CENTRE D'ÉTUDES
ET DE RECHERCHES
SUR LE DÉVELOPPEMENT
INTERNATIONAL

Document de travail de la série

Etudes et Documents

E 2012.33

Are reforms productive?
Explaining productivity and efficiency in the Indian manufacturing

Arup Mitra
Chandan Sharma
Marie-Ange Véganzonès -Varoudakis

September 2012

CERDI
65, bd. F. Mitterrand
63000 CLERMONT FERRAND - FRANCE
TÉL. 04 73 17 74 00
FAX 04 73 17 74 28
www.cerdi.org

Les auteurs

Arup Mitra
Institute of Economic Growth, University of Delhi Enclave, India

Chandan Sharma
National Institute of Financial Management, Faridabad, India

Marie-Ange Véganzonès -Varoudakis
CNRS Researcher, Clermont Université, Université d'Auvergne, CNRS, UMR 6587, Centre d'Etudes et de Recherches sur le Développement International (CERDI), F-63009 Clermont-Ferrand, France
Email :

Corresponding author:
Marie-Ange Véganzonès –Varoudakis: veganzones@aol.com

La série des *Etudes et Documents* du CERDI est consultable sur le site :
http://www.cerdi.org/ed

Directeur de la publication : Patrick Plane

Directeur de la rédaction : Catherine Araujo Bonjean

Responsable d'édition : Annie Cohade

ISSN : 2114-7957

Abstract

India's economic liberalization in the 1990s provides scope for research on the effect of policy reforms on economic performance. This paper addresses the question of some of these policy changes and their impact on firms' productivity and efficiency. We test specifically the role of export, import (total, intermediary and capital goods), R&D, technology transfer and infrastructure endowment over the period 1994-2008. Result of the analysis suggests that infrastructure is a crucial determinant of manufacturing performance in India. This is true for a wide range of variables such as transport, energy and information & communication technology (ICT). This result is important in the Indian context of infrastructure bottlenecks. Empirical results also suggest that knowledge transfers through exports are more important than through imports. Other findings indicate that R&D is not a productivity-enhancing activity in India and that firms rely more on purchase of foreign technology. This outcome does not come as a surprise because Indian firms are known for low in-house research and innovation-oriented activities.

JEL Classification: L60, H54, D24, O53, O3, F43

1. Introduction

The role of productivity in determining income levels and economic performance, as well as issues concerning accurate measurement techniques, have attracted a large number of researches in India (see Goldar, 2004). Not too many studies, however, have attempted to answer the question of the determinants of productivity and efficiency over time. To fill this gap, this paper focuses on the manufacturing industry and examines the role of some of the important factors in explaining the productive performance in this sector.

A vital element of India's rapid economic growth since the early 1990s has been the improved performance of its manufacturing industry. Manufacturing is an important sector in terms of value added and earning of foreign exchange of the Indian economy, comprising about 31 % of the non-agricultural GDP (Natarajn and Duraisamy, 2008). This sector has gained in strength in many ways over the past twenty years, as a consequence of a liberalization of industrial controls, as well as a gradual integration with the world economy. The average output growth rate was of 8 % in the last decade (see Fig. A.1.1 in *Appendix* 1), and targeted at around 12 % in the eleventh plan period (2007-08 to 2011-12) (Planning Commission, 2006).

In the reform era (since 1991) in India, the manufacturing sector has witnessed major policy changes, particularly in licensing, technology transfer and trade policies. Industrial de-licensing and removal of restrictions on foreign investment have modified the profile of this sector considerably. Successive trade policies have stimulated export and import, especially of intermediary and capital goods, since tariff rates have been reduced drastically and quantitative restrictions on imports by and large abolished. To encourage firms to innovate and conduct R&D activities, the government has developed a system of fiscal incentives and financial benefits (for details, see Sharma, 2012). Thus, factor cost advantages are being replaced by technology-related factors in determining international competitiveness of the Indian firms, such as zero-defect product quality and international certification of firms' quality assurance systems (UNIDO, 2005). These reforms aimed at making the Indian industry more efficient, technologically up-to-date and competitive. However, despite these policy changes, *TFP* growth of this sector declined to less than two % in the 1990s, from above five % in the 1980s (see Trivedi *et al.,* 2000; Goldar and Kumari, 2003). Recent estimates indicate as well a marginal improvement in *TFP* growth in the manufacturing industries in the 2000s (Seghal and Sharma, 2010; Kathuria *et al*., 2010). Thus, it is relevant and important for policy point of view to ask if the recent reforms have had the expected impact on the Indian industrial performance. The present paper addresses this question.

In the literature, the role of export and import in promoting growth, through productivity gains in particular, has been debated extensively (see Balassa, 1988; Bhagwati, 1988, Krugman, 1994). International trade is considered as one key sources of the transmission and adoption of new technology (see Romer, 1987; Coe and Helpman, 1995; Barro, 1997; Frankel and Romer, 1999). This channel is particularly important for developing economies where new technology is relatively scarce and firms are dependent of high quality imported intermediate goods. On the one hand, imports are generally described as increasing competition for the domestic firms, inciting them to invest and be more productive. The positive effect of import is also associated with knowledge spillover between foreign and domestic goods, as developed by Aitken *et* al. (1997) and Keller (2004). On the other hand, imports of intermediary and capital goods are seen as stimulating productivity through technology transfer and better quality of products imported. As for exporting firms, international competition is a factor of innovation and investment in more productive technologies and organization as well. In the case of India, Chand and Sen (2002), Goldar and Kumari (2003), Sharma (2011), Mishra and Sharma (2012) confirm that trade and productivity are closely related.

Research and innovation have also been identified as another key channel of firms' productivity and income gains. Endogenous growth models explain that R&D expenditures, in addition to directly enhance firms' productivity through innovation, contribute to this process through their industry-wide spillover effect (see Grossman and Helpman, 1990; Romer; 1986). Most of the empirical studies have invariably found a significant and positive impact of R&D on firms' performance (see Griliches, 1979 and 1986; Griffith *et* al., 2006; O'Mahony and Vecchi, 2009). But the success of the manufacturing sector has also been linked to foreign technology transfer. In India, Raut (1995) and Sharma (2012) have shown the role (however at varying degree) of innovation in productivity performance of firms.

Another important factor which has direct implications on manufacturing performance is physical infrastructure. In the related literature, infrastructure is considered to be a crucial factor of productivity and efficiency enhancement through external economies and complementarity with other factors of production (see Romer, 1986; Lucas, 1988; Barro and Sal-i-Martin, 1995; Anwar, 1995). In India, the infrastructure inadequacies have been recognized as a major constraining factor for the performance of firms (see Pinto, Zahir and Pang, 2006). In recent years, however, the Indian government has been putting in efforts to enhance the infrastructure services by liberalizing the related policies, encouraging the private sector in infrastructure projects through public private partnership (PPP), and directly investing in the infrastructure sector. Government expenditure, in particular, has been increased from 4.6% of GDP to a figure between 7 and 8% in the eleventh plan period (2007-08 to 2011-12) (Planning Commission, 2006). On the empirical side, Mitra *et al*. (2002 and 2011) Hulten *et al*. (2006), Sehgal and Sharma (2010) have shown that infrastructure endowments have played a critical role in improving the performance of the Indian industrial sector.

Against this background, the present paper revisits the issue of the impact of the reforms on the manufacturing performance. We test the effect of several factors: import (total, intermediate and capital inputs), export, in-house R&D, technology transfer and physical infrastructure, which we link to the productivity and efficiency of the industries. While doing so, we introduce several novelties from the empirical standpoint. *First*, in the standard literature, the factors mentioned above are most of the time tested separately. We move a step ahead and test them in a single framework in order to compare the drivers of the industrial performance. *Second,* in most of the previous studies on India, data was mainly taken from the Annual Survey of Industry (ASI). We utilize a new manufacturing database, Prowess, which includes eight important industries and allows us to extend the time horizon of the analysis up to 2008. *Third*, while the previous studies in India mainly focused on total factor productivity (*TFP*), we analyse the impact on another crucial indicator of industrial performance, namely the technical efficiency (*TE*). *Fourth*, the inclusion of too many infrastructure variables separately in a regression analysis may lead to multicollinearity problem. In order to avoid this, we construct two composite indices of infrastructure (*G*) for total infrastructure and (*ICT*) for information & communication technology, by using principal component analysis (*PCA*). *Fifth*, some recent researches (see Kasahara and Rodrigue, 2008; Goldberg *et al*. 2008) have shown that intermediate imported inputs are crucial sources of industrial productivity gain, while some others (see Ziesemer, 1995, Dovis and Milgram-Baleix, 2009) highlight that it is imported capital goods which are important for technology adoption and implementation. In the paper, we consider both the variables separately in the model.

The rest of paper is organized as follows. The second section provides some theoretical background and justifies our empirical models of investigation. The third section introduces the data used in the analysis. The fourth section discusses some methodological aspects linked to the computation of total factor productivity (*TFP*) and technical efficiency (*TE*). The fifth section estimates our empirical models and illustrates the impact of our variables of interest. The last section concludes with policy recommendations.

