553	0.000	694.482
FII	0.016	0.127	0.000	3.080
GOVT	0.039	0.681	0.000	33.246
COMP	0.247	5.649	0.000	255.975
OTHER	0.088	2.507	0.000	181.301
R&D	0.004	0.015	0.000	0.340
IMP	0.110	0.170	0.000	3.236
EXP	0.176	0.263	-0.111	4.738
REER	101.5	4.763	95.9	113.4
FIN	67620.7	1999.3	65153	72165
POWER	136.2	16.5	112.6	168
RAIL	16.7	1.2	14.3	17.9
ROAD	59.1	5.4	49.6	66.6
MACRO	0.000	2.074	-2.947	3.969
Observations	5389			

4.2. Empirical Specification

We specify a time-varying stochastic frontier model with a simple Cobb–Douglas production function specification[3] as:

$$y_{it} = \beta_{0t} + \sum_{i=1}^{n} \beta_n x_{nit} + v_{it} - u_{it} \qquad ....(1)$$

where, y_{it} is the logarithm of output of the *i*-th firm at time *t*; x_{nit} is the logarithm of *n*-th input used by the *i*-th firm at time *t*; v_{it} is the statistical noise distributed $N(0,\sigma_v^2)$, and u_it is the inefficiency term that commonly follows an exponential or half-normal distribution.

In this paper, we follow Battese and Coelli (1992) and model the technical inefficiency term as an exponential function of time. This can be written as:

$$u_{it} = \exp[-\eta(t-T_i)]u_i \qquad ......(2)$$

where, T_i is the last period in the *i*-th panel, η is the decay parameter and u_{it} is the inefficiency term distributed $N^+(\mu, \sigma_u^2)$, i.e. it follows a truncated-normal distribution with mean μ and variance σ_u^2.

In Eq. (1), y_{it} is the log value of output for the *i*-th firm at time t, whereas x_{nit} is an input vector that includes logged values of labour (L_{it}), capital (K_{it}) and raw materials (M_{it}) as its elements. The output and raw material were deflated using the index of wholesale prices from the World Trade Organisation data set. For the capital goods, the deflator is the ratio of gross capital formation at current prices and gross capital formation at constant prices, calculated using the World Trade Organisation data set. The method of deflating labour was less straightforward since our data set had information on wages but not on the number of employees or the number of hours that they worked. We approximated this information from the wage bill by first calculating an average wage rate for each industry (total wages divided by the number of employees in each industry) at the two-digit industry level from the Annual Survey of Industries. We then used the constructed industry-average wage to deflate the wage bill of each firm to approximate the numbers employed in each industry (see also Srivastava, 1996; Driffield and Kambhampati, 2003). This method of arriving at labour employed implicitly assumes a homogeneous industry-wide workforce with no skill differences, and we are mindful of the limitations it might impose on our estimates.

The parameters $[\beta, \sigma_v^2, \sigma_u^2, \mu, \eta]$ in Eqs. (1) and (2) are estimated by the method of maximum likelihood using the Stata statistical software. This yields estimates of a firm's time-varying efficiency score, which is simply the expected exponential of inefficiency scores conditional on the error (i.e. $(TE)_{it}=E[\exp(-u_{it}|\epsilon_{it})]$). The efficiency scores are computed for each of the six industries covered in this study, that is, we estimate every firm's frontier output, which is, by definition fully efficient, and compare it with the observed output in that year to determine its inefficiency of operation. We then analyse the impact of a set of firm-level variables (firm's loan structure, its research and development expenditure and foreign exchange earnings and expenditure) as well as a set of exogenous macroeconomic variables that might influence the operational efficiency of firms. In addition, we use the estimated coefficients from the production function to predict the frontier output of firms (y_{it}) and explore the factors that explain differences in firm-level output within an industry.

We estimate the following equation to identify the firm-level factors that are significantly correlated with its degree of efficiency:

$$(TE)_{it} = \gamma_0 + \gamma_1\, loan_{it} + \gamma_2\, rnd_{it} + \gamma_3\, forex_{it} + \gamma_4\, size_{(it-1)} + \epsilon_{it} \qquad \text{......(3)}$$

where $(TE)_{it}$ is the technical efficiency score for the *i*-th firm at time *t*, $loan_{it}$ is a vector that includes a firm's borrowings expressed as a percentage of net sales from different sources such as Indian financial institutions, commercial banks, institutional investors, government, from the company itself, as well as from other sources. The variable rnd_it is a measure of the research and development expenditure of a firm, while $forex_{it}$ is a vector comprising of expenditures on imports and earnings from exports and captures the extent to which firms are integrated with the global economy. We also include a lagged value of log output to control for firm size. γ_n is the coefficient corresponding to the *n*-th variable in the equation that is to be estimated.

To determine the impact that different macroeconomic factors have on firm efficiency, we estimate equations of the following type:

$$(TE)_{it} = \delta_0 + \delta_i M_{(t-1)} + \zeta_i Z_{(it-1)} + \varepsilon_{it} \quad \ldots\ldots(4)$$

where, $(TE)_{it}$, as before, is the technical efficiency scores for the *i*-th firm at time *t*. $M_{(t-1)}$ is a placeholder for a (single) macroeconomic variable from among the set of macroeconomic variables considered, i.e. real effective exchange rate (REER), financial development (FIN), power generation capacity (POWER), length of roads and highways (ROAD) and length of rail route electrified (RAIL). It is important to stress that these infrastructure variables are chosen as ex-ante variables: the capacity to generate power (rather than the amount of power actually generated), the length of rail route electrified (rather than passengers and goods carried). This is important because it helps to reduce at least some of the direct endogeneity between output and infrastructure utilisation. Lagging the variables also helps to further reduce this endogeneity though in the context of path dependence, this is less effective. $Z_{(it-1)}$ is a set of (lagged) firm-specific controls, which includes all the variables that are entered in Eq. (3) as independent variables.

