CHAPTER 4

FOREIGN DIRECT INVESTMENT, PRODUCTIVITY AND TECHNOLOGICAL PROGRESS – METHODOLOGY AND DATA FOR ANALYSIS

4.1 GENERAL

This chapter gives the methodology to analyse the role of FDI in building up technological capabilities, spillover generation, which in turn leads to the productivity growth in Indian manufacturing industries. The effect of FDI on firm level productivity through technology upgradation and spillover generation is estimated using econometrics models. There are two major problems in devising a proper methodology for analysing the impact of FDI on firm level productivity and technological upgradation. The first problem is in measuring technology and subsequently its changes or progress. The second is in measuring the contribution of FDI in facilitating technological progress. A large volume of literature is available on these two aspects.

Since ‘technology’ is an inherently abstract concept, measuring it and subsequently evaluating its progress is a difficult task. In addition, technology is diffused in different ways. Traditionally, economists consider ‘productivity’ as a measure of the current state of technology used in producing the goods and services in an economic entity (a firm, industry, or an economy). Any change in productivity is mainly considered as due to technological change,
showing a shift in the production possibility frontier (Griliches, 1987). Technological progress is thus measured by quantifying its impact on productivity.

Since the early 1950s, the literature on technological progress has received much attention with a debate on the measurement of TFP and its implications. The earlier studies on technological progress have been centered around the concept of aggregate production function. In these studies the observed growth in output was divided into two independent and additive elements: capital-labour substitution, reflecting the movements around the production function, and increased efficiency in resource use, as reflected by shifts in the production function. The neoclassicals considered that growth in labour productivity is due to the substitution of capital for labour. These studies assumed perfect competition and constant returns that allows marginal productivity pricing to identify the contribution of each input to the growth of output per worker. They have also assumed that all the contributing sources of economic growth have been taken into account and the residual represents the errors of measurement or aggregation.

The time series estimation of production function has shown that the observed growth in aggregate output cannot be fully attributed to the growth in conventionally measured capital and labour inputs alone. Earlier researchers tried to solve this problem by attributing the rest of the growth in aggregate output to the residual in a production function as reflecting technological change or TFP growth. The idea of incorporating the residual in a production function as reflecting technological change or TFP growth was first formulated by Solow (1957), where the change in output is unexplained by a change in
inputs is interpreted as the change in TFP (Griffith, 1999). Economists like Abramovitz (1956), Solow (1957) and Kendrick (1961) showed that the modern economic growth is due to increased efficiency in the use of productive inputs (i.e., technological progress) and not due to growth in the quantity of resource inputs per se. They have given greater thrust on productivity improvements driven by advances in the technology and organization of production.

There are many potential problems in using the conventional measures of productivity to reflect the technological change. One of such potential problem is that the conventional measures of productivity do not take into account the measurement of inputs over time. The changing skill mix of labour, quality change in the machinery and equipment used, and the changing utilisation of the labour force as well as existing capital stock are not accounted in the conventional measurements (Griliches, 1987). This drawback with conventional measures of technological progress resulted in reorientation of growth models over the past two decades. Some economists revised the input measures so as to reduce the size of the residual by allocating part of it to the redefined input classes. The advantage of this approach is that, it is possible to incorporate various factors like improvement in labour quality due to education and technological change (Lucas, 1967). Denison (1962) tried to incorporate the effects of education on labour quality and Jorgenson and Griliches (1967) attempted an accurate measurement of capital goods and their services. They argued that the size of the residual could be reduced by incorporating these quality factors of productive inputs in the analysis.¹

¹ For a detailed discussion on different methodologies of measuring technology and its changes, refer Griliches (1987), Romer (1990), Griffith (1999) and Hulten (2000).
Measuring the contribution of FDI to technological progress is a keenly debated topic. One argument is that the measure has to just taking the partial derivatives of output \( Y \) with respect to some measure of foreign participation while the other argument says that it should be by taking the total derivatives, including the direct and indirect effects of changes in foreign equity participation on output \( Y \) through induced changes in input vector \( X \). In other words, one has to see whether the marginal effect of an additional foreign equity capital, holding all other investments constant, to be tested or the total effect of a particular foreign equity investment, including the contribution of all other investments induced by it, to be tested. Griliches (1998) points out that to some extent, this is a distinction between economic accounting approach and causal-historical approach. The empirical studies, which are usually based on the estimation of cross-country and time series growth equations, the conventional methodology is based on standard growth accounting pioneered by Solow (1957) and Denison (1962). Such studies considered FDI as an additional input in an augmented production function. Most of the recent empirical studies take FDI as a dummy variable and considers a firm as foreign-owned/controlled if it has a certain percentage of foreign equity share or above.