2. Theoretical background and empirical model

In the standard economic literature, a large number of factors are modeled as determinants of the industrial productivity. This includes, among others, trade, technology, innovation, ownership, market structure, institutions and public capital (for a detail discussion see Syverson, 2010). In this paper, we test some important factors in the Indian context, which are as follows:

Export: The economic linkage between export and productivity has long been a highly debated topic in the international economics and trade literature. The issue has, however, taken on added importance since the pioneering work of Bernard and Jensen (1995 and 1999) that brought into focus the exceptional qualities of exporting firms which have been found to be more productive, larger in size, more skill and capital intensive, and high wage payers. On the theoretical front, there is a common opinion that international trade in general, and export in particular, improves the productivity of firms, which finally leads to economic growth (see Beckerman, 1962; Balassa, 1988; Bhagwati, 1988). For exporting firms, international competition is a factor of investment in more productive technology and organization (see Krugman, 1994; Rodrik, 1988). For the advocates of endogenous growth, the effect comes from innovation (Grossman and Helpman, 1990; Rivera-Batiz and Romer, 1991) and technology transfer (Barro and Sala-I-Martin, 1995; Parente and Prescott, 1994). Economic policies based on trade liberalization and export-led growth strategies have also been widely supported by the argument that exposure to foreign markets produces positive learning effects by exposing the domestic firms to advanced technology from international competitors (see Bernard and Wagner, 1997; Bernard and Jensen, 1999). It is also argued that exporting reallocates the available resources from the less efficient firms to the more efficient ones, resulting in a more optimal use of available resources (Bernard and Jensen, 2004).

These arguments have justified the major trade reform announced by the Indian government in July, 1991. Subsequent trade policies, in the 1990s and the 2000s, have then dramatically changed the dynamics of India's export. Policies such as the liberalization of import, the removal of export restrictions, the elimination of the trade monopolies of the state trading agencies, the simplification of the trade regime, the reduction of tariff levels and of their dispersion, the full convertibility of the domestic currency for foreign exchange transactions, and the policy of export promotion have boosted the industrial export growth (see Fig. A.1.2 in *Appendix* 1).

Despite the relative consensus on the positive impact of export on productivity and growth, the empirical literature has produced mixed and inconclusive results (see the survey by Wagner 2007). Bernard and Jensen (2004a) found that, while exporters have noticeably higher productivity levels, there is no strong evidence to conclude that export participation increases plants' productivity. Similarly, Arnold and Hussinnger (2005a) reached the conclusion that firms with higher productivity self-select into the export market and that exporting does not improve the performances of German firms. On the contrary, empirical evidence in favor of learning-by-exporting has been revealed in the case of Colombia by Robert and Tybout (1997), and Fernandes and Isgut (2005), China by Kraay (1999), Canada by Baldwin and Gu (2003), Korea by Kim *et al*. (2009), and Sweden by Andersson and Loof (2009), which confirm that past export performance has a significant impact on productivity. Similarly, Aw *et al.* (2000), Van Biesebroeck (2006), De Locker (2007), and Yasar and Rejesus (2005) have determined that firms experience productivity improvement after entering the export market. Greenaway *et* al. (2005) for Swedish firms, and Damijan and Kostevc (2006) for Slovenian manufacturing have failed to detect any evidence for both hypotheses: learning-by-exporting or self-selection of more productive firms in the export market. In the case of India, results regarding the role of export on productivity performance have provided contrary results as well (see Singh, 2003; Mishra and Sharma, 2011 and 2012). Keeping this in view, in our empirical model, we consider export intensity (*export*) as a measure of industries' exporting performance. This variable is calculated as the ratio of export of goods to total sales and is expected to influence positively firm's productivity and efficiency.

Import: A significant body of literature suggests that imports have large positive effects on income, output and productivity (see Romer, 1987; Coe and Helpman, 1995; Barro, 1997; Frankel and Romer, 1999). Imports are generally described as increasing competition for the domestic firms, inciting them to invest and be more productive. Besides, the role of imported intermediates inputs has recently been understood as vital and attracted considerable attention. In the literature, the utilization of imported intermediate and capital goods is seen as an important channel of obtaining new technology. By doing so, developing countries take advantage of the R&D of developed economies to improve the efficiency of their domestic production. Growth models also suggest that imported inputs can potentially enhance productivity because of their better quality, which leads to better final products too (see Grossman and Helpman, 1990), Imported intermediate's inputs are also considered as complementary to the other inputs in the production. Gains in that case are found to be higher than the sum of the individual effects. These gains could come from imperfect substitution across goods, as in the love-variety framework of Krugman (1979) and Eitheir (1982). The learning-spillovers between foreign and domestic goods could be another channel in this process (see Aitken *et al.*, 1997; Keller, 2004).

Empirical validation of these models has, however, produced rather mixed results. Some studies confirm a significant role of import or imported intermediary inputs on domestic firms' performance. Harpern *et al.* (2009) found that imported inputs have large productivity effect: increasing the share of imported goods from 0 to 100 per cent increases productivity by 11 % for Hungarian firms. Kasahara and Rodrigue (2008) suggest that becoming an importer of foreign intermediates improves the productivity of the Chilean's firms. Goldberg *et al.* (2008) show that access to new intermediates inputs produces substantial productivity gains in India. Amiti and Konings (2007) reveal that the productivity gains from cutting tariffs on intermediate goods is twice as big as those from comparable cuts for final goods in Indonesia. As for Ziesemer (1995), and Dovis and Milgram-Baleix (2009), they highlight that imported capital goods are important for technology adoption and implementation.

On the other side, although Lawrence and Weinstein (1999) indicate that lower tariffs and higher import volumes have been beneficial for Japan during the period 1964-1973, the salutatory impact of import seems to stem more from their contribution to competition than to intermediate inputs. Van Biesbroek (2003) finds, as well, that productivity improvement do not happen through the use of more advance inputs in Colombia. Similarly, Muendler (2004) reached the conclusion that there is only a small contribution of foreign materials and investment goods on output for Brazil. As for Bigsten and Gebreeyesus (2009), not only they establish strong evidence in favor of self-selection of more productive firms into the export market, but they validate also the learning-by-exporting hypothesis.

In India, the issue of the productive impact of import is highly critical, as trade regime in pre-reform era was amongst the most restrictive in Asia. In 1991, in the aftermath of a balance-of-payments crisis, India embarked a dramatic import liberalization of the economy as part of an IMF adjustment program. An important part of this reform was to abandon the extremely restrictive import policies. The average tariffs were reduced from about 86 % in 1989-90 to about 30 % in 1999-2000. For manufacturing, there was a decline from about 120 % in 1989-90 to about 33 % in 1997-98. The non-tariff barriers (NTBs) in manufacturing also fell from 87 % in 1988-89 to 28 % in 1999-2000. Within manufacturing, the NTB for machinery and intermediates goods dropped considerably to only 10 and 12 % respectively in 1995. Currently, almost all commodities are free from quantitative restrictions on imports (see International Trade Economic Survey, 2009-10). As a consequence, import (both capital and intermediary) surged dramatically in the recent years (see Fig. A.1.3 in *Appendix* 1) (see Topalova, 2007 and Goldberg *et* al., 2010, for a detailed discussion on imports and productivity in India).[1] In our empirical model, we defined import intensity (*import)*, as well as imported intermediate (*importraw*) and capital goods intensity (*importcap*) as the ratio of total, intermediate and capital goods imports respectively to total sales. These variables are expected to have a positive effect on industries' productivity' and efficiency.

[1] Khadelwal and Topalova (2011) examine reductions in trade protection in individual industries and find that procompetitive forces, resulting from lower tariffs on final goods, as well as access to better input, due to lower input tariffs, increased firm-level productivity, with the latter having a large impact. Sivadasan (2009) considers the liberalization of both the trade and FDI regime in manufacturing and concludes that both increased firm-level productivity. Goldberg *et al*. (2001a) find that lower input tariffs accounted on average for 31 percent of the new products introduced by Indian firms, which suggests that an important consequence of the input tariff liberalization was to relax technological constraints through firms' access to new imported inputs that were unavailable prior to the liberalization.

R&D, innovation and direct technology transfer: Advocates of endogenous growth theory also believe that R&D plays a critical role in improving productivity through innovation (Grossman and Helpman 1991; Rivera-Batiz and Romer 1991) and technology transfer (Barro and Sala-i-Martin 1995; Parente and Prescott, 1994). Other models explain that R&D expenditures contribute to productivity through their industry-wide spillover effect (Grossman and Helpman, 1990; Romer, 1986). In this framework, firms spend on innovation to obtain new technology that augments their productivity growth. This has additionally a significant implications for overall economy, as private know-how of individuals firms easily spills over to other firms of the same industry, and latter to firms of other industries. This acts as an external effect, enhancing the productivity of all firms.

In the empirical literature, there is no dearth of study which investigates the role of R&D and technology transfer in explaining manufacturing performance. Although most of these studies find a significant and positive effect of R&D on firms' performance, the estimated elasticity with respect to R&D varies widely (see Griliches, 1979 and 1986; Jaffe, 1986; Griliches and Mairesse, 1990; Griffith *et al.*, 2006)[2]. Some of these recent studies for the developed countries suggest that knowledge generating activities is no silver bullet for productivity growth and '*manna from heaven'* impact is very small (see for example, O'Mahony and Vecchi, 2009).