Since the macroeconomic variables are found to be highly correlated amongst themselves, including them all together in one equation will result in multicollinearity that will bias our estimates. To avoid this problem, we include one macroeconomic variable at a time and estimate their individual impacts separately. However, in line with the literature, and to provide a broad sense of the overall impact of domestic macroeconomic development on firm efficiency, output and growth, we create a synthetic macroeconomic index using principal components analysis. The index, which we call MACRO, comprises of REER, FIN, POWER, ROAD and RAIL. We then use MACRO to estimate Eq. (4) by substituting it in place of $M_{(t-1)}$. The macroeconomic variables and firm controls are lagged one period to minimise simultaneity bias. δ_{is} in the equation are the corresponding coefficient estimates of $M_{(t-1)}$ while ζ_{is} are the respective coefficients for firm-specific controls $Z_{(it-1)}$. The ex-ante hypothesis concerning how each of the financial, trade and infrastructure variables might affect efficiency, frontier output and actual output growth is presented in Section 4.3.2.

Since efficiency measures the output of a firm relative to the efficient frontier, a decrease in efficiency might occur either because the frontier has shifted out at a rate higher than the rate of increase in the firm's actual output or because the output of existing firms has fallen while the frontier has remained unchanged or a combination of the two. We analyse these effects separately by looking at the impact of key firm-specific and macroeconomic factors on efficiency, frontier output and growth in actual output of firms in each of the six industries.

Eqs. (3) and (4) can be estimated using regular fixed or random effects models for panel data. It is quite likely that observations over time for the same firm are correlated due to some fixed unobservable firm-specific attributes, which suggest that a fixed effects model is more appropriate.[4]

4.3 Independent Variables

In this section, we provide a description of the independent variables included in our analysis of firm-level efficiency, output and growth and outline our ex-ante hypotheses based on economic theory. We categorise the variables into two groups for ease of discussion: firm-specific factors, i.e. variables that are within the control of the firms, and macroeconomic factors, i.e. variables that are exogenously determined and outside the direct scope of influence from the point of view of firms. A glossary of the complete set of independent variables is provided in Table in Appendix A.

4.3.1 Firm-specific Factors

We include a list of variables that capture the structural characteristics of the firms and can be directly altered by the firms. These include information on their sources of borrowing, expenditure on research and development, the integration of the firm with the global market and firm size.

(a) *Sources of borrowing:* This includes the borrowings of each firm from different sources namely, Indian financial institutions (IFIs), commercial banks (BANK), foreign institutional investors (FIIs), government (GOVT), from the company itself (COMP) as well as from other sources (OTHER) that are classified accordingly. The nominal values of these variables are normalised by net sales of the company in the corresponding year and included with a lag to minimise simultaneity bias in the estimation.

The reason for including each of the different sources of borrowing separately instead of creating an index is because we believe that the source of debt might have a differential impact on efficiency and output. For instance, the government might have an express interest in supporting a particular industry, or it might lack the capacity to effectively monitor the allocation of credit and its utilisation. To the extent that the government pursues its own policy interests or is less effective in monitoring the performance of firms, government loans may have a worse impact on efficiency than loans from IFIs and commercial banks that come with more stringent assessment and monitoring. However, this needs to be tested.

(b) *Research and development:* Firms that spend more on research and development (R&D) may be expected to have higher efficiency. Sutton (2001), for instance, argues that the main impact of trade liberalisation derives from two basic mechanisms – an intensification of price competition and a consequent narrowing of the 'capability' window in which firms operate, as the minimum level consistent with viability increases. A firm's optimal response to these pressures, according to Sutton (2001), will involve injecting resources to increase capabilities through R&D expenditure as one of its channels. Hence, the importance of R&D may be expected to have increased post-liberalisation. Of course, it is also possible that in the context of liberalisation, especially in developing countries, firms scrap and scale down their R&D (product-development) programmes and focus on increasing efficiency through investment in modern (imported) equipment, adoption of organisation practices, and so on.

(c) *Global integration:* This includes the firm's expenditure on imports (IMP) as a percentage of net sales and the value of the firm's exports (EXP) as a percentage of net sales. Import intensity is expected to influence efficiency because in the newly liberalised economy, firms are able to import capital goods and the latest technology. On the other hand, high export intensity is expected to increase efficiency because exporting firms have to compete against firms in world markets and therefore might be expected to decrease X-inefficiency or the difference between theoretical and observed output given some input bundle. We might, therefore, expect a more globally integrated firm to be more efficient than one that is more inward looking.

(d) *Firm size:* Many studies have hypothesised that large firms are able to operate, not only at a lower point on their cost functions than small firms, but also on lower cost functions (Clarke et al., 1984; Gale and Branch, 1982). It is well known that there is likely to be a two-way relationship between firm size and efficiency, a simultaneity that has been commented on in many earlier studies. To take this into account, we lag the firm size variable by one year. This would imply that a large market share in the previous period could increase efficiency in the current period but the impact that efficiency will have on market share is in future periods.

4.3.2 Macroeconomic Factors

Macroeconomic variables are driven by the government's plans and priorities and hence exogenous and beyond the direct influence of firms. Within this, we include a measure of exchange rate fluctuations, financial coverage and a range of infrastructure related variables. Table 2 illustrates the changes in these variables from 1960 until 2007.

(a) Exchange rate fluctuations: In a globally integrated market, exchange rates fluctuations pose a significant risk to the firms with distributional implications. An appreciating currency, for instance, will make imports cheaper and exports more expensive. This will help firms that predominantly rely on imported technology and supply their output domestically but hurt export-oriented firms, whereas depreciation in the currency will benefit exporting firms and possibly reduce investments in imported technology. We include the real effective exchange rate

Table 2 : *Changes in key macroeconomic variables, 1960–2007*

Year	Exchange rate	Bank branches	Installed power generation capacity	Road	Rail
1960	NA	8262	5.6	22	0.8
1970	NA	NA	16.3	24	3.7
1980	NA	NA	33.3	24	5.4
1990	NA	NA	52.3	32	10
1999-00	95.98	65153	112.6	52	14.3
2000-01	101.02	65931	117.8	57.7	14.9
2001-02	100.91	65922	122.1	58.1	16
2002-03	95.97	66267	126.2	58.1	16.3
2003-04	97.44	66696	131.4	65.6	17.5
2004-05	100.00	67409	137.5	65.6	17.5
2005-06	104.40	68553	145.6	66.6	17.9
2006-07	103.80	69616	154.6	66.6	17.8
2007-08	113.40	72165	168	NA	17.8

Sources and notes : (a) Exchange rate shows the movements in the six currency trade-weighted CPI-based real effective exchange rate; Bank branches is the number of bank branches; Installed power generation capacity is the electricity generation capacity in thousand MW; Road measures the length of national highways in thousand km; Rail is the length of railway route electrified in thousand km; (b) NA=not available.

to capture fluctuations in efficiency and output that arise due to changes in global demand and supply. The real effective exchange rate is the nominal exchange rate against a basket of currencies of trade partner countries adjusted by the ratio of domestic price to foreign prices.