The present study has also used econometric models to estimate the effect of FDI on firm-level productivity, technology capability building and spillover generation. To test its impact on the firm-level productivity, FDI is taken as an additional input variable in the production function. However, since the equity participation is not available for all the years, the study classifies firms into two categories – domestic and foreign, and compares their performance to know the impact of foreign investment. In order to understand the role of FDI in creating technological capability among firms in India, the
impact of various technological (knowledge) variables on the output of domestic and foreign owned firms are analysed separately. For this purpose, part of the residual is allocated to certain pre-defined knowledge variables.

This chapter is organised as follows. Section 4.2 provides the major hypotheses of the study along with the methodology used to test these hypotheses. The estimation models used to analyse the association between foreign ownership and firm level productivity, and the role of foreign ownership in technology upgradation and spillover generation are derived in this section. Section 4.3 provides the details of data used for the analyses of various hypotheses in this study, such as data sources and the various truncation and classification methods used for sample construction. The chapter concludes with Section 4.4 that gives the methods used in construction of various variables as used in the study and Section 4.5 concludes the chapter.

4.2 HYPOTHESES AND MODEL SPECIFICATION

Based on the objectives of the study specified in Section 1.6 of Chapter 1, the following hypotheses are framed.

**Hypothesis I:** Higher foreign equity participation leads to higher productivity gains for firms.

**Hypothesis II:** The productivity impact of technological factors in foreign-owned firms are significantly higher than that of domestic-owned firms and this impact varies to the industry type.
Hypothesis III: There exist spillovers from FDI on the productivity of domestic-owned firms and these spillovers are determined by the absorptive capacity of firms.

The main hypotheses in this study are tested using econometric models. The test includes estimation of the association between foreign equity participation (the extent of foreign ownership) and plant level productivity (using cross sectional data), and the role of FDI in technology upgradation and spillover generation (using panel data). The process begins with a production function, where output $Q$ is a function of a vector of inputs, $X$.

$$Q_{ijt} = A_{ijt}F(X)$$

(4.1)

where $A_{ijt}$ is the shift factor in the production function to denote technological change, which is considered as a vector of knowledge. The indices $i$ and $t$ denote firm and time respectively, and $j$ represents the industry group.

In the production function, given by equation (4.1), $A_{ijt}$ is considered as Hicks-neutral productivity shift parameter or the residual, and is interpreted as TFP. One major problem in interpreting TFP that has been measured as a residual is in identifying the proportion of it attributed to technological difference/change or other spillovers and externalities variables and the portion attributed to measurement error. Previous studies have incorporated all these in a single residual $A_{ijt}$ (Solow, 1957). However, there are various causes of differences in $A_{ijt}$ between firms. The present study tries to reduce the (bias) size of this residual by accounting for the observable factors of technological progress. Therefore, the factors that contribute to the technological progress of
a firm are identified and treated separately as a knowledge variable in the production function.

The economically relevant knowledge available to a firm may come from different sources such as knowledge from learning, in-house R&D, through technology purchase or licensing, and through spillovers. Hence, the level of technology in firm $i$ in industry $j$ at time $t$, $A_{ijt}$ in (4.1), is given as a function of different sources of knowledge available to it (Gustavsson et al., 1996).

$$A_{ijt} = F(N,T)$$

where $N = N(KL, KO, KF, KS)$ consists of various possible sources of knowledge that help for the technological progress of a firm such as, knowledge from learning ($KL$), knowledge from own R&D expenditure ($KO$), knowledge obtained from abroad ($KF$), and knowledge acquired through spillovers ($KS$). $T$ represents a time trend that captures technical change and any other effects not accounted for by these variables. The knowledge from learning can be either come from firm's own experience of production or from exporting to knowledgeable buyers. The knowledge obtained from abroad may be either embodied in imported capital goods or disembodied technology purchase through licensing. The knowledge spillover can be from technology stock of other domestic firms in the industry or the technology stock of foreign firms in that industry. The various possible sources of knowledge helping for the technological progress of a firm are given in Table 4.1.2

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2 In our analysis we have considered knowledge acquired by learning ($AGE_i$ and $EXPINT_i$), knowledge produced from firm's own R&D activity ($RAD_i$) and knowledge obtained from abroad ($TPE_i$ and $CG_i$). The spillover effects of FDI are separately analysed.
Incorporating all the possible knowledge variables in (4.2), we can write \( A_{ijt} \) as,

\[
A_{jt} = F(AGE_{ijt}, EXPI\_NT_{ijt}, RAD_{ijt}, CG_{ijt}, TPE_{ijt}, T) \tag{4.3}
\]

and the functional form of \( A_{ijt} \) can be written as

\[
A_{jt} = Ae^{\lambda t} N_{t}^a
\]