In India, although R&D had traditionally been negligible, the outlook of the industries has, in the recent years, changed considerably. Firms have started taking R&D activities mores seriously and more funds are being invested in these activities. Results of the empirical literature however, give contrary results on the issue (Aggarwal, 2000 and Sharma, 2012). Therefore we intend to re-estimate the role of R&D intensity (*R&D*), taken as a proxy variable for research and

[2] Considering the US manufacturing, Griliches (1979 and 1986) found an elasticity of 0.07, Jaffe (1986) of 0.02, and Griliches and Mairesse (1990) between 0.25 and 0.45. In the case of France, this elasticity was estimated between 0.09 and 0.33 by Cuneo and Mairesse (1984), while Griliches and Mairesse (1990) found a value between 0.20 and 0.50 for the Japanese manufacturing, and Wand and Tsai's (2003) of 0.19 in the case of Taiwan. In a recent paper, however, Griffith *et al.* (2006) found a value ranging from 0.012 to 0.029, for the UK manufacturing firms, what looks particularly low. In India, this elasticity has been estimated at 0.064 in the heavy industry, 0.357 in the light industry, and 0.101 in the overall industries by Raut (1995).

innovation. In our model, this variable is calculated as the ratio of in-house R&D expenditure to total sales and is expected to impact positively the firm's productive performance.

In other models, however, it is the introduction of new technologies through international knowledge transfer which is vital for the competitiveness of firms in developing countries. These technologies are expected to improve the performance of the host firm through increased productivity and potential technology spillovers. In the standard empirical literature the impact of international technology transfer through licensing has been recently examined in the context of local firms (Basant and Fikkert, 1996; Branstetter and Chen, 2006, Belderbos et al., 2008). In our model, we consider the intensity of technology transfer (*tech*) measured by expenditure on royalty on technology to total sales. As for R&D, this variable is expected to impact positively the industries' productivity and efficiency.

Infrastructure: The importance of infrastructure in the context of growth has been felt intensely by the researchers and policy maker, as it is considered to be one of the prime productivity stimulators. In the theoretical literature, public infrastructure is considered to be a crucial factor for productivity and efficiency enhancement through complementarities with other production factors and external economies (Romer, 1986; Lucas, 1988; Barro and Sala-i-Martin, 1995; Anwar, 1995). Good infrastructure reduces production and transaction costs. A reliable power supply, for example, reduces the need to produce in-house power, as well as the amount of capital needed for starting a new firm. Empirical findings on this issue are, however, inconsistent and often contrary to each other. Over the last two decades, a large number of studies have focused on this issue. Most have noted that public infrastructure positively and sizably affects economic performance (Aschauer, 1989; Munnel, 1990a and b; Ford and Poret, 1991). Some others, for example, Evans and Karras (1994) and Holtz-Eakin (1994), challenged these findings and show insignificant or minimal impact of public infrastructure. Nevertheless, with improvement in empirical methodologies, some recent studies again estimated large effects (Stephan, 2003; Everaert and Heylen, 2004; Kamps, 2005). [3] In the case of India, Mitra et *al*. (2002 and 2012), Hulten *et al*. (2006), Sehgal and Sharma (2010) estimated moderate to large impact of infrastructure on the manufacturing performance.

[3] For detailed survey of the related literature, see Sturm et al. (1998) and Romp and Haan (2007).

In India, accompanying high industrial growth has increased demand for infrastructure services. It has been very well documented and widely debated that a failure to respond to this demand (by increasing infrastructure availability) is causing serious impediments in achieving the country's economic growth objectives (see Bhanumurthy and Sharma, 2011). Actually, despite the recent efforts made by the government to enhance infrastructure services, bottlenecks are still a serious issue in the country. As a matter of facts, India ranks very low in several domains, behind China, Brazil, and South Africa, which are India's main competitors on the world market (see Table A.1.1. in *Appendix* 1). Also, if government spending has recently increased to reach seven to eight % of GDP during the eleventh plan period (2007-08 to 2011-12), this is still far from China effort, which has invested between 15 and 20 % of its GDP since the mid-1990s. In the empirical models, we utilize two measures of public infrastructure: a total infrastructure index (G), and an information & communication technology index (*ICT*) (see Appendix *2* and *3* for details on the infrastructure indicators and the aggregation method). Both variables are expected to have a positive impact on industries' productivity and efficiency.

In light of the above discussion, our empirical model is as follows:

$$X_{it} = \beta_0 + \beta_1 Export_{it} + \beta_2\, Import_{it} + \beta_3 R\&D_{it} + \beta_4\, tech_{it} + \beta_5 G_{it} + e_{it} \qquad (1)$$

where X is the measure of *TFP* or *TE*, while $Export, Import$, *R&D*, *Tech* and *G* are as explained previously and βs are parameters to be estimated.

3. Data on infrastructure and the manufacturing sector

In this study, we have utilized data for two-digit industry groups taken from the Prowess database[4] provided by the Center for Monitoring Indian Economy (CMIE). The data set is rich and provides heterogeneity across firms and time. Annual financial statements of firms

[4] Prowess Database is online database provided by the Centre for Monitoring Indian Economy (CMIE). The database covers financial data for over 23000 companies operating in India. Most of the companies covered in the database are listed on stock exchanges, and the financial data includes all those information that operating companies are required to disclose in their annual reports. The accepted disclosure norms under the Indian Companies Act, 1956, makes compulsory for companies to report all heads of income and expenditure, which account for more than 1% of their turnover.

belonging to eight manufacturing industries --namely *Food & Beverages*, *Textiles*, *Chemicals*, *Non-metallic Minerals*, *Metal & Metal Products*, *Machinery*, *Transport Equipment,* and *Miscellaneous Manufacturing* -- have been used. Firm-level data have been transformed into industry-level data by aggregation. This is done for each year over the sample period, 1994-2008. The prime reason for taking 1994 as the initial year is that the Indian economy underwent structural reforms in the early 1990s, which have subsequently brought in vast changes in the manufacturing sector. Another practical reason is that the data on price indices and deflators for all variables are available from this year onwards.

We use the gross value added of the industries as the measures of nominal output, which is deflated by industry specific wholesale price indices (WPI) to obtain output in real terms[5]. The deflator is from the Office of the Economic Adviser (OEA), Ministry of Commerce & Industry, Government of India (http://eaindustry.nic.in/). The series on real capital stock is constructed using the perpetual inventory capital adjustment method as in Levinson and Petrin (2003). Specifically, we compute it as:

$$K_t = (1-\delta)K_{t-1} + I_t \ldots\ldots\ldots\ldots \quad (2)$$

where, K is the capital stock, I is the deflated gross investment, δ is the rate of depreciation taken at 7%, consistent with similar studies for India (Unel 2003; Ghosh 2009), and t indicates the year. The initial capital stock equals the net book value of capital stock for the year 1994.

As for labour, Prowess does not provide information on the workforce, but only on wages and salaries. To obtain this information, we used the wage rate (obtained by dividing the total emoluments by the total man days) from the Annual Survey (ASI) database. The number of workers is then approximated by dividing the Prowess information on wages and salaries by the average wage rate obtained previously. Data on other control variables such as trade (export and import) and R&D have also been extracted from the same database. All data series used in the analysis have been deflated with appropriate deflator with base 1994. A summary statistics of the variables is reported in Table A.1.2, *Appendix* 1.

[5] We prefer gross value added as a measure of output in computing *TFP*, as it is widely used in the Indian manufacturing sector literature (see Kumar, 2006; Goldar, 2004; Unel, 2003; Ahluwalia 1991; Balakrishnan and Pushpangadan, 1994). There are many advantages of using gross value added over output. *Firstly*, it allows us a comparison between the firms that use different raw materials. *Secondly*, if gross output is used as a measure of output, it adds the necessity of including raw materials, which may obscure the role of labor and capital in the productivity growth (Hossain and Karunaratne, 2004; Kumar, 2006).

For infrastructure, this analysis considers physical infrastructure for the period 1994-2008. It covers transportation (road, rail and air), information & communication technology (*ICT*) and energy sectors. The data sources for these variables are World Development Indicators (WDI) online (2011), and Infrastructure (2009) publications of CMIE (see Table A.2.1 in *Appendix* 2). Instead of using all infrastructure variables separately, which is likely to lead to multicollinearity (see correlation between infrastructure variables in Table A.2.2. of *Appendix* 2), we construct a total and an *ICT* infrastructure index for India by using Principal Component Analysis (*PCA*). For the methodology of construction of both these indices see *Appendix* 3.