(b) Financial coverage: We include the number of bank branches in the economy (FIN) as an overall indicator of financial coverage. The post-1991 period has seen a large increase in the number of bank branches from 65,153 branches in 1999 to 72,165 branches by 2007 (see Table 2). This has been accompanied by improved services as well as greater efficiency within this sector, partly driven by private sector competition. There is considerable evidence that such liberalisation of the financial sector and consequent financial sector development leads to improved growth in the economy. Given this, we would expect such expansion to help firms to increase investment and therefore to help decrease inefficiency and increase growth.

(c) *Infrastructure:* We include a list of infrastructural variables at a economy-wide level: power generation capacity (POWER), length of national highways (ROAD) and length of rail-route electrified (RAIL). An uninterrupted supply of power is a pre-requisite for production planning and timely delivery, which not only impact current but also future production. Increasing capacity generation of electricity is therefore expected to have a positive effect on firm efficiency and output. As mentioned earlier, the post-liberalisation phase has witnessed increasing investments in transport infrastructure. Two variables are included to capture the state of transport infrastructure in the Indian economy: the length of national highways (ROAD) and the length of rail-route electrified (RAIL). Investment in transport infrastructure connects producers to a wider domestic market and brings down transport costs, which ought to have a positive impact on production and firm efficiency. Since infrastructure could itself be dependent on output growth in the economy, we use infrastructure variables as a proxy potential for production (i.e. supply side variables) rather than infrastructure utilisation variables, which will be directly determined by the demand for infrastructure (which, in turn, will be determined by output growth).

(d) *Macroeconomic index:* The macroeconomic variables discussed above are highly correlated amongst themselves and including all or even a subset of them in estimating an equation will result in multicollinearity. To avoid this problem, we create an index that includes real effective exchange rate, financial coverage and infrastructure variables and refer to it as MACRO in this paper. Including this variable will provide a broad picture of the overall impact of macroeconomic variables on firm efficiency, frontier output and growth of firms.

4.3.3 Methodological Issue

The issue of endogeneity of the independent variables is a potential problem in most models involving firm behaviour and performance. In such models, there is a potential simultaneity in the relationship between firm efficiency and the way in which the firm is financed or its ability to trade, for instance. Thus, while the a firm's source of financing will affect its governance and monitoring structure and thereby impact efficiency, it is equally possible that the firm's efficiency levels will influence the kind of financing that it is able to access. This would imply that only already efficient firms are likely to obtain funds from FIIs (see also Alba et al., 1998) and other private sector sources. It is also possible that while the way in which a firm is financed will influence the firm's efficiency, the reverse causality may be not between efficiency and financing but between profitability and financing, i.e. that the type of financing a firm is able to attract may depend upon its profitability rather than its efficiency. If this is the case, then the simultaneity is less problematic. Such endogeneity is true of a number of other variables: more efficient firms can export or invest in R&D, for instance, while exporting or R&D may in its turn improve efficiency.

We try to deal with this two-way relationship by estimating our model with lags. Thus, a firm's current borrowing (say from banks) can be hypothesised to affect its efficiency next year (because it takes time for banks to discipline the firms they lend to or because it takes time for firms to invest the funds they borrow). On the other hand, the reverse causality will be from current efficiency to next year's borrowing. To allow for this, we lag all the financial variables by one period. By doing this, we can delineate the impact of FII finance, for instance, on a firm as opposed to the impact of efficiency on the possibility of obtaining FII finance. We also lag R&D, imports and exports as per cent of net sales. The choice of lag structure is the shortest possible that will correct for simultaneity, while providing for as long a trend a possible (especially pre-1991). For some variables (like imports), this is also sufficient to capture the major impact of the variable on efficiency. For others, like R&D, a longer lag may be more appropriate because R&D expenditure may take much longer than one year to have an impact on firm efficiency. To the extent that there is path dependence in these variables, such a simple lag structure will not help to deal with endogeneity. For the purposes of this paper, however, we will go no further.

In addition, as noted above, we include a range of variables (at economy-wide level), which are more exogenous in their impact. Thus, while the amount of credit obtained by the firm or the source of this credit may be endogenous to the firm's performance, an improvement in the availability of funds (through the establishment of more bank branches) is exogenous to the firm's performance and might be expected to capture the availability of funds. This is also true for installed power generation capacity or length of railway-route electrified or the length of national highways, which are all exogenous to the firm's decision making. We have, however, been careful to include capacity for power generation or road transport rather than the ex post levels of power generated or road usage or goods transported by rail in our model to avoid such endogeneity. The latter, in particular, are highly endogenous to the extent of economic activity so that the larger the economic activity, the more electricity will be used or transport infrastructure will be used. By including supply capacity of these variables rather than their demand-determined output, we are ensuring a certain extent of exogeneity.

Another complication faced by our analysis is that we do not have the location of the firm in the data. We are therefore unable to make use of regional variations in the macroeconomic variables and instead have to use national level estimates, which vary over time. This, of course, is not perfect since the quality of governance in a decentralised administrative system is affected by local governments and therefore may well exhibit geographical differences. In addition, having the data at national level reduces variability in these data series and therefore makes it harder to identify the effect of these variables. We are mindful of this limitation in our study and the results should be interpreted accordingly.

5. Results

In what follows, we discuss our results. First, we present the results from our estimation of the stochastic frontier model for each of the six industries considered in this study. This enables us to compute firm-level technical efficiency and frontier output. We then proceed to identify the firm-specific characteristics as well as key macroeconomic variables that are significant in explaining differences in firm efficiency, output and growth differences across all the firms in our sample and over time.

