Productivity and Technical Change in the Indian Pharmaceutical Sector: A Comparison of Foreign and Domestic Firms

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The effect of foreign investment on the productivity of a knowledge-intensive industry such as pharmaceuticals holds much importance. The present firm-level study uses a non-parametric mathematical linear programming model, Data Envelopment Analysis based on Malmquist Productivity Index to calculate and compare productivity, efficiency change and technical change of foreign and domestic firms of Indian pharmaceutical sector for the period 2001-2020. The findings include that foreign investment has a positive impact on the productivity of the firms. Foreign firms adapted better to the technological progress as compared to the domestic firms. The sector also experienced a regression in efficiency, especially in the years registering technological progress suggesting that a majority of firms are not able to enjoy the benefits but certain firms have progressed due to foreign investment and shifted the production frontier outwards. Domestic firms' productivity would improve through mergers and acquisitions, government support for public–private technical collaborations, expansion of research and development capabilities, and assistance in importing raw materials.

Keywords: Data Envelopment Analysis, Malmquist Productivity Index, Productivity, Technical Change, Foreign Direct Investment

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The Indian pharmaceutical industry has been one of the fastest growing industries in the country since independence. According to the annual report of the Department of Pharmaceuticals (2019), it ranks tenth largest in the world in terms of value and third in volume. It accounts for 1.72 percent of the country's GDP and is projected to grow to USD 80-90 billion by 2030 (Indian Pharmaceuticals Alliance, 2019). It is one of the top FDI attracting sectors with 100 percent FDI permissible throughout automatic route in greenfield investment and 74 percent in brownfield investment.

The process of globalisation started in the 19th century and slowly engulfed the whole world. World integration is the by-product of the process. With the globalisation movement in such stride, there has been an ease in the movement of trade, flow of personnel and capital across cross-national borders. Foreign Direct Investment (FDI) has played a key role in facilitating such movements. With the remarkable development of technology, every kind of exchange, may it be business skills, production techniques or market know-how began to happen swiftly and with much ease.

The Indian pharmaceutical sector, being a high-skill, research-intensive industry has been at the centre of this transformation. At the time of independence, the Indian pharmaceutical industry did not have a prominent position. Over a period of time, it grew to be one of the most important sectors on account of a series of favourable steps taken up by the government and the initiatives of the entrepreneurs. The Patents Act, 1970 came into effect in 1972. This act provided special provisions for food, chemicals and pharmaceutical sectors which led to the abolition of product patents with the retention of process patents (Nair, 2003; Nair, 2008). It provided restrictive industrial policies which act as a stimulus in the speedy growth of the pharmaceutical sector. It also provided a base for the manufacturing of the bulk drugs as well as for the formulations (Ganguli, 2003; Nair, 2003).

The process patent regime lasted a while but since 1990s, the world has been going through a transformation regarding intellectual property protection rights in the form of Trade- Related Aspects of Intellectual Property Rights (TRIPS) Agreement. The implementation of the agreement for developing countries was done phase-wise and got completed on January 1, 2005. The objective of the transformation was to revolutionize the areas associated with intellectual property such as patents, copyrights, trademarks etc. by setting a minimum impartial level of protection for the same across the countries. TRIPS Agreement was widely accepted by the developed nations as it was seen as a tool to promote innovation and R&D in developing nations and lead to overall growth. Shapiro et al. (2014) found that stronger Intellectual Property Rights (IPRs) are associated with the transfer of the technological and innovative capabilities from developed to developing countries. This transfer generally takes place via FDI. MNCs that have patented drugs in

the developed markets are more comfortable with transferring their technology, business models and management to the countries that have stronger IPRs.

It is also a common belief that the influx of foreign investment leads to a change in firm or industry technology (Driffield & Love, 2007). The change in technical knowledge, modernization of production processes, world market integration with domestic markets and strengthening of forward and backward linkages have a positive impact on the efficiency and productivity of the firms in the sector (De Mello, 1997; Ernst, 2005). The global shift in the paradigm lead to a need for domestic firms to increase their productivity and efficiency. They took the steps of acquiring firms, new products, stepping into newer therapeutic segments, taking up better management practices and finding access to new markets (Mahajan, 2020).

Given this background, the rest of the paper has been divided as follows. Section 2 gives a brief review of earlier literature on productivity. Section 3 explains the methodology adopted in the analysis and section 4 gives the details of the data collection. Results are explained in section 5 and section 6 concludes the paper.