4. Measuring total factor productivity (*TFP*) and technical efficiency (*TE*)

We start our empirical analysis by computing the total factor productivity *(TFP)* of the Indian industries. For this purpose, we follow a two-stage procedure. In the first stage, we construct a panel of the eight industries and, following Mitra *et al*. (2002), we estimate a basic production function in Cobb-Douglas form:

$$\ln(Q_{it}) = \alpha_1 \ln(K_{it}) + \alpha_2 \ln(N_{it}) + \alpha_3(T_{it}) + \eta_t + u_{it} \qquad (3)$$

where Q, *K*, and *N* are the value added, the capital and the labour defined previously (see section 3), for industry *i* and period *t*. T_i is the time trend specified for each industry *i* and α_1 , α_2 and α_3 are the parameters to be estimated. The term η_t represents fixed time effects, while *ln* represents log of the variables. Year dummies are also included in the model.

Equation (3) is estimated using the fixed effect method[6]. Results of estimation are shown in *Appendix 4* (column 1 of the Table A.4). These results are used, in a second step, to calculate the *TFP* of the industries as follows:

$$\ln(TFP_{it}) = \ln(Q_{it}) - \widehat{\alpha_1} \ln(K_{it}) - \widehat{\alpha_2} \ln(N_{it}) \qquad (4)$$

where $\hat{\alpha}_1$ and $\hat{\alpha}_2$ are the estimated parameters of capital and labour, respectively.

---

[6] The advantage of the *FE* estimator is that it can handle the issue of omitted variables that may be correlated with the explanatory variables. Also *FE,* to some extent, tackles the endogeneity bias, as well as the problem of non-stationarity because in the estimation for the within form, deviations from the mean are used.

To measure the technical efficiency (*TE*) of the Indian manufacturing sector, we estimated the stochastic frontier production function by maximum likelihood (*ML*) method, developed by Battese and Coelli (1992) for panel data. In this model, industry effects are assumed to be distributed as a truncated normal variable, which allows it to vary systemically with time.[7] Specifically, we employ time-varying efficiency model of the stochastic frontier as suggested by Battese and Coelli (1992). The model may be specified as:

$$Q_{it} = \alpha X_{it} + (V_{it} - \mu_{it}) \text{........................} \qquad (5)$$

where Q_{it} and X_{it} are output and inputs in log-form of *i*-th industry at time *t*.

Disturbance term is composed of two independent elements, V_{it} and μ_{it}. The former is assumed to be independently and identically distributed as $N(0, \sigma^2{}_v)$. The element μ_{it} is a nonnegative random variable, associated with technical inefficiency in production, assumed to be independent and identically distributed with truncation (at zero) of the distribution $N(\mu_{it}, \sigma^2{}_\mu)$. The parameters α s can be obtained by estimating the stochastic production function (4) using a ML technique.

Coelli (1996) utilizes the parameterization of Battese and Corra (1977) to replace $\sigma^2{}_v$ and $\sigma^2{}_\mu$ with $\sigma^2 = \sigma^2{}_v + \sigma^2{}_\mu$ and $\gamma = \dfrac{\sigma^2{}_\mu}{\sigma^2{}_v + \sigma^2{}_\mu}$ in the context of ML estimation. The term γ lies between 0 and 1 and this range provides a good initial value for use in an iterative maximization process. Subsequently, the relative technical efficiencies (*TEs*) of each industry can be predicated from the production frontier as follows:

$$TE = \frac{Q_{it}}{\exp(f(X_{it}; \alpha))} = \exp(-\mu_{it}) \text{..............} \qquad (6)$$

Since μ_{it} is, by definition, a nonnegative random variable, *TE* is bounded between zero and unity, where unity indicates that the industry is technically the most efficient. Our model measuring the efficiency is:

[7] The original model of Battese and Coelli (1992) is for firm level data, whereas we employ the model on industry data. Our working hypothesis is that some industries operate more efficiently than others.

$$\ln Q_{i,t} = \alpha_0 + \alpha_1 LnK_{i,t} + \alpha_2 LnN_{i,t} + \sum_t \lambda_t D_t + (v_{it} - u_{it}) \ldots\ldots\ldots\ldots\ldots(7)$$

Here D_t is a dummy variable having a value of one for t^{th} time period and zero otherwise and λ_t s are parameters to be estimated. The dummy variable is introduced in the model for the technical change; this is in line with the general index approach of Baltagi and Griffin (1988). The change in λ_t between successive periods becomes a measure of rate of technical change.

$$TC_{t,t+1} = \lambda_{t+1} - \lambda_t \;\ldots\ldots \qquad (8)$$

This implies that the hypothesis of no technical change is: $\lambda_t = k \,\forall t$.

Using the above model (see equation 7), we estimate the *TE* of the Indian manufacturing. Our dataset for the panel of industries is the same as that used for *TFP* calculations. A Cobb-Douglas form is as well postulated for the purpose of the production frontier. Results of estimation are presented in *Appendix* 4 (column 2 of Table A.4). These results have been used to calculate the *TE* of the industries (as in equation 6).

5. Explaining Indian manufacturing productive performances

After having estimated the *TFP* and *TE* for the manufacturing sector, we turn to assessing the impact of the explanatory factors: import intensity (total, intermediary and capital), export and R&D intensity, technology transfer and infrastructure availability (total and *ICT*), on the sectors' productive performances. We apply the fixed effect (*FE*) model to our panel of eight manufacturing industries. Results are presented in Table 1 for the explanation of *TFP* and in Table 2 for *TE*.

Column 1 of Table 1 reports the results pertaining to the impact of import (*import*), export (*export*), and R&D (*R&D*) intensity, as well as total infrastructure availability (*G*) on *TFP*. Findings suggest that infrastructure is the most important determinant of productivity, with an elasticity of 0.109 at the conventional significance level. This can be interpreted as a 1% increase in infrastructure endowments leads to 0.109% growth in *TFP*, which is substantially large. Export intensity (*export*) is also estimated to be statistically significant with a substantial impact on productivity as well (elasticity of 0.099). As for import (*import*) and R&D (*R&D*) intensity, they are not found to be statistically significant.

Column 2 of Table 1 presents the results when total imports are replaced by imports of intermediate (*importraw*) and capital (*importcap*) goods, along with expenditure on royalty for technology transfer (*tech*). Similar as before, results regarding export-intensity (*export*) and infrastructure availability (*G*) are found to be crucial determinants of *TFP* of the industries. As for royalties (*tech*), the impact, though significant, is not sizable. Results fail, as well, to recognize any effect of import intensity (*import*) on productivity, as both imported intermediate (*importraw*) and capital (*importcap*) good variables are estimated to be statistically insignificant.

Columns 3 and 4 display the results when the *ICT* index replaces the total infrastructure index. Findings regarding exports (*export*), imports (*import*), imported intermediate (*importraw*) and capital (*importcap*) goods, R&D intensity (*R&D*) and royalty for technology transfer (*tech*), are very similar to the ones estimated with the total infrastructure index. As for *ICT*, elasticity is found to be statistically significant and varying between 3 to 4 per cent, which is quite sizable.

Table 1. *TFP* determinants of the Indian manufacturing, 1994-2008

Variable	Coefficient (1)	Coefficient (2)	Coefficient (3)	Coefficient (4)
C	1.673679** (32.01509)	1.752190** (32.70074)	1.811760** (81.30494)	1.889999** (66.11011)
IMPORT	0.002244 (0.151267)		0.002828 (0.193949)	
EXPORT	0.099762** (6.911471)	0.083143** (5.954704)	0.099598** (6.963184)	0.086476** (6.284772)
R&D	0.001916 (0.305954)	-0.000674 (-0.110176)	0.001799 (0.290074)	-0.00048 (-0.007975)
INFRA-index (G)	0.109809** (4.206162)	0.082415** (3.239839)		
IMPORTRAW		0.020950 (1.561013)		0.020987 (1.591312)
IMPORTCAP		-0.010503 (-1.871463)		-0.009615 (-1.719517)
Tech		0.027090** (2.427236)		0.024297 ** (2.172017)
ICT-index (ICT)			0.041783** (4.446658)	0.029637** (3.384770)
R^2	0.623296	0.663626	0.629479	0.669675

Source: Authors' estimations
Notes: t-values in parentheses. ** indicates statistical significance at 5% level.

In the next stage, the same models are tested for technical efficiency (*TE*). Findings are reported in Table 2. Results of column 1 are very similar to that on *TFP*, as for the total infrastructure index. The impact of export intensity (*export*) is however found to be much lower in that case. The analysis also suggests that import intensity (*import*) has a significant effect on the efficiency of the industries, though not very sizable (elasticity of 0.02). On the contrary, R&D intensity (*R&D*) is not found to having any role in determining *TE*.

In the next estimation, results of column 2 indicate that imported intermediate goods (*importraw)* and direct technology transfer (*tech*) variables display a significant impact on firms' efficiency, although not very sizable either (elasticity of 0.02). Estimations however fail to show a significant role of imported capital goods (*importcap)* on the efficiency. Findings regarding other variables, i.e. infrastructure availability (*G*), R&D (*R&D*) and export (*export*) intensity are very similar to the ones in column 1.

Considering the role of *ICT* in the efficiency movements, it is again found similar to that of *TFP* and it varies from 0.03 to 0.04 (see columns 3 and 4 of Table 2). As for the other variables, conclusions are the same as in column 1 and 2, when estimating the impact of total infrastructure on efficiency.