5.1 Firm Efficiency and Frontier Output

Table 3 presents results from our estimation of the stochastic frontier model for six different industries: motor vehicles, chemicals, cotton, jute, plastics and pharmaceuticals. As mentioned earlier in Section 4.2, the efficiency term is modelled as a function of time using the Battese and Coelli (1992) specification. Thus, frontier output is estimated every year for each of the six industries, and the efficiency of firms is calculated relative to the most efficient frontier in that year. The variables K, L and M are respectively deflated values of capital, labour and raw materials used

Table 3 : *Estimating stochastic frontier models for six Indian industries, 1999–2007*

Variable	Motor Vehicles	Chemicals	Cotton	Jute	Plastics	Pharma
Log(K_{it})	0.069***	0.175***	0.197***	0.055***	0.023	0.105***
	(0.017)	(0.013)	(0.016)	(0.020)	(0.020)	(0.014)
Log(L_{it})	0.200***	0.257***	0.183***	0.131***	0.202***	0.274***
	(0.017)	(0.015)	(0.015)	(0.026)	(0.018)	(0.013)
Log(M_{it})	0.684***	0.572***	0.543***	0.712***	0.754***	0.605***
	(0.010)	(0.010)	(0.011)	(0.030)	(0.013)	(0.011)
Constant	2.704***	3.125***	3.252***	2.615***	2.191***	3.722***
	(0.549)	(0.315)	(0.216)	(0.297)	(0.212)	(0.334)
γ	1.613***	0.809***	0.838***	2.146***	0.827***	1.171***
	(0.130)	(0.095)	(0.134)	(0.341)	(0.161)	(0.127)
μ	1.012*	1.965***	1.368***	0.535**	1.014***	2.265***
	(0.549)	(0.294)	(0.181)	(0.216)	(0.167)	(0.316)
η	-0.006*	-0.002	-0.010***	-0.019*	-0.017***	-0.003**
	(0.003)	(0.001)	(0.003)	(0.010)	(0.005)	(0.001)
Log Lik	372.473	-265.060	131.052	147.387	113.551	156.990
N	865	1786	956	150	595	970

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes : This table regresses output (log(Y_{it})) on a set of inputs – capital (K), labour (L) and materials (RM) – for six different industries namely, motor vehicles, chemicals, cotton, jute, plastics and pharmaceuticals to estimate stochastic frontier models. The equations are estimated using the maximum likelihood method. $\gamma=(\sigma^2_u)/(\sigma^2_S)$ where $\sigma_S^2=\sigma_u^2+\sigma_v^2$, μ is the estimated mean inefficiency of the firms in our sample and η is the time decay parameter. $\eta<0$ implies inefficiency is increasing over time.

in the production process that enter Eq. (1) in logs. The term μ denotes an estimate of the mean inefficiency of all firms in our sample. η is the time decay parameter in the specification of inefficiency. A value of $\eta<0$ indicates that inefficiency is increasing over time whereas if $\eta>0$ it implies declining inefficiency.

The coefficient estimates in Table 3 have the expected signs. The largest significant input seems to be materials, while the impact of labour is in the region of 13–27 per cent across different industries. The contribution of capital inputs to output is surprisingly low – 7 per cent in motor vehicles, 17.5 per cent in chemicals, 19.7 per cent in cotton, 5.5 per cent in jute, 2.3 per cent in plastics and 10.5 per cent in pharmaceuticals. While the capital coefficient might seem low in comparison to other studies (Mitra et al., 2002; Kathuria et al., 2013), this is because we have three inputs in our production function (capital, labour and raw materials) whereas these other studies include only capital and labour. Excluding the raw material variable from the model implies that at least some of the impact of materials is absorbed by the coefficient of capital.

We find that the mean inefficiency (μ) is positive and significant in all the sectors that we consider and highest in the pharmaceuticals and chemicals industry. The η term is significantly less than 0 in five out of the six industries implying that the degree of inefficiency in these industries has increased over time with the exception of the chemicals industry where efficiency has remained stagnant (in statistical terms). The magnitude of η – the time decay parameter – is larger in cotton, jute and plastics industry, indicating that the rate of increase in inefficiency of these industries has been higher in comparison to that in the motor vehicles and pharmaceuticals industries.

5.2 Determinants of Firm Efficiency, Frontier Output and Growth of Firms

As mentioned earlier, we estimate stochastic frontier production functions for six industries to yield efficiency and frontier output estimates. In this section, we analyse the firm-specific and macroeconomic factors that explain variations in firm efficiency, frontier output and growth in realised output across all firms in the industry in our sample.

5.2.1 Firm Efficiency and Frontier Output

Here, we analyse the firm-specific and macroeconomic factors that explain variations in technical efficiency and frontier output across all firms within an industry in our sample. Table 4 presents results relating to firm specific factors whereas Table 5 presents results relating to macroeconomic factors.

Firm-specific factors

In Table 4, we find that firms with a high percentage of bank loans as a proportion of net sales (or output) are associated with lower levels of efficiency in all industries except jute and cotton where it has a negative sign but is not statistically significant. On the other hand, a high percentage of loans from Indian financial

Table 4 : *Firm-specific factors affecting firm efficiency and frontier output by industry, 1999–2007*