Literature Review

There is ample literature regarding productivity analysis which covers vast portions of theoretical as well as empirical analysis. To narrow down the literature as per the requirement of the present research, the papers highlighting the effect of foreign investment on productivity in Indian markets have been considered.

One of the most prominent researched areas while considering productivity is the productivity of the Indian manufacturing industry but the studies provide ambiguous results. Krishna & Mitra (1998) using firm-level data from different Indian manufacturing industries studied the impact of liberalization reforms on productivity and reported an increase in productivity in the time followed by the reforms. Another study by Manjappa & Mahesha (2008) examined the productivity growth and its components for manufacturing industries and found that the capital-intensive industries reported a positive productivity growth owing to positive technological change but the labour-intensive industries showed a decline in technological progress and thus a regress in productivity. Certain studies have also indicated a decline in productivity. Goldar (1986) used a multiple regression framework to understand the total factor productivity (TFP) pattern of Indian manufacturing industries in 1960-70 and recorded it be negative for majority of the firms. Another study by Balakrishnan & Pushpangadan (1994) found the productivity of Indian manufacturing firms in 1980s to be lesser than the previous decades. Jena & Chattopadhyay (2016) demonstrated positive effects of FDI on manufacturing sector provided the economy has absorptive capacity else it leads to crowding out of domestic firms.

As the Indian pharmaceutical sector is a technologically advanced sector with skilled labour and firms investing in R&D, many studies have analysed the growth, reasons and pattern of productivity of the sector. Certain studies found that the Indian pharmaceutical sector experienced technological advancements owing to technological change, investment and R&D but the benefits were not enjoyed by all firms (Mazumdar & Rajeev, 2009; Saranga & Banker, 2010; Mahajan, 2020). The implementation of TRIPS also contributed to a rise in productivity as well as profitability of Indian pharmaceutical firms (Bajaj & Nigam, 2007). Technical Efficiency Change (TEC) has been majorly found responsible for the increase in Total Factor Productivity Growth (TFPG) (Chakraborty & Pal, 2020). Firms with larger size exhibited higher productivity compared to medium and smaller enterprises (Mahajan, 2020; Das & Hoque, 2024). The level of productivity also has a direct effect on the absorption of R&D benefits of the firms (Goldar, 2013).

A certain number of studies have also highlighted the role of foreign investment on the level of productivity. As foreign firms are expected to bring better opportunities, managerial staff and technical know-how, the productivity of the firms is expected to increase. Sharma (2011) used firm level data of Indian pharmaceutical firms and stated that firms receiving FDI have better sensitivity to R&D which leads to an increase in productivity of the firms. Similar results were traced by Sharma (2015) and found out that the foreign investment received by the Indian pharmaceutical firms in the post-reform period led to a sizeable impact on the productivity of the firms. Foreign investment has also shown a positive effect on productivity growth via ownership (Thangavelu & Pattnayak, 2006), technological advancements and research efforts (Pattnayak & Thangavelu, 2011) as well as due to presence of foreign equity (Arora & Lohani, 2017). It also has a positive effect on exports which in turn leads to a rise in productivity (Mathiyazhagan & Sahoo, 2008). Foreign investment has aided the rise in productivity of the Indian pharmaceutical firms in the post-patent regime with innovation and R&D playing a decisive role (Pannu et al., 2011; Tripathy et al., 2013). Another study by Dhanora et al. (2020) examined the effect of technological innovations and foreign investment on 168 Indian pharmaceutical firms for the period 2000-2013 and found that both R&D and FDI have a positive effect on the productivity of the firms. On the other hand, an absence of horizontal spillovers from foreign firms to domestic ones has also been noted due to their ability to prevent technological outflow within the same industry (Desai et al., 2022).

As there are certain number of studies that have tried to examine the effect of foreign investment on the productivity of Indian pharmaceutical firms but most of those studies show an effect of the foreign investment on the technological innovations of the firm which in turn has an effect on the productivity of the firm. As the literature is scarce to examine the effect of foreign investment and draw a comparison with the domestic firms over a significant period of time on

the productivity of Indian pharmaceutical firms, this paper attempts to make a comparison between foreign and domestic firms of the Indian pharmaceutical sector for the period 2001–2020.