Table 2. *TE* determinants of the Indian manufacturing, 1994-2008

Variable	Coefficient (1)	Coefficient (2)	Coefficient (3)	Coefficient (4)
C	1.735706** (59.70154)	1.776961** (60.02388)	1.858225** (157.5004)	1.883326** (139.8301)
IMPORT	0.020874** (2.531729)		0.020222** (2.617551)	
EXPORT	0.041235** (5.104132)	0.036789** (4.768981)	0.040479** (5.305632)	0.036888** (4.975370)
R&D	0.003533 (1.015530)	0.001923** (0.568914)	0.003120 (0.949727)	0.001700 (0.522831)
INFRA-index (G)	0.100634** (6.928806)	0.090462** (6.436513)		
IMPORTRAW		0.021913** (2.955259)		0.021992** (3.114389)
IMPORTCAP		-0.001886 (-0.608385)		-0.000339 (-0.113113)
Tech		0.019362** (3.140027)		0.016042** (2.673233)
ICT-index (ICT)			0.040631** (8.155484)	0.036484** (7.278718)
R^2		0.734463	0.731006	0.753879

Source: Authors' estimations
Notes: t-values in parentheses. ** indicates statistical significance at 5% level.

Overall, our findings validate some of the conclusions of the earlier literature. Regarding infrastructure, in particular, it corroborates the outcomes of Mitra *et al*. (2002 and 2012), Hulten *et al*. (2006), Sehgal and Sharma (2010). It suggests that, despite a major shift in infrastructure availability and manufacturing performance in India in the recent years, the linkage remains intact and infrastructure is still a major determinant of the manufacturing performance. On the other hand, the results regarding export are important because most of the previous analysis in India failed to find a significant role of this variable (Singh, 2003; Mishra and Sharma, 2011, see section 2). Our findings thus recognize the hypothesis of *learning-by-exporting* in the case of Indian manufacturing. As for imports (total, intermediate and capital goods), the effects appear uncertain. Our results may suggest that knowledge transfers through exports are more important than through imports. This outcome is similar to that of Sjoholm (1999) for Indonesia. Sjoholm also concluded that imported capital and intermediate goods should be tested separately. Our efforts in that direction, however, failed to bring out any conclusive effect. One explanation can be that the share of imported intermediary and capital goods has not reached a sufficient level to materialize a higher productivity. Not surprisingly, our findings regarding R&D do not validate the impact noted in other studies for India (Raut, 1995; Sharma, 2012). This is understandable, as the Indian firms are known for low R&D intensity. The variable *tech* (technology transfer) being significant, it seems that firms are relying more on this channel than pursuing in-house research and innovation activities.

6. Conclusions and policy recommendations

India's economic liberalization in the 1990s provides a rich opportunity to assess the effect of policy reforms on economic performance. Given that one of the main objectives of these reforms was to improve the productivity of the manufacturing sector, the question that we have addressed in this paper is if some of these policy changes have had the expected impact on the Indian firms 'productive performance. In order to do so, we have tested the role of export and import (total, intermediary and capital goods), R&D, technology transfer and infrastructure endowment -- some of the important areas in which the government has shown keen interest during the reform period.

Actually, despite a substantial increase in trade and production following the economic reforms, the manufacturing industry has experienced quite a disappointing productive performance. This situation constitutes a puzzle that the literature has not very well explained until now. One factor suggested in some of the studies relates to the infrastructure deficiency being a serious impediment to the manufacturing performance. Our analysis confirms this view by establishing infrastructure as an important determinant of the manufacturing productivity and efficiency. This is true for a wide range of physical infrastructure, in the field of transport, energy and telecommunication. Our findings confirm as well the results of Mitra *et al* (2011) on the productive role of the information & communication technology (*ICT*), which experienced an extensive development over the same period. Despite the recent efforts to modernize the infrastructure sector, bottlenecks still persist as a serious problem in India.

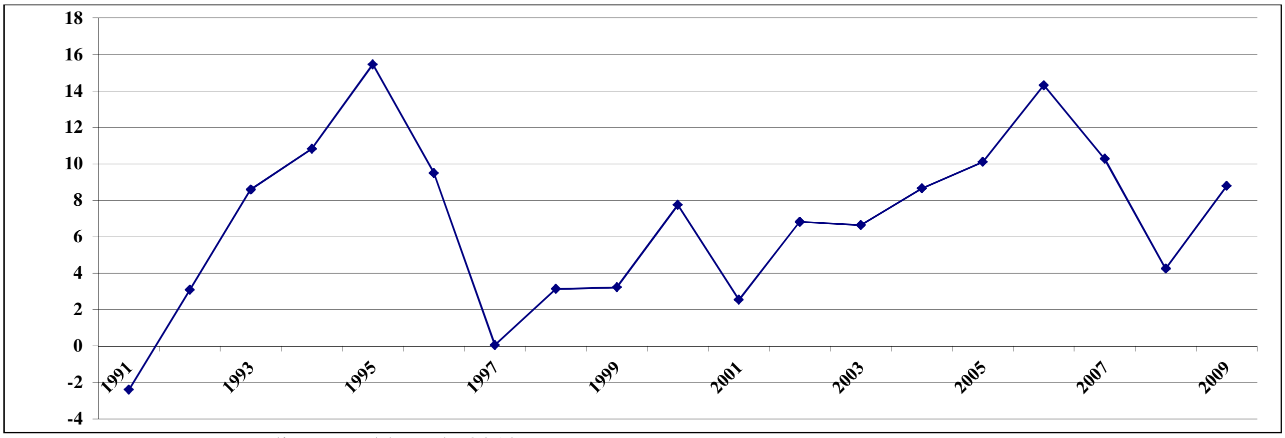
Our empirical work suggests another explanation of the poor manufacturing performances. Trade liberalization is motivated by expected productivity gains coming from an increased competition for domestic firms, as well as knowledge spillover and technology transfer from more developed countries. These gains seem to have imperfectly materialized in the case of India, since our empirical analysis failed to validate a significant role of total imports, as well as intermediate and capital goods imports, as factors of productivity and efficiency. One explanation of this result can be that the share of import -- intermediate and capital goods specifically -- has not reached a threshold level to materialize into productivity-gains. However, as regards exports, our empirical analysis is more conclusive. Exports exhibit a sizeable impact on firms' productive performances. It appears that the Indian manufacturing sector has benefited more from knowledge transfer through exports than through imports. Our findings thus validate not only the hypothesis of learning-by-exporting, extensively debated in the literature, but also the incitation to be more productive due to competition in the foreign market.

Another result of our empirical work concerns R&D which does not appear to be a significant determinant of productivity. This outcome, consistent with other studies, does not look surprising as Indian firms are known for low R&D activities, despite the recent efforts of the government to stimulate in-house R&D. This conclusion is supplemented by our results on technology transfer, which turns out to be significant in explaining firms 'productive performances. This finding tends to show that firms in India rely more on this channel than on pursuing in-house research and innovation, limiting their ability to be competitive in the medium-long run.

Like most other developing countries, India is increasingly concerned about improving productivity and competitiveness as the country faces the intensified pressure of globalization. As per our results, enhancing total and ICT infrastructure could help the manufacturing sector to resist international competition and reinforce the industrial export capacity of the country. Reducing infrastructure bottlenecks would also lead to a rise in productivity and growth, which in turn may help the manufacturing sector to diversify. Low in-house R&D represents lack of innovation necessary to grow and become competitive. Our results also suggest that export liberalization constitutes another means of boosting the productivity and efficiency of the industries. This policy needs to be continued since Indian manufacturing is still not integrated with the world economy. As for import liberalization, although our empirical work did not validate its impact on firms' productive performance, our findings call for more investigation on the subject since import intensity, of intermediate and capital good in particular, may have not reach a level at which competition, knowledge spillover and technology transfer can play a crucial role in augmenting productivity growth .

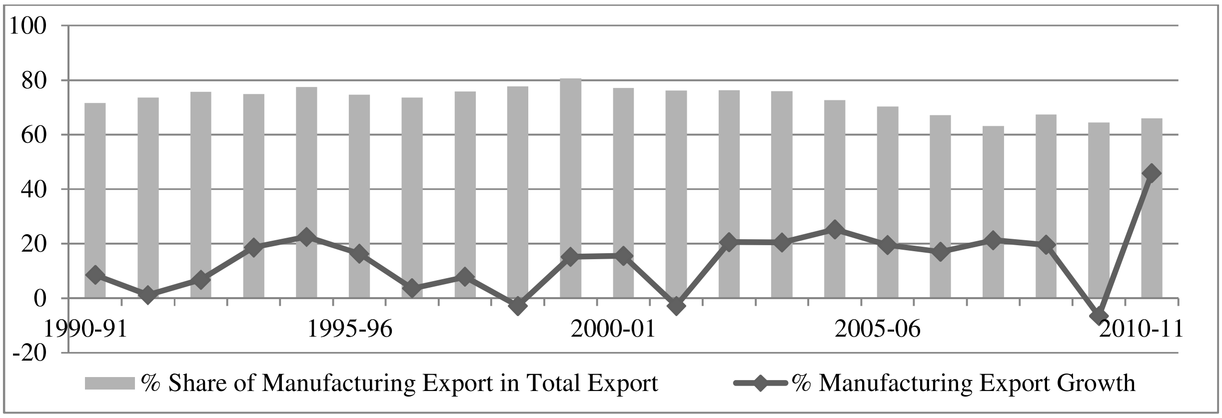
Appendix 1

Fig. A.1.1. Growth in manufacturing in the post reform era (value added, annual % growth)



Source: WDI on line, World Bank, 2012.