Variable	Motor vehicles		Chemicals		Cotton		Jute		Plastics		Pharmaceuticals	
	TE	F	TE	F	TE	F	TE	F	TE	F	TE	F
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$BANK_{it-1}$	-0.005***	0.240***	-0.000**	-0.002	-0.000	0.093***	-0.028	0.936	-0.003**	0.091***	-0.002***	0.028
	(0.002)	(0.079)	(0.000)	(0.008)	(0.000)	(0.015)	(0.027)	(0.604)	(0.001)	(0.030)	(0.000)	(0.051)
IFI_{it-1}	0.008***	-0.018	0.000	0.091***	0.015***	0.106	0.095**	-1.939*	0.001	0.030	0.001***	-0.205***
	(0.002)	(0.081)	(0.000)	(0.016)	(0.002)	(0.076)	(0.044)	(0.983)	(0.002)	(0.042)	(0.000)	(0.078)
FII_{it-1}	-0.001	0.521***	-0.002**	0.364	-0.024	-0.590	0.361	-0.641	0.009**	0.003	-0.001	0.269*
	(0.003)	(0.162)	(0.001)	(0.235)	(0.016)	(0.573)	(0.328)	(7.271)	(0.005)	(0.112)	(0.001)	(0.138)
$GOVT_{it-1}$	-0.011*	-0.184	-0.001	-1.557***	-0.005	-1.189*	0.019	2.189*	-0.015	1.147***	-0.003**	0.837***
	(0.006)	(0.289)	(0.002)	(0.354)	(0.019)	(0.662)	(0.056)	(1.235)	(0.017)	(0.406)	(0.001)	(0.307)
$COMP_{it-1}$	-0.002	0.163*	-0.000	-0.020	-0.003	0.220	-0.085	-2.499	-0.005**	-0.078	-0.001	0.086
	(0.002)	(0.087)	(0.000)	(0.066)	(0.007)	(0.253)	(0.077)	(1.708)	(0.002)	(0.049)	(0.001)	(0.111)
$OTHER_{it-1}$	-0.002	-0.224	-0.001**	0.098	0.001	-0.340***	-0.076	-0.506	-0.005	-0.025	-0.002***	-0.045
	(0.004)	(0.165)	(0.000)	(0.113)	(0.003)	(0.116)	(0.065)	(1.433)	(0.004)	(0.088)	(0.001)	(0.114)
$R\&D_{it-1}$	-0.208***	4.948*	0.004	3.742	1.223*	-3.980	1.111	69.433	-0.365	1.060	-0.007*	1.501*
	(0.060)	(2.791)	(0.011)	(2.468)	(0.731)	(25.837)	(3.251)	(71.986)	(0.700)	(16.665)	(0.004)	(0.789)
IMP_{it-1}	-0.000	0.391**	-0.000	0.331***	-0.017***	0.275**	-0.024	0.680	-0.036***	0.685***	0.000	0.200
	(0.004)	(0.178)	(0.000)	(0.076)	(0.003)	(0.124)	(0.049)	(1.085)	(0.009)	(0.217)	(0.001)	(0.152)
EXP_{it-1}	-0.012***	0.109	-0.001**	0.272**	0.012***	-0.136*	-0.078**	-0.228	-0.010***	0.027	-0.000	0.135
	(0.003)	(0.135)	(0.001)	(0.125)	(0.002)	(0.074)	(0.034)	(0.756)	(0.004)	(0.087)	(0.001)	(0.110)
$Log(Y_{it-1})$	-0.005***	0.921***	-0.001***	0.580***	0.004***	0.797***	0.010	0.007	-0.007**	0.767***	-0.002***	0.741***
	(0.001)	(0.026)	(0.000)	(0.031)	(0.001)	(0.041)	(0.008)	(0.180)	(0.003)	(0.065)	(0.000)	(0.038)
Constant	0.450***	2.119***	0.161***	7.690***	0.207***	4.102***	0.497***	14.243***	0.476***	3.894***	0.130***	5.743***
	(0.008)	(0.383)	(0.002)	(0.426)	(0.016)	(0.567)	(0.116)	(2.558)	(0.036)	(0.851)	(0.002)	(0.517)
R-sq	0.325	0.788	0.080	0.400	0.232	0.522	0.238	0.188	0.150	0.516	0.240	0.538
N	646	646	1345	1345	687	687	112	112	428	428	729	729

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

institutions (IFIs) is positively associated with efficiency in the motor vehicles, cotton, jute and pharmaceuticals industry. The impact of FIIs is less obvious given that they are associated with an increase in efficiency in the plastics industry and a decrease in efficiency in the chemicals industry but not statistically significant for the other industries. With respect to government loans, firms with a high percentage of government loans to total output are associated with lower efficiency in the motor vehicles and the pharmaceuticals industry. Chemicals and pharmaceuticals industry with a high share of other sources of loans are also associated with lower efficiency levels.

Our results indicate that while higher R&D positively affected technical efficiency in the cotton industry, its effect was negative in the case of pharmaceuticals and motor vehicles industry. Firms with a larger import intensity had lower efficiency scores in the cotton and plastics industry. Export-intensive firms in motor vehicles, chemicals, jute and plastics were associated with lower efficiency scores, whereas those in the cotton industry were associated with higher efficiency scores. In the case of firms in the pharmaceuticals industry, export intensity did not turn out to be significant. With regard to firm size, larger firms measured by their output levels last year (in logs) were generally less efficient than smaller ones, with firms in the cotton industry being the only exception.

These results are, on the face of it, rather surprising. Most factors seem to lower efficiency rather than having a positive effect. This is especially worrying in the context of R&D, exports and imports. A careful analysis of the firm-specific factors affecting efficiency in conjunction with its impact on frontier output seems to hold the key to this puzzle. While these firm-specific factors decrease efficiency (the actual output to frontier output ratio), this is the reality in many cases because they increase the frontier output of firms (see columns labelled F in Table 4). Thus, these variables seem to shift the frontier outwards. Given that efficiency of firms is relative to the frontier, as the latter shifts out so efficiency levels seem to decrease. Another way to understand these results is to consider that sources of finance, imports, exports and R&D seem to increase frontier output of firms rather than improving the efficiency of use of these inputs. Thus, industrial growth during this period has been extensive rather than intensive.