Methodology

While considering the productivity analysis, the calculation can be done either by Single Factor Productivity (SFP) or Total Factor Productivity (TFP) technique. SFP is the method of calculation by dividing the total output by only one input (Manjappa & Mahesha, 2008). It fails to provide a complete picture as it disregards the effect of other inputs in productivity of the units. It only provides partial information. TFP solves this problem as it is defined as the ratio of weighted sum of outputs to the weighted sum of inputs. It includes the effect of all the inputs on the productivity and provides comprehensive results. Total factor productivity takes into account both the changes in technical progress as well as technical efficiency.

Over a course of time, the parametric Stochastic Frontier Analysis (SFA) and the non-parametric DEA-based Malmquist Productivity Index (MPI) have become the favoured approaches for productivity analysis as they presume that the decision-making units (DMUs) are not operating at their maximum efficiency (Singh & Agarwal, 2006).

In our study, MPI has been used as it takes the efficiency of the firms into account while calculating productivity. It was first introduced by Caves et al. (1982). He used distance functions or technical efficiency functions to estimate the productivity of the firms. The technical progress and efficiency were included in the model by Fare et al. (1994). The firms in the pharmaceutical industry are expected to go through continuous technological progress which makes the adjacent period version of Fare et al. (1989) of MPI, which is defined in terms of distance functions for period t and t+1, the correct approach for the analysis.

The distance function measures, keeping inputs constant for period t, the maximum proportion by which outputs can be expanded for the firm in period t. Similarly, the expansion of the same output bundle relative to the frontier in the period t+1 is also measured. These two frontiers, for the initial as well the target period, are used to calculate the productivity changes of a firm for adjacent periods. To minimise the effect of randomly chosen technology set, the MPI production indices are calculated as the geometric mean of period t and t+1 ratios (Manjappa & Mahesha, 2008).

Grifell-Tatje & Lovell (1996) states certain reasons which makes MPI a popular approach in productivity analysis. The approach only uses quantity data and thus the information on input or output prices is not required. This provides a clear picture even if the information on prices is unavailable or distorted. MPI also does

not follow any particular assumption of profit maximization or cost minimization. Lastly, it decomposes the productivity indices into technical progress (outward shifting of the frontier) and the change in technical efficiency (movement along the frontier). This segregation of the indices into its two components helps in acquiring an in-depth knowledge of the whole procedure (Ma et al., 2002).

The adjacent period version of Malmquist productivity index can be expressed as

$$\mathrm{MI} = \left[\frac{D^{t}(X^{t+1},Y^{t+1})}{D^{t}(X^{t},Y^{t})} * \frac{D^{t+1}(X^{t+1},Y^{t+1})}{D^{t+1}(X^{t},Y^{t})}\right]^{\frac{1}{2}}$$

Where Dt(xt+yt) represents the distance function which gives the maximum proportion expansion of the output bundle in period t relative to the frontier in period t. Similarly, Dt+1(xt+yt) is the distance function that gives the maximum proportion expansion of the output bundle in period t relative to the frontier in period t+1.

While measuring the productivity using adjacent periods, two sperate frontiers, namely, base and final period frontiers are created. The two portions of the equation 1 represents the changes in productivity taking different periods as benchmark.

$$\frac{D^{t}(X^{t+1},Y^{t+1})}{D^{t}(X^{t},Y^{t})}$$

considers the frontier for base period as the benchmark while

$$\frac{D^{t+1}(X^{t+1},Y^{t+1})}{D^{t+1}(X^{t},Y^{t})}$$

captures the productivity changes keeping the frontier of the final period as the benchmark for comparison.

As there is no preference between the base and the final period frontiers as benchmarks, a geometric mean of both is taken to calculate the Malmquist Productivity Index.

Malmquist Index can be decomposed into its two components i.e. Technical Change (TC) and Efficiency Change (EC).

According to the definition of Malmquist Index:

$$\mathrm{MI} = \mathrm{TC} * \mathrm{EC}$$

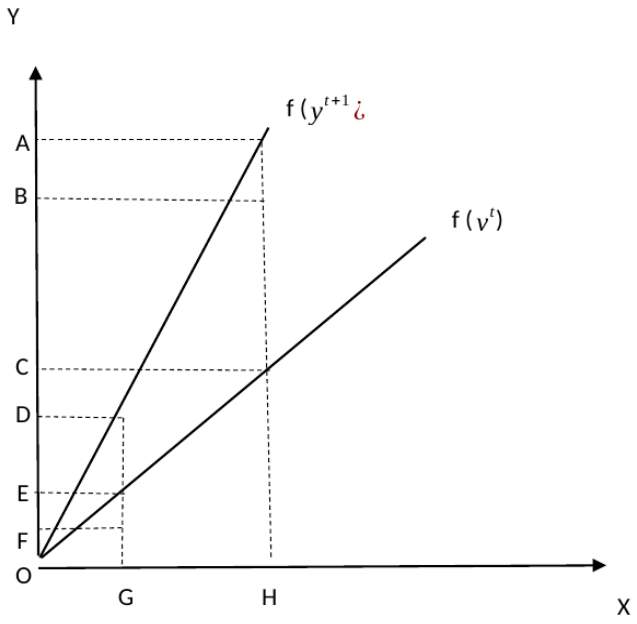
$$\text{Where EC} = \left[\frac{D^{t+1}(X^{t+1},Y^{t+1})}{D^{t}(X^{t},Y^{t})}\right]$$

and,

$$\mathrm{TC} = \left[\frac{D^{t}(X^{t+1},Y^{t+1})}{D^{t+1}(X^{t+1},Y^{t+1})} * \frac{D^{t}(X^{t},Y^{t})}{D^{t+1}(X^{t},Y^{t})}\right]$$

Technological progress is indicated by a value greater than one of TC and technological regress is indicated by a less than one value of TC. Similarly, EC indicates a relative shift of an inefficient firms towards or away from the frontier.

Figure 1: Decomposition of Productivity into Efficiency Change and Technical Chang



Source: Mazumdar (2013)

Mazumdar (2013) also explains the decomposition of Malmquist Index into its two components using a graph as depicted below:

Let f (yt) and f (yt+1) be the two frontiers representing base period and final period. The position of the firm relative to base period is F and relative to final period is B.

The efficiency change of the firm is given as:

$$\mathrm{EC} = \frac{OB}{OA} \Big/ \frac{OF}{OE}$$

As, while calculating technical change, MPI allows the frontier to shift in non-uniform manner, TC can be different at different inputs levels. As stated earlier, the technical change component is expressed in two portions. The first part is the TC measured relative to base period and can be expressed as

$$\frac{OB}{OC} \Big/ \frac{OB}{OA}$$

The TC component measured relative to the final period can be expressed as

$$\frac{OF}{OE}\Big/\frac{OF}{OD}$$

Therefore, the technical change component of a firm relative to MPI can be expressed as:

$$\mathrm{TC} = \left[\frac{OF}{OE}\Big/\frac{OF}{OD} * \frac{OB}{OC}\Big/\frac{OB}{OA}\right]^{\frac{1}{2}}$$

Data

The data for the study has been collected from the Prowess package of Centre for Monitoring Indian Economy (CMIE). It is the firm- level data of Indian pharmaceutical industry for the period 2001-2020. Following Ghali & Rezgui (2001), any firm with more than 10 percent foreign equity participation is classified as a foreign firm. The study includes 38 such foreign firms. To select a comparable group of domestic firms, the asset sizes of the foreign firms were divided into ten percentile ranges. From each percentile range, domestic firms with similar asset sizes were randomly selected to ensure comparability. In total, 38 domestic firms were included in the study.

- **MPI**

The model used for calculating the productivity of the firms has one output and four inputs. The inputs included are labour, capital, material input and energy input. Total output is defined as the value of total sales plus change in stock which in turn is measured as opening stock minus the closing stock in output. The inputs of the model are defined as follows: (1) labour is measured in terms of wages and salaries of the workers; (2) capital is the book value of plant and machinery; (3) material input is the firm's expenditure on raw materials; and (4) energy input is the value of the firm's expenditure on power, fuel and water.

Table 1 presents the different variables and their definitions used in the model. As all the variables are expressed in monetary terms, they are appropriately deflated using price indices collected from the monthly bulletins of Reserve Bank of India (RBI). They are presented in table 2. Perpetual Inventory Method (PIM) (Balakrishnan et al., 2000) has been used to deflate capital taking 2011 as the benchmark year (Mazumdar, 2013).