Fig. A.1.2. Manufacturing export from India, 1990-2010



Source: Economic survey-2009-10 (chap-7, pp-172, http://indiabudget.nic.in/es200910/chapt2010/chapter07.pdf

Fig. A.1.3. Manufacturing import and tariff rate in India, 1990-2010

Source: Economic survey-2009-10 (chap-7, pp-172, http://indiabudget.nic.in/es200910/chapt2010/chapter07.pdf

Table A.1.1. Relative infrastructure endowments in India (a)

Country/Group	Fixed broadband Internet subscribers (per 100 people)	Internet users (per 100 people)	Mobile cellular subscriptions (per 100 people)	Quality of port infrastructure (b)	Roads, paved (% of total roads)	Secure Internet servers (per 1 million people)	Telephone lines (per 100 people)	Electric power consumption (kWh per capita)	Electric power transmission and distribution losses (% of output)
India	*0.67*	*5.3*	*45.5*	*3.9*	*49.3*	*2.2*	*3.2*	570.9	24.4
Brazil	7.52	39.3	90.0	2.9	N.A.	40.7	21.5	2206.2	17.2
China	7.78	28.8	56.1	4.3	53.5	1.9	23.6	2631.4	4.9
Russian Federation	9.09	42.1	162.5	3.7	80.1	20.4	31.6	6132.9	10.8
South Africa	0.98	8.9	94.2	4.8	N.A.	62.6	8.8	4532.0	9.8
South Asia	*0.56*	*5.5*	*45.8*	*3.8*	*58.9*	*1.9*	*3.0*	516.9	23.1
East Asia & Pacific	8.05	29.8	65.7	4.8	47.6	91.5	22.5	2797.4	5.2
Low-middle income	3.54	18.2	60.9	3.8	29.3	7.7	12.7	1527.0	11.1

Source: World Development Indicators 2011.
Note: (a) Years of comparison are 2010, 2009 and 2008. (b) 1=extremely underdeveloped to 7=well developed and efficient by international standards;

Table A.1.2. Descriptive statistics

(in log)	**EXPORT**	**IMPORT**	**IMPORTCAP**	**IMPORTRAW**	**Tech**	**R&D**	**G**	**ICT**
Mean	1.0683	1.1581	0.1619	0.9948	-0.6413	-0.68	2.2120	2.4957
Median	1.0593	1.1618	0.1733	0.9924	-0.4724	-0.805	2.2262	2.5555
Maximum	1.5856	1.6299	0.8114	1.5881	0.0658	0.3300	2.2517	2.5814
Minimum	0.7101	0.3306	-0.5483	0.1111	-1.7185	-1.368	2.000	2.000
Std. Dev.	0.2129	0.2116	0.3101	0.2450	0.4198	0.4186	0.0594	0.1604
Skewness	0.2779	-0.4946	-0.1444	-0.3566	-0.5805	0.3067	-3.0260	-2.3246
Kurtosis	2.4767	4.4446	2.4938	4.2798	2.2283	1.9492	11.1285	6.9299
Jarque-Bera	2.8899	15.2002	1.6843	10.6068	9.6367	7.3412	509.220	185.293
Observations	120	120	120	120	120	120	120	120

Source: Authors' calculation

Appendix 2: Infrastructure variables

Table A.2.1. Sources of data

Variable	Sector	Indicator	Data sources
Air	Transportation	Air transport, passengers carried	WDI
Electricity	Electricity	Electricity production (kWh/per-capita)	WDI
Internet	Information and Communication	Internet users (per 100 people)	WDI
Mobile	Information and Communication	Mobile cellular subscriptions (per 100 people)	WDI
Tel.	Information and Communication	Telephone lines (per 100 people)	WDI
Mobile-tel.	Information and Communication	Mobile and fixed-line telephone subscribers (per 100 people)	WDI
Port	Transportation	Port (commodity wise traffic , 000 tones)	CMIE
Rail-goods	Transportation	Railways, goods transported (million ton-km)	WDI
Rail-pass	Transportation	Railways, passengers carried (million passenger-km)	WDI
Roads	Transportation	Roads, total network (km/1000people)	WDI

Table A.2.2. Correlation between infrastructure variables

Variable	Air	Internet	Rail-goods	Rail-pass	Roads	Electricity	Mobile Tel.	Port
Air	1.0000							
Internet	0.9444 (11.12)	1.0000						
Rail-goods	0.9549 (12.45)	0.9892 (26.19)	1.0000					
Rail-pass	0.9250 (9.429)	0.9736 (16.53)	0.9882 (24.99)	1.0000				
Roads	0.4472 (1.94)	0.5946 (2.86)	0.6323 (3.16)	0.7149 (3.96)	1.0000			
Electricity	0.8633 (6.62)	0.9128 (8.65)	0.9413 (10.80)	0.9697 (15.37)	0.7911 (5.01)	1.0000		
Mobile-tel.	0.96660 (14.61)	0.9658 (14.42)	0.9696 (15.34)	0.9428 (10.96)	0.4997 (2.23)	0.8482 (6.20)	1.0000	
Port	0.8463 (6.15)	0.9271 (9.58)	0.9487 (11.62)	0.9688 (15.15)	0.7728 (4.72)	0.9856 (22.62)	0.8502 (6.25)	1.0000

Source: Authors' calculation

Appendix 3

Total and *ICT* composite infrastructure indicators

The Principal Component Analysis (*PCA*) methodology is a widely used aggregation technique, designed to linearly transform a set of initial variables into a new set of uncorrelated components, which account for all of the variance in the original variables. Each component corresponds to a virtual axe on which the data are projected. The earlier component explains more of the variance of the series than do the later component. The number of components is proportional to the number of initial variables that are used in the *PCA*. Usually, only the first components are retained, because they explain most of the variance in the dataset. The cumulative R^2gives the explanatory power of the cumulative components.

In order to construct a composite total infrastructure index for India, we apply the Principal Component Analysis (*PCA*) to our nine infrastructure indicators. The results bring out one significant component and this component explains 90 % of the variance in the underlying individual indicators (see Table A.3.1). In the next stage, on the basis of the results of the *PCA*, the factor loadings of the initial variables are used as weights of the respective variables in constructing the composite infrastructure index (see Table A.3.2). For more details on the aggregation method using Principal Component Analysis (*PCA*), see Nagaraj *et al*. (2000) and Mitra *et al.* (2002).

Table A.3.1. Principle component analysis:
Total infrastructure indicator (*G*) (*1994 to 2008*)

	Eigenvalue	**Proportion**
P1	**7.25486****	**0.9069**
P2	0.561524	0.0702
P3	0.128091	0.0160
P4	0.03333	0.0042
P5	0.009241	0.0012
P6	0.007714	0.0010
P7	0.004457	0.0006

Source: Authors' calculation

Table A.3.2. Factor loadings:

Total infrastructure indicator (*G*) (*Eigenvectors*)

	P1
Air	0.3391
Internet	0.3454
Rail-goods	0.3587
Rail-pass	0.3688
Roads	0.3063
Electricity	0.3694
Mobile-Tele	0.3679
Port	0.3681

Source: Authors' calculation

Using the same methodology as for the composite total infrastructure index, an *ICT* index (*ICT*) is also constructed in this study. The result of the *PCA* for this sector suggests as well the presence of one significant component, which explains 94 % of the variance in the individual *ICT* indicators (see Table A.3.3). On the basis of the factor loadings, the weights are assigned to the respective variables for constructing the *ICT* index (see Table A.3.4).

Table A.3.3. Principle component analysis:
***ICT* infrastructure indicator (*ICT*) (1994 to 2008)**

	Eigenvalue	**Proportion**
P1	2.8351**	0.9451
P2	0.15522	0.0517
P3	0.00959	0.0032

Source: Authors' calculation

Table A.3.4. Factor loadings:
***ICT* infrastructure indicator (*ICT*)** (Eigenvectors)

	P1
Internet	0.5908
Mobile	0.5762
Tele	0.5647

Source: Authors' calculation

Appendix 4

Table A.4. Cobb- Douglas production function: Estimation results, 1994-2008
(Dependent variable: ln(GVA))

Variables	**Coefficients (1)**	**Coefficients (2)**
ln (K)	0.40264 (0.0694)	0.4244 (0.0681)
ln (N)	0.46544 (0.0642)	0.4444 (0.0632)
Trend	0.02426 (0.0019)	0.02348 (0.0019)
Const	2.2192 (0.2818)	2.61173 (0.3202)
R^2	0.6477	
Year-dummy	Yes	Yes
Estimator	Fixed	Time-invariant inefficiency model

Source: Authors' calculation

Notes: Standard errors are in parentheses. For column (2), log likelihood: 174.54228, Wald λ^2:1296.01, μ: 0883 $(s.e.\ \mathbf{0.146})$. Number of observations (panel):120(8). *TFP* computed on the basis of results of column (1). *TE* computed on the basis of results of column (2).