Macroeconomic factors

Table 5 shows results relating to the effect of different macroeconomic variables on firm efficiency and frontier output. These estimates are arrived at by regressing each of the macroeconomic variables on firm efficiency and output individually for all the industries. The reason, as discussed earlier, is the high degree of multicollinearity among the variables that prevents us from including all the variables in the same equation. We, however, present a broader perspective by creating a synthetic index of macroeconomic factors (MACRO) from real exchange rates, financial coverage and infrastructure variables by using their

Table 5 : *Macroeconomic factors affecting firm efficiency and frontier output by industry, 1999–2007*

Variable	Motor vehicles		Chemicals		Cotton		Jute		Plastics		Pharmaceuticals	
	TE	F	TE	F	TE	F	TE	F	TE	F	TE	F
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$REER_{it-1}$	-0.001***	0.006**	-0.000***	0.006*	-0.001***	-0.002	-0.002***	0.006	-0.002***	0.014**	-0.000***	0.013***
	(0.000)	(0.003)	(0.000)	(0.003)	(0.000)	(0.004)	(0.000)	(0.010)	(0.000)	(0.006)	(0.000)	(0.004)
FIN_{it-1}	-0.000***	0.000***	-0.000***	0.000***	-0.000***	0.000	-0.000***	-0.000	-0.000***	0.000***	-0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$POWER_{it-1}$	-0.000***	0.005***	-0.000***	0.002***	-0.001***	0.001	-0.001***	-0.002	-0.001***	0.008***	-0.000***	0.005***
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.003)	(0.000)	(0.001)	(0.000)	(0.001)
$ROAD_{it-1}$	-0.001***	0.010***	-0.000***	0.004*	-0.001***	0.003	-0.002***	-0.014*	-0.002***	0.022***	-0.000***	0.012***
	(0.000)	(0.002)	(0.000)	(0.002)	(0.000)	(0.003)	(0.000)	(0.007)	(0.000)	(0.004)	(0.000)	(0.003)
$RAIL_{it-1}$	-0.004***	0.064***	-0.001***	0.026***	-0.006***	0.001	-0.010***	-0.037	-0.012***	0.075***	-0.001***	0.050***
	(0.000)	(0.008)	(0.000)	(0.008)	(0.000)	(0.011)	(0.000)	(0.027)	(0.000)	(0.017)	(0.000)	(0.011)
$MACRO_{it-1}$	-0.003***	0.031***	-0.001***	0.016**	-0.004***	0.002	-0.007***	-0.026	-0.007***	0.068***	-0.001***	0.045***
	(0.000)	(0.007)	(0.000)	(0.007)	(0.000)	(0.009)	(0.000)	(0.023)	(0.000)	(0.013)	(0.000)	(0.009)

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table presents coefficient estimates on regressing firm-efficiency (odd numbered columns) and frontier output (even numbered columns) on each of the macroeconomic variables and a synthetic macroeconomic index, separately. For instance, TE in the motor vehicles industry was regressed on $REER_{it-1}$ to yield -0.001 as its coefficient estimate in the cell intersected by the first row and the first column. Then, TE was regressed on FIN_{it-1} to yield -0.000 (row 2, column 1), and so on. All regressions include a constant and a full range of firm controls.

correlated structure, and regressing this index on firm efficiency and frontier output, respectively.

The results are striking. We find that the macroeconomic variables have a consistently significant negative effect on efficiency across all the six industries. Thus, increase in financial coverage, addition of power generation capacity, electrification of rail-routes and extension of national highways all seem to be negatively associated with efficiency levels in Indian manufacturing. The coefficient corresponding to the macroeconomic index variable presents a similar finding. Although it might seem counterintuitive at first glance, the puzzle can be resolved by observing that similar to firm-specific factors (see Table 4), macroeconomic factors positively influence frontier output (see Table 5). If the infrastructural improvements help shift the frontier outwards, then the firms that are not at the frontier will be left behind. Thus, the infrastructural variables, once again, help to improve firm output levels in response to K, L and M and therefore, while they facilitate the extensive growth of firms, they do not help improve the efficiency with which K, L and M are being used. It is worth noting that, with the units for the macroeconomic variables being very large, the coefficients are often extremely small, though highly significant. Our results therefore lead us to conclude that improvements in infrastructure facilitate the growth of the most efficient firms (i.e. the frontier firms in the industry). However, not all firms are able to take advantage of these improvements in infrastructure and this is reflected in the negative impact of these factors on firm efficiency.

5.2.2 Growth of Firms

The above results in Section 5.2.1 indicate that macroeconomic factors negatively affect firm efficiency while having a positive effect on frontier output. In this section, we consider the impact of firm-specific and macroeconomic factors on the growth of firms' output (Table 6 and 7) rather than on frontier output (as in Table 4 and 5 above). While in the previous section we were interested in the determinants of frontier output, that is, output predicted by inputs in the absence of any form of inefficiency, here we are interested in analysing the determinants of growth of observed output that factors input usage as well as inefficiency.

Firm-specific factors

The results in Table 6 indicate that bank loans increase growth in all sectors except chemicals where its effect is negative and plastics where it is positive but not statistically significant. Firms with a higher share of loans from IFIs relative to their net sales are associated with higher growth in chemicals, whereas its effect is negative for firms in the jute and pharmaceuticals industry. Thus, whereas these loans decrease efficiency, they are positively associated with output growth. FIIs are effective only in motor vehicles, whereas government loans have a positive effect on the growth of firms in chemicals, jute, plastics and pharmaceutical industries. R&D has no significant impact on growth in any sector. Imports increase growth

Table 6 : *Firm-specific factors affecting growth in firm output by industry, 1999-2007*

	Motor vehicle	Chemicals	Cotton	Jute	Plastics	Pharma
	(1)	(2)	(3)	(4)	(5)	(6)
$BANK_{it-1}$	0.166*	-0.335***	0.015***	1.364**	0.035	0.025*
	(0.086)	(0.030)	(0.002)	(0.584)	(0.046)	(0.015)
IFI_{it-1}	-0.000	1.537***	-0.053	-1.872*	0.087	-0.203**
	(0.088)	(0.060)	(0.091)	(0.949)	(0.069)	(0.092)
FII_{it-1}	0.894***	0.854	-0.167	-0.223	0.029	0.255
	(0.176)	(0.888)	(0.792)	(7.026)	(0.188)	(0.171)
$GOVT_{it-1}$	0.068	2.529***	-0.260	3.029**	1.570**	0.702*
	(0.313)	(0.290)	(0.201)	(1.193)	(0.680)	(0.376)
$COMP_{it-1}$	0.257***	0.036	0.081	0.249	-0.077	0.221
	(0.094)	(0.022)	(0.069)	(1.650)	(0.082)	(0.138)
$OTHER_{it-1}$	-0.296*	1.374***	2.422***	0.428	0.054	-0.028
	(0.180)	(0.418)	(0.068)	(1.384)	(0.148)	(0.141)
$R\&D_{it-1}$	4.087	4.631	4.820	17.553	2.366	1.253
	(3.044)	(9.337)	(35.922)	(69.557)	(27.992)	(0.977)
IMP_{it-1}	0.070	0.127	0.287*	-0.179	1.121***	0.027
	(0.192)	(0.286)	(0.170)	(1.048)	(0.364)	(0.188)
EXP_{it-1}	0.149	1.409***	-0.116	-0.166	0.124	0.193
	(0.146)	(0.465)	(0.102)	(0.731)	(0.146)	(0.136)
$\log(Y_{it-1})$	-0.092***	-0.653***	-0.126**	-1.053***	-0.277***	-0.218***
	(0.029)	(0.102)	(0.056)	(0.174)	(0.105)	(0.046)
Constant	1.342***	8.658***	1.668**	14.929***	3.470**	3.119***
	(0.417)	(1.397)	(0.769)	(3.944)	(1.377)	(0.623)
R-sq	0.134	0.548	0.796	0.710	0.123	0.089
N	648	1360	699	113	433	739