Results

In the analysis of productivity, it is important to measure the extent of variation in efficiency due to technological changes. Productivity, in general terms, is defined as the ratio of outputs and inputs. It is a very similar concept to efficiency. The

Table 1: Variables and definitions used in the MPI model

Variable	Definition
Total Output	Total sales combined with change in stock (opening stock minus closing stock)
Labour	Salaries given to workers
Capital	Book value of plant and machinery
Material Input	Expenditure on raw materials
Energy Input	Expenditure in power, fuel and water

Table 2: Deflators

Variable	Deflator
Output	Wholesale Price Index for drugs and pharmaceuticals
Labour	Consumer Price Index for industrial workers
Capital	Perpetual Inventory Method
Material Input	Wholesale Price Index for chemical and chemical products
Energy Input	Wholesale Price Index for machinery and equipment

two concepts go hand -in -hand. A firm performing at a high level of efficiency would yield higher productivity. Such a firm, eventually, would cover the distance to the frontier and become one of the best performing firms in the sample under consideration. To further increase its efficiency, keeping the production frontier constant, the firm could employ more inputs to produce more outputs. This way the firm moves along the frontier. As the variable returns to scale are under consideration, the diminishing marginal returns would set in and employing more inputs no longer remains a choice. Thus, the only way to increase productivity is to experience a positive technical change and an outwards shift of the production frontier. Innovation is the prime source of such positive technical change. In conclusion, it is evident that there are two ways for a firm to experience productivity gains, one is with an increase in efficiency and the other is via positive technical change. While the first mentioned is calculated by the distance from the frontier, the latter is calculated by the shift in the production frontier.

MPI is a frontier approach that takes efficiency into consideration. It has been applied to calculate efficiency and technical change for a panel of 38 foreign and 38 domestic firms to see the effect of foreign investment on the productivity of the firms of Indian pharmaceutical sector for a period of 20 years (2001-2020).

Table 3 gives the values of the MPI and its components. A value of more than 1 for MPI suggest a percentage increment for the total factor productivity. Similarly, a value less than 1 for MPI suggest a percentage decrease in total factor productivity for an average firm. A value of 1.101 in 2004 implies that, in comparison to 2003,

Table 3: Technical Change and Efficiency Change of foreign firms of Indian pharmaceutical sector, 2001–2020

Year	Total Factor Productivity	Technical Change	Efficiency Change
2001	–	–	–
2002	0.942	0.720	1.038
2003	1.024	1.085	0.944
2004	1.101	1.072	1.027
2005	1.033	1.142	0.904
2006	1.023	1.068	0.958
2007	0.857	1.014	0.845
2008	0.972	1.049	0.926
2009	1.007	0.939	1.072
2010	1.032	0.952	1.084
2011	1.137	1.056	1.077
2012	0.963	1.024	0.941
2013	1.028	1.058	0.972
2014	1.089	0.975	1.117
2015	1.010	1.079	0.936
2016	1.099	1.089	1.010
2017	1.042	1.113	0.936
2018	1.124	1.106	1.016
2019	1.040	1.083	0.961
2020	0.925	1.084	0.853

there was an increment of 10 percent in total productivity of foreign firms, whereas, a value of 0.942 in 2002 implies that total productivity regressed by 6 percent compared to 2001. Similarly, table 4 represents the same calculations for domestic firms. The value of 1.036 for 2003 represents that total productivity increased by 3 percent in 2003 compared to 2002. A value of 0.997 in 2006 means that total productivity decreased by almost 1 percent as compared to 2005. For foreign firms, out of 19 years, total productivity shows increment for 14 years whereas for domestic firms, total productivity shows increment for 11 years. This is an initial indication that foreign investment has a positive impact on the productivity of firms. A further analysis into its components will provide a clearer picture.

Colum 3 of table 3 represents technical change for the foreign firms. A value of greater than unity represents technological progress while a value less than unity represents technological regress. A value of 0.72 for technical change in 2002 implies that technology regressed by 28 percent for foreign firms as compared to 2001. A value of 1.142 for 2005 implies that relative to 2004, technology progressed or the production frontier shifted out by 14 percent. While interpreting the technical change values for domestic firms using table 4, we see a value of 0.982 in 2002 means an average firm faced a technological regression by 2 percent as

Table 4: Technical Change and Efficiency Change of domestic firms of Indian pharmaceutical sector, 2001–2020

Year	Total Factor Productivity	Technical Change	Efficiency Change
2001	–	–	–
2002	0.998	0.982	1.016
2003	1.036	1.016	1.020
2004	1.032	0.958	1.078
2005	1.145	1.106	1.035
2006	0.997	0.937	1.065
2007	0.836	1.008	0.830
2008	1.226	0.985	1.244
2009	1.033	1.015	1.018
2010	1.033	1.031	1.002
2011	0.937	0.946	0.991
2012	1.040	1.059	0.982
2013	1.071	1.077	0.995
2014	1.166	0.835	1.396
2015	0.950	0.900	1.055
2016	1.005	1.046	0.961
2017	0.886	0.914	0.969
2018	1.033	1.059	0.976
2019	0.981	0.973	1.009
2020	0.905	0.939	0.964

compared to 2001. A value of 1.016 for 2003 suggests the production frontier shifted out by 1 percent for domestic firms as compared to 2002. Foreign firms register technological progress for 15 years and technological regress for only 4 years while domestic firms register a positive technical change for just 9 years and a regress for 10 years out of a total of 19 years.