References:

Aggarwal, A. (2000) Deregulation, technology imports and in-house R&D efforts: An analysis of the Indian experience, *Research Policy*, **29**, 1081-1093.

Ahluwalia I J (1991) *Productivity and Growth in Indian Manufacturing*, Oxford University Press, New Delhi.

Aitken, B. J., Hanson, H. G. and Harrison, A. E. (1997) Spillovers, foreign investment and export behavior, *Journal of International Economics*, **43**, 103-132.

Amiti, M. and Konings, J. (2007) Trade liberalization, intermediate inputs, and productivity: Evidence from Indonesia." *American Economic Review*, **97**, 1611–1638.

Andersson, M. and Loof, H. (2009) Learning-by-exporting revisited: the role of intensity and persistence, *Scandinavian Journal of Economics,* **111**, 893–916.

Anwar S (1995) An impure public input as a determinant of trade, Finnish *Economic Papers,* **8**, 91-5.

Arnold J.M. and Hussinger, K. (2010) Exports versus FDI in German manufacturing: Firm performance and participation in international markets, *Review of International Economics*, **18**, 595-606, 09.

Aschauer D. A. (1989) Is public expenditure productive, *Journal of Monetary Economics*, **23**, 177-200.

Aw, B.Y., Chung, S. and Roberts, M.J. (2000) Productivity and turnover in the export market: micro evidence from Taiwan and South Korea, *World Bank Economic Review,* **14**, 65–90.

Balakrishnan, P. and Pushpangadan, K. (1994) Total factor-productivity growth in manufacturing industry: a fresh look, *Economic and Political Weekly,* **29**, 2028-35.

Balassa, B. (1988), "Outward orientation", in *Handbook of Development Economics,* (Eds) Chenery, H.B. and Srinivasan, T.N., Vol. 2, North-Holland, Amsterdam.

Baldwin, J.R. and W. Gu. (2003) Export-market participation and productivity performance in Canadian manufacturing, *Canadian Journal of Economics,* **36**, 634–57.

Baltagi, B.H. and Griffin, J.M. (1988) A general index of technical change, *Journal of Political Economy*, **96**, 20-41.

Barro R.J. and Sala-i-Martin, X. (1995) *Economic Growth*, International Editions, McGraw-Hill, New York, NY.

Barro, R. J. (1997) *Determinants of Economic Growth*, MIT Press, Cambridge MA.

Basant, R. and Fikkert, B. (1996) The effects of R&D, foreign technology purchase, and domestic and international spillovers on productivity in Indian firms, *Review of Economics & Statistics,* **78**, 187-199.

Battese, G.E. and Coelli, T.J. (1992) Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India, *Journal of Productivity Analysis,* **3**, 153-69.

Battese, G.E. and Corra, G. S. (1977) Estimation of a production frontier model: with application to the Pastoral zone of Eastern Australia, *Australian Journal of Agricultural Economics*, **21**, 169-79.

Beckerman, W. (1962) Projecting Europe's growth, *Economic Journal*, **72**, 912-25.

Belderbos, R., Ito, B. and Ryuhei, W. (2008) Intra-firm technology transfer and R&D in foreign affiliates: Substitutes or complements? Evidence from Japanese multinational firms, *Journal of the Japanese and International Economies*, **22**, 310-319.

Bernard, A.B. and Wagner, J. (1997) Exports and success in German manufacturing, *Review of World Economics,* **133**, 134–57.

Bernard, A.B. and Jensen, J.B. (1995) Exporters, jobs, and wages in U.S. manufacturing: 1976–1987, *Brookings Papers on Economic Activity: Microeconomics*, 67–119.

Bernard, A.B. and Jensen, J.B. (1999) Exceptional exporter performance: Cause, effect, or both?, *Journal of International Economics*, **47**, 1–25.

Bernard, A.B. and Jensen, J.B. (2004a) Exporting and productivity in the USA, *Oxford Review of Economic Policy*, **20**, 343–57.

Bhagwati, J.N. and Desai, P. (1970) *India, Planning for Industrialization: Industrialization and Trade Policies since 1951*, Oxford University Press, London.

Bhanumurthy, N.R. and Sharma, C. (2011) Estimating infrastructural investment needs for India, *The Journal of Applied Economic Research,* **5**, 221–243.

Bigsten, A. and Gebreeyesus, M. (2009) Firm productivity and exports: evidence from Ethiopian manufacturing, *The Journal of Development Studies*, **45**, 1594-614.

Branstetter, L.G. and Chen, J.R. (2006) The impact of technology transfer and R&D on productivity growth in Taiwanese industry: micro econometric analysis using plant and firm-level data, *Journal of the Japanese and International Economies*, **20**, 177–192.

Chand, S. and Sen, K (2002) Trade liberalization and productivity growth: Evidence from Indian manufacturing, *Review of Development Economics*, **6**, 120-32.

Coe, D. T. and Helpman, E. (1995) International R&D spillovers, *European Economic Review,* **39**, 859-887.

Coelli, T.J. (1996) Measurement of total factor productivity growth and biases in technological change in western Australian agriculture, *Journal of Applied Econometrics*, **11**, 77-91.

Cuneo, P. and Mairesse, J. (1984) Productivity and R&D at the firm level in French manufacturing, in *R & D, Patents, and Productivity*, NBER Chapters, 375-392.

Damijan, J.P. and Kostevc, C. (2006) Learning-by-exporting: continuous productivity improvements or capacity utilization effects? Evidence from Slovenian firms, *Review of World Economics*, **142**, 599-615.

De Locker, J. (2007) Do exports generate higher productivity? Evidence from Slovenia, *Journal of International Economics*, **73**, 48-68.

Dovis, M. and Milgram-Baleix, J. (2009) Trade, tariffs and total factor productivity: The case of Spanish firms, *The World Economy*, Wiley Blackwell, **32**, 575-605.

Ethier, W. J. (1982) The general role of factor intensity in the theorems of international trade, *Economics Letters*, **10**, 337-342.

Evans, P. and Karras G. (1994) Are government activities productive? Evidence from a Panel of U.S. States, *The Review of Economics and Statistics*, **76**, 1-11.

Everaert, G. and Heylen, F. (2004) Public capital and long term labor market performance in Belgium, *Journal of Policy Modeling*, **26**, 95-112.

Fernandes, A.M. and Isgut, A.E. (2005) Learning-by-doing, learning-by-exporting, and productivity: Evidence from Colombia, Policy Research Working Paper, WPS3544, World Bank, Washington, DC.

Ford, R., and Poret, P. (1991) Infrastructure and private sector productivity, *OECD Economic Studies*, **17** (Autumn), 63–89.

Frankel, J. A. and Romer, D. (1999) Does trade cause growth?, *American Economic Review* **89**, 379-399.

Goldar, B.N. (2004) Indian manufacturing: productivity trends in pre- and post-reform periods, *Economic and Political Weekly*, **37** (46/47).

Goldar, B.N. and Kumari, A. (2003) Import liberalization and productivity growth in Indian manufacturing industries in the 1990s, *The Developing Economies*, **XLI-4**,436-60

Goldberg, P., Khandelwal, A., Pavcnik, N. and Topalova, P. (2008) Imported intermediate inputs and domestic product growth: Evidence from India, Working paper, Princeton University, Columbia Business School, Dartmouth College and IMF.

Ghosh, S. (2009) Do productivity and ownership really matter for growth? Firm-level evidence, *Economic Modelling,* **26**, 1403–13

Greenaway, D., Gullstrand, J. and Kneller, R. (2004) Exporting and productivity in the United Kingdom, *Oxford Review of Economic Policy*, **20**, 358-71.

Griffith, R., *et al.* (2006) Innovation and productivity across four European countries, *Oxford Review of Economic Policy*, **22**, 483–498.

Griliches, Z. and Mairesse, J. (1990) R&D and productivity growth: comparing Japanese and American manufacturing firms, in *Productivity growth in Japan and the United States*, (Ed.)

Hulten, C., NBER studies in income and wealth, Chicago: University of Chicago Press, **53**, 317–348.

Griliches, Z. (1979) Issues in assessing the contribution of R&D to productivity, *Bell Journal of Economics*, **10**, 92–116.

Griliches, Z. (1986) Productivity, R &D, and basic research at the firm level in the 1970s. *American Economic Review*, **76**, 141–154.

Grossman, G.M. and Helpman, E. (1990) Product development and international trade, NBER Working Paper, W2540. Cambridge, M A: National Bureau of Economic Research.

Grossman, G.M. and Helpman, E. (1990) Endogenous product cycles, *Economic Journal,* Royal Economic Society, **101**, 1214-29.

Halpern, L., Koren, M. and Szeidl, A. (2009) Imported Inputs and Productivity, CeFiG Working Papers, 8, Center for Firms in the Global Economy.