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7 : *Macroeconomic factors affecting growth in firm output by industry, 1999–2007*

Variable	Motor vehicles	Chemicals	Cotton	Jute	Plastics	Pharma
	(1)	(2)	(3)	(4)	(5)	(6)
$REER_{it-1}$	0.004	0.026**	-0.009*	0.005	0.014	0.016***
	(0.003)	(0.011)	(0.005)	(0.009)	(0.009)	(0.004)
FIN_{it-1}	0.000***	0.000***	-0.000**	-0.000	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$POWER_{it-1}$	0.004***	0.010***	-0.003*	-0.001	0.007***	0.005***
	(0.001)	(0.003)	(0.001)	(0.002)	(0.003)	(0.001)
$ROAD_{it-1}$	0.010***	0.034***	0.001	-0.007	0.020***	0.014***
	(0.002)	(0.006)	(0.003)	(0.007)	(0.007)	(0.004)
$RAIL_{it-1}$	0.064***	0.122***	-0.024	-0.030	0.058**	0.047***
	(0.009)	(0.031)	(0.015)	(0.026)	(0.030)	(0.013)
$MACRO_{it-1}$	0.028***	0.115***	-0.001	-0.011	0.062***	0.051***
	(0.008)	(0.019)	(0.008)	(0.023)	(0.023)	(0.011)

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Notes: This table presents coefficient estimates from regressing growth in firm output on a set of macroeconomic variables individually. All regressions include a constant and a full range of firm controls.

in cotton and plastics whereas exports increase growth only in chemicals. Similar to the results in Table 6 relating to frontier output, firm size has a negative impact on growth.

Macroeconomic factors

Table 7 shows the relationship between macroeconomic factors and growth of firms. We observe that an appreciation of the real exchange rate is associated with an increase in output growth in all the industries except cotton, where its effect is negative, and in jute where it is not statistically significant. It has a significant positive impact on pharmaceuticals and chemicals. Likewise, bank expansion increases growth in every sector except cotton and jute. On a consistent basis, we observe that output growth goes hand in hand with macroeconomic variables except in cotton and jute industries.

Juxtaposing the results relating to frontier output and growth with that of efficiency places the impact of infrastructure in context. We are clearly not debating the positive impact infrastructure has had on frontier output and growth. What we are less certain about is its impact on firm efficiency and our results suggest a statistically significant negative effect of infrastructure improvements on firm efficiency for the panel of firms in our sample.

6. Conclusions

In this paper, our main aim was to analyse the effect of firm-specific and macroeconomic factors on the efficiency and output of Indian manufacturing firms in six different industries. To this end, we estimated stochastic frontier production functions for six industries using company-level annual data between 1999 and 2007. Our results indicate that while frontier output increased in all the sectors (though it declined in jute towards the end of our sample period), efficiency levels were largely stagnant. We find no positive impact of infrastructural improvements on firm efficiency. The results are robust to using a synthetic index of macroeconomic variables. In almost all cases, we find that infrastructural improvements in power generation capacity, electrification of railways, bank expansion or road construction are associated with a rise in frontier output (or production potential of firms) and a decline in firm efficiency (or the actual to potential output ratio). Our analysis suggests that the underlying reason for this puzzle might be a shifting-out of production frontiers over time at a pace higher than the rate of increase in output, which is consistent with uneven utilisation of improvements in infrastructure amongst firms. However, the use of economy-wide rather than a more granular measure of macroeconomic factors calls for cautious interpretation of the results.

Notes

[1] The data set provides no information on the variety of products produced by a firm or on coverage ratios. However, studies have indicated that firms in India tend to diversify narrowly (within the same three-digit industry category) though industry

houses span wider industries. There is very little broad diversification amongst firms, even though industrial houses are very broadly diversified. Government licensing has also played a role in maintaining such a narrow range of diversification. Given this, it looks likely that though firms may produce a number of different products, these products fall within the same industry group.

2 For example, the combined balance sheet analysis based on the data published by the RBI in 1993 (Bulletin, December) reported results for 1988–89, 1989–90 and 1990–91 based on a sample of 2131 companies. A similar analysis in 1992 (Bulletin, November) reported results for 1908 companies for 1987–88, 1988–89 and 1989–90. The two samples had 1647 companies in common.

3 We tested both the Cobb–Douglas and Translog frontier production functions for each of the six industries considered in this study. We found that the Cobb-Douglas production function fitted 5 of our 6 industries and the Translog production function (which includes the squares of all the factors of production and also the cross-products) fitted the pharmaceuticals industry. However, in order to ease comparison across the industries, we have limited ourselves to the Cobb-Douglas model in all six sectors.

4 If the fixed-effects approach is used, then one does not need to assume a probability distribution for the inefficiency index. In addition, the fixed effects approach has the advantage of dispensing with the assumption that firm level inefficiencies are uncorrelated with input levels. The random-effects approach, on the other hand, requires us to assume that firm level inefficiencies and input levels are independent but unlike the fixed effects approach, it can accommodate time-invariant variables such as industry or location dummies.