In this study, a simple extended Cobb-Douglas production function is used incorporating this knowledge variable and is given as,

\[
Q_{ijt} = Ae^{\lambda t} K_{ijt}^\alpha L_{ijt}^\beta M_{ijt}^\gamma N_{aijt}^\theta \epsilon^\tau
\tag{4.4}
\]

where \( Q \) is the measure of output at constant prices, \( \lambda \) measures the disembodied growth rate and \( \alpha, \beta, \theta, \text{and } \gamma \) are output elasticities with respect to capital \( (K) \), labour \( (L) \), materials \( (M) \), and knowledge capital \( (N) \), respectively. \( \epsilon \) is the error term reflecting the effects of unknown factors, data approximations and other disturbances, and \( a = 1,2,3,\ldots5 \) representing different knowledge variables from \( AGE_{ijt} \) to \( TPE_{ijt} \).

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3 Though Basant and Fikkert (1996) have followed a similar model incorporating separate input variable on technical capital, they do not give any theoretical justification. This study tries to give the theoretical justification for taking out the technology factors from the residual.
Table 4.1 Knowledge variables used in the study

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>$AGE_{ij}$</td>
<td>Knowledge acquired by learning from experience.</td>
<td>The age of the firm is taken as a proxy for its experience from learning from production.</td>
</tr>
<tr>
<td>$EXPINT_{ij}$</td>
<td>Knowledge acquired through learning from exporting to knowledgeable buyers.</td>
<td>Export intensity is calculated dividing the total exports of the firm by its total sales.</td>
</tr>
<tr>
<td>$RAD_{ij}$</td>
<td>Knowledge generated from firm's own R&amp;D activity.</td>
<td>R&amp;D stock is constructed (see Section 4.6.2 for details)</td>
</tr>
<tr>
<td>$CG_{ij}$</td>
<td>Technical knowledge embodied in new capital goods imported.</td>
<td>Capital goods import intensity is computed by dividing total capital goods import of the firm by total sales.</td>
</tr>
<tr>
<td>$TPE_{ij}$</td>
<td>Disembodied technical knowledge purchased in the form of technology licensing from foreign sources.</td>
<td>Imported technology stock is constructed (see Section 4.6.2 for details).</td>
</tr>
<tr>
<td>$T$</td>
<td>A time trend, captures technical change and any other effects not accounted for by the other variables.</td>
<td>Time dummies are used.</td>
</tr>
</tbody>
</table>
From (4.3), using logarithmic transformations (represented by lower case letters), the estimation equations are given as:

\[ q_{it} = a_0 + \alpha k_{it} + \beta l_{it} + \theta m_{it} + \gamma_1 \text{AGE}_{it} + \gamma_2 \text{EXPINT}_{it} + \gamma_4 \ln \text{RAD}_{it} + \gamma_5 \text{CG}_{it} + \gamma_5 \ln \text{TPE}_{it} + \lambda \text{TIME} + \epsilon_{it} \] (4.5)

Here \( \lambda \) has been replaced by year dummies, \( \text{TIME} \), since such dummies impose less structure than a constant trend, \( \lambda \), on any unobserved period-specific effects. If some important shock (technological or institutional) affects the environment at a certain time, \( \text{TIME} \) controls for it.\(^5\)

4.3 DATA
4.3.1 Macroeconomic Analysis Vs Micro-level Panel Data Analysis

Most of the empirical studies that analyse the effect of international investment flows and the activities of multinational firms on economic growth have used macro (country or industry) level data. Such macroeconomic analysis is generally conducted within one of the two alternative frameworks: (a) a macroeconomic model, (b) a multifactor technological production function. Macroeconomic growth models consider foreign investment inflows as supplementing domestic investments and savings, and emphasize on how they effect the growth parameters. But, the production function analysis focuses on the scale, productivity and efficiency parameters of the production function,

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\(^4\) A log-linear expression has a number of advantages as it allows for diminishing heteroskedasticity among firms as extreme observations are flattened with respect to average observations and for interpreting estimated coefficients as elasticities.

\(^5\) The \( \text{TIME} \) dummy captures possible common aggregate shocks in production and any other unobserved time varying factors.
treated foreign investment as an endogenously generated input factor to be used in the production function (Marwah and Klein, 1998). "Looking at a cross section of firms within a particular industry, one will not be able to distinguish the effects of FDI on productivity of firms or industry. Since the pools of knowledge transferred through FDI and other sources differ for different industries, some of the

Recently the micro level data sets have gained popularity in productivity analysis. There are certain advantages in using micro-level data in the present context. First, using micro panel data it is possible to control for unobservable firm-specific characteristics that may be correlated with the other regressors. Many econometric studies have shown its importance (Stocker, 1998; Blundell and Stocker, 1998). Second, the theory, upon which most of the earlier empirical studies were drawn, is based on the profit maximising behaviour