Holtz-Eakin, D. (1994) Public Sector Capital and the Productivity Puzzle, *Review of Economics and Statistics*, **76**, 12-21.

Hossain M.A. and Karunaratne, N.D. (2004) Trade liberalization and technical efficiency: evidence from Bangladesh manufacturing industries. *The Journal of Development Studies*, **40,** 87-114.

Hulten, C.R., Bennathan, E. and Srinivasan, S. (2006) Infrastructure, externalities, and economic development: a study of the Indian manufacturing industry, *The World Bank Economic Review*, **20**, 291-308.

Jaffe, A.B. (1986) Technological opportunity and spillovers of R&D: evidence from firms' patents, profits, and market value, *American Economic Review*, **76**, 984–1001.

Kamps, C. (2005) The dynamic effects of public capital: VAR evidence for 22 OECD countries, *International Tax and Public Finance*, **12**, 533-558.

Khandelwal, A. K. and Topalova, P. B. (2011) Trade liberalization and firm productivity: The case of India, *The Review of Economics and Statistics*, **93**, 995-1009.

Kasahara, H. and Rodrigue, J. (2008) Does the use of imported intermediates increase productivity? Plant-level evidence, *Journal of Development Economics*, **87**, 106-118.

Kathuria, V, Raj, R. S. N, and Sen, K. (2010) Organized versus Unorganized Manufacturing Performance in the Post-Reform Period, *Economic and Political Weekly*, **45**, 55-64.

Keller, W. (2004) International technology diffusion, *Journal of Economic Literature,* **42**, 752-782.

Kim, S., Kim, H. and Gopinath, M. (2009) High productivity before or after exports? An empirical analysis of Korean manufacturing firms, *Journal of Asian Economics*, **20**, 410–18.

Kraay, A. (1999) Exports and economic performance: Evidence from a panel of Chinese enterprises, *Revue d'Economie du Développement*, **1–2**, 183–207.

Krugman, P. (1979) A model of innovation, technology transfer, and the world distribution of income, *Journal of Political Economy*, 87, 253-66.

Krugman, P. (1994) *Rethinking International Trade*, Mit Press.

Kumar, S. (2006), A decomposition of total productivity growth: a regional analysis of Indian industrial manufacturing growth, *International Journal of Productivity and Performance Management*, **55**, 311-31.

Lawrence, R.Z., Weinstein, D.E. (1999) Trade and growth: import-led or export-led? Evidence from Japan and Korea, NBER Working Papers, **7264**, National Bureau of Economic Research, Inc.

Levinsohn J, Petrin, A (2003) Estimating production functions using inputs to control for unobservables, *Review of Economic Studies*, **70**, 317–341.

Lucas RE (1988) On the mechanics of economic development planning, *Journal of Monetary Economics,* **22**, 3-42.

Mishra, R.K. and Sharma, C. (2011) Does export and productivity growth linkage exist? Evidence from the Indian manufacturing industry, *International Review of Applied Economics*, **25**, 633–652.

Mishra, R .K. and Sharma, C. (2012) Export participation and productivity performance of firms in the Indian transport manufacturing, *Journal of Manufacturing Technology Management*, **23**, 351-369.

Mitra, A., Varoudakis A. and Véganzonès-Varoudakis, M-A. (2002) Productivity and technical efficiency in Indian States' manufacturing: the role of infrastructure, *Economic Development and Cultural Change*, **50**, 395-426.

Mitra, A., Sharma, C. and Véganzonès-Varoudakis, M-A. (2011) Total factor productivity and technical efficiency of Indian manufacturing: The role of infrastructure and information & communication technology, CERDI, Etudes et Documents, 2011.15, Clermont- Ferrand.

Mitra, A., Sharma, C. and Véganzonès-Varoudakis, M-A. (2012) Estimating impact of infrastructure on productivity and efficiency of Indian manufacturing, *Applied Economics Letters*, **19**, 779-783.

Muendler, M.A. (2004) Trade, technology and productivity: A study of Brazilian manufacturers, 1986-98, *Mimeo*, University of California, San Diego.

Munnell, A-H. (1990a) Why has productivity growth declined? Productivity and public investment, *New England Economic Review* (January/February), 2–22.

Munnell, A-H. (1990b) How Does Public Infrastructure Affect Regional Economic Performance? New England Economic Review (September/October), 11–32.

Nagaraj, R., Varoudakis, A. and Véganzonès, M-A. (2000) Long-Run Growth Trends and Convergence Across Indian States: The Role of Infrastructures, *Journal of International Development*, **12**, 45-70.

Natarajan, R. and Duraisamy, M. (2008) Efficiency and productivity in the Indian unorganized manufacturing sector: did reforms matter?," *International Review of Economics*, **55**, 373-399.

O'Mahony, M. and Vecchi, M. (2009) R&D, knowledge spillovers and company productivity performance, *Research Policy*, **38**, 35–44.

Parente, S.L and Prescott, E.C. (1994) Barriers to technology adoption and development, *Journal of Political Economy*, University of Chicago Press, **102**, 298-321.

Pinto, B., Zahir, F. and Pang, G. (2006) From rising debt, to rising growth in India: Microeconomic dominance, in *Inclusive Growth and Service Delivery: Building on India's Success: World Bank Development Policy Review*, The World Bank, Washington D.C.

Planning Commission (2006) Towards faster and more inclusive growth, Planning Commission Government of India, an approach to the 11th five year plan, Available at: http://planningcommission.nic.in/plans/planr el/appp ap_11.pdf (accessed October 2011).

Raut, L .K. (1995) R & D spillover and productivity growth: evidence from Indian private firms, *Journal of Development Economics*, **48**, 1–23.

Rivera-Batiz, L. A. and Romer, P. M. (1991) International trade with endogenous technological change, *European Economic Review*, **35**, 971-1001.

Roberts, M.J. and Tybout, (J. 1997) The decision to export in Colombia: An empirical model of entry with sunk costs, *American Economic Review*, **87**, 545–64.

Rodrik, D. (1988) Imperfect competition, scale economies and trade policy in developing countries, in *Trade policy issues and empirical analysis*, (Ed) Baldwin, R.E. Chicago: University of Chicago Press.

Romer P.M. (1986) Increasing returns and long-run growth, *Journal of Political Economy*, **94,** 1002-37.

Romer, P. (1987) Growth based on increasing returns due to specialization, *American Economic Review,* **77**, 56-62.

Sehgal, S. and Sharma C. (2010) Impact of infrastructure on output, productivity and efficiency: Evidence from the Indian manufacturing industry, *Indian Growth and Development Review*, **3**, 100 – 121.

Sharma, C. (2011) Imported intermediary inputs, R&D and firm's productivity: Evidence from Indian manufacturing, Proceedings of the German Development Economics Conference, Berlin, Verein für Socialpolitik, Research Committee Development Economics.

Sharma, C. (2012) R&D and firm performance: evidence from the Indian pharmaceutical industry, *Journal of the Asia Pacific Economy*, **17**, 332-342.

Singh, T. (2003) Effects of exports on productivity and growth in India: an industry-based analysis *Applied Economics*, **35**, 741-749.

Sivadasan, J. (2009) Barriers to Competition and Productivity: Evidence from India, *The B.E. Journal of Economic Analysis & Policy,* **9**, 42.

Sjoholm, F. (1999) Productivity growth in Indonesia: The role of regional characteristics and direct foreign investment, *Economic Development and Cultural Change*, **47**, 559-84.

Stephan, A. (2003), Assessing the contribution of public capital to private production: evidence from the German manufacturing sector, *International Review of Applied Economics*, **17**, 399-418.

Syverson, C. (2011) What determines productivity?, *Journal of Economic Literature*, **49**, 26-65.

Topalova, P. and Khandelwal, A. (2011) Trade liberalization and firm productivity: The case of India, *The Review of Economics and Statistics*, **93**, 995-1009.

Trivedi, P., Prakash, A. and Sinate, D. (2000) Productivity in major manufacturing industries in India: 1973-74 to 1997-98, *Development Research Group Study,* **20**, Department of Economic Analysis and Policy, Reserve Bank of India, Mumbai.

Unel, B (2003) Productivity trends in India's manufacturing sectors in the last two decades, IMF Working Paper 03/22, International Monetary Fund.

UNIDO (2005) *Indian Manufacturing Industry: Technology Status and Prospects*, Available at: https://www.unido.org/fileadmin/media/documents/pdf/tcb_roadmap_to__qualitiy_vol1.pdf (accessed October 2011).

Van Biesebroeck, J. (2006) Exporting raises productivity in sub-Saharan African manufacturing firms, *Journal of International Economics,* **67**, 373–91.

Wagner, J. (2007), Exports and productivity: A survey of the evidence from firm-level data, *The World Economy*, **30**, 60-82.

Yasar, M. and Rejesus, R.M. (2005) Exporting status and firm performance: evidence from a matched sample, *Economics Letters*, **88**, 397-402.

Ziesemer, T. (1995) Growth with imported capital goods, limited export demand and foreign ebt, *Journal of Macroeconomics*, **17**, 31-53.