5 Since the location of the firms is not available, we proxy local external factors with economy-wide variables.

6 Our results differ from those in Mitra et al (2002) for two reasons. First, Mitra et al (2002) use infrastructure variables that are different from ours. In particular, they use per capita industrial electricity consumption, the density of road and rail networks, the number of vehicles per inhabitant, and the development of the postal system. On the financial front, they include bank branch offices per 1,000 inhabitants, which we use in this paper, but also deposits and loans as a percentage of income. Second, a number of these variables are ex post demand determined infrastructure variables, for example, the consumption of industrial electricity or the percentage of loans. These must depend upon the level of output in the economy and therefore may be expected to be endogenous.

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Appendix : A *Data description and sources of independent variables*

We provide a brief description of the different variables used in estimating efficiency scores and in predicting frontier output along with their sources.

Table A.1: *Glossary of independent variables used in the analysis*

Variable name	Description	Aggregation level	Source
Firm-specific factors:			
Source of borrowing:			
IFI	Loans from International Financial Institutions (IFIs) as % of net sales	Firm	RBI
BANK	Loans from commercial banks as % of net sales	Firm	RBI
FII	Loans from Financial Institutional Investors (FIIs) as % of net sales	Firm	RBI
GOVT	Loans from government as % of net sales	Firm	RBI
COMP	Loans from company as % of net sales	Firm	RBI
OTHER	Loans from other sources as % of net sales	Firm	RBI
Research and development:			
R&D	Expenditure on research and development as % of net sales.	Firm	RBI
Global integration:			
IMP	Expenditure on imports as a % of net sales.	Firm	RBI
EXP	Expenditure on exports as a % of net sales.	Firm	RBI
Firm size:			
SIZE	Lag of observed output in logs	Firm	RBI
Macroeconomic factors:			
Exchange rate fluctuations:			
REER	Real Effective Exchange rate	National	Economic Survey
Financial coverage:			
FIN	Financial development: number of bank branches.	National	Economic Survey
Infrastructure:			
POWER	Capacity generation of electricity in thousand MW	National	Economic Survey
ROAD	Length of roads and highways in thousand km	National	Economic Survey
RAIL	Railway route electrified in thousand km	National	Economic Survey
Macroeconomic Index			
MACRO	Synthetic index of macroeconomic variables (REER, FIN, POWER, ROAD, RAIL)	National	Authors' own estimate

Table A.2: *Summary statistics by industry*

	Chemicals				Cotton				Jute			
Variable	**Mean**	**sd**	**Min**	**Max**	**Mean**	**sd**	**Min**	**Max**	**Mean**	**sd**	**Min**	**Max**
Log(Y)	13.717	1.803	5.535	18.995	13.573	1.401	6.204	17.139	13.671	1.129	5.402	15.364
Log(K)	12.984	1.803	7.689	18.404	13.151	1.395	5.877	17.058	12.624	1.139	8.180	14.669
Log(L)	11.001	1.689	4.522	16.103	11.305	1.392	6.379	14.908	12.591	1.280	6.999	14.597
Log(RM)	13.065	1.904	3.534	18.465	13.014	1.442	5.138	16.510	12.968	1.062	5.677	14.764
BANK	0.793	8.483	0.000	199.382	1.324	18.363	0.000	497.113	0.106	0.110	0.000	0.608
IFI	0.127	0.813	0.000	26.694	0.950	22.290	0.000	694.482	0.490	5.277	0.000	65.041
FII	0.013	0.110	0.000	2.609	0.005	0.032	0.000	0.412	0.002	0.011	0.000	0.094
GOVT	0.058	0.833	0.000	23.100	0.065	1.121	0.000	33.246	0.022	0.061	0.000	0.448
COMP	0.474	9.183	0.000	255.975	0.300	4.291	0.000	95.120	0.141	0.921	0.000	9.244
OTHER	0.048	0.455	0.000	18.604	0.074	0.658	0.000	17.383	1.264	14.716	0.000	181.301
R&D	0.002	0.008	0.000	0.246	0.000	0.001	0.000	0.008	0.001	0.002	0.000	0.016
IMP	0.142	0.206	0.000	2.592	0.072	0.132	0.000	2.507	0.043	0.061	0.000	0.320
EXP	0.168	0.250	-0.111	1.184	0.240	0.330	0.000	4.738	0.135	0.251	0.000	1.724
Obs.	**1807**				**Obs.**	**975**			**Obs.**	**152**		
	Motor vehicles				**Pharmaceuticals**				**Plastics**			
Variable	**Mean**	**sd**	**Min**	**Max**	**Mean**	**sd**	**Min**	**Max**	**Mean**	**sd**	**Min**	**Max**
Log(Y)	14.414	1.618	6.938	19.664	13.511	1.866	7.608	17.739	12.926	1.594	7.910	16.821
Log(K)	13.394	1.639	7.583	18.569	12.630	1.691	7.372	16.726	12.472	1.500	7.126	16.209
Log(L)	11.760	1.529	5.476	16.541	11.073	1.936	2.205	15.439	10.276	1.575	4.477	13.912
Log(RM)	13.797	1.787	7.109	19.265	12.745	1.906	4.713	16.969	12.411	1.695	5.065	16.392
BANK	0.215	0.488	0.000	8.210	0.406	1.610	0.000	27.017	0.500	1.830	0.000	29.442
IFI	0.058	0.178	0.000	2.222	0.104	0.448	0.000	8.277	0.255	1.602	0.000	34.222
FII	0.018	0.146	0.000	2.703	0.020	0.109	0.000	1.405	0.039	0.236	0.000	3.080
GOVT	0.014	0.041	0.000	0.465	0.018	0.124	0.000	3.413	0.017	0.064	0.000	0.623
COMP	0.032	0.231	0.000	4.888	0.023	0.119	0.000	2.503	0.179	1.499	0.000	25.551
OTHER	0.020	0.074	0.000	1.307	0.052	0.240	0.000	5.013	0.092	0.357	0.000	5.323
R&D	0.003	0.006	0.000	0.046	0.012	0.030	0.000	0.340	0.000	0.001	0.000	0.016
IMP	0.096	0.164	0.000	3.236	0.111	0.144	0.000	0.847	0.109	0.148	0.000	0.986
EXP	0.102	0.163	0.000	1.001	0.220	0.265	0.000	1.064	0.139	0.263	0.000	3.830
Obs.	**869**				**Obs.**	**986**			**Obs.**	**600**		

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