This suggests that due to foreign investment, firms are experiencing technological progress with an outward shift in the production frontier for the majority of the years while the domestic firms are unable to adapt with technical progress and are seen facing technological regress for most of the period. Such technical progress suggests that due to investment, the sector is facing new production possibilities or new efficient firms have entered the market with superior technology.

A shift in the production frontier also increases the distance of output of firms from the frontier. This increase in distance increases average inefficiency. For foreign firms, the column 4 of table 3 represents the efficiency change component. A value of 0.944 for the efficiency change in 2003 implies that compared to 2002, the average efficiency of firms regressed by 6 percent, whereas, a value of 1.027 in 2004, implies that, on an average, the efficiency of firms has improved by 2 percent in 2004 as compared to their efficiency in 2003. The efficiency component can be interpreted in the same manner for domestic firms using table 4.

Indian pharmaceutical sector as a whole project that during the years that the industry experienced technological progress, it also witnessed a regression in its efficiency. This signifies that most of the firms are not able to enjoy the benefits that the technological progress brings along with it to the sector. As the production frontier shifts outwards, simultaneously, the fall in the level of average efficiency is also registered (Mazumdar, 2013). This implies that the technical and efficiency components in the sector have a strong negative correlation. This correlation is seen to be higher for foreign firms (79 percent) than in domestic firms (50 percent). It also suggests that a large number of firms entered the market due to lack of strong patent protection (Mazumdar, 2013). Such firms lack R&D activities and their original products. As foreign investment brings better opportunities along with it, the shift of the production frontier and also increase in inefficiency is noted more in foreign firms as compared to domestic firms.

Conclusion and Policy Recommendations

The present research extends the literature of the effect of foreign investment on the productivity and its components on the firms of the Indian pharmaceutical sector for the period 2001-2020. There are two ways for a firm to experience productivity gains, either by efficiency change (movement along the frontier) or a gain in technical change (outwards shift of the frontier). The study draws a comparison between the foreign and the domestic firms of the sector and list out the reasons for the differences in their productivities. The non-parametric MPI approach is used to decompose the productivity in efficiency change and technical change. The data comprises of 38 foreign firms and 38 domestic firms which is collected from CMIE.

The study concluded that foreign investment has a positive impact on the productivity of the firms. Foreign firms also adapted better to the technological progress as compared to the domestic firms. The sector also experienced a regression in efficiency, especially in the years registering technological progress suggesting that a majority of firms are not able to enjoy the benefits but certain firms have progressed due to foreign investment and shifted the production frontier outwards. Thus, we conclude that foreign investment is paramount for firms to perform better and improve their productivity but certain policy changes are required for the whole sector to enjoy the benefits brought along with it. The firms would benefit from mergers and acquisitions as it would overall increase their size which in turn would increase their absorptive capacity and lead to reap better benefits from investments. With an increase in size, the firms might also be able to use the unutilised plant and machinery and this might lead to capital efficiency as well.

Smaller firms do not possess the resources necessary to engage in importing which would also lead to increase in productivity. These firms might receive assistance

from the government in one of two ways: either by providing financial assistance or by establishing markets. These markets would facilitate firms to do business by purchasing medicines at a lower price which would help the firms in recouping the money that they invested.

Research and development is also known to be an important determinant in productivity enhancement. Hence, it is recommended that all businesses invest in R&D. This investment should be done in order to develop new goods as well as processes. Scale economies are also present for firms that invest in R&D. However, not all firms are able to absorb foreign investment by assuming the risk of investing in R&D-related activities. In order to facilitate these processes, the government might engage in public-private technical collaborations and contribute to the expansion of research and development endowment, which in turn would assist in more effective utilisation of the received foreign investment.

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• **Author Contributions:** TR and BN contributed to the conception and design of the study. TR was responsible for the acquisition, analysis, and interpretation of data, as well as drafting and writing the manuscript. BN provided supervision and project administration. Both authors critically revised the manuscript, approved the final version to be published, and agreed to be accountable for all aspects of the work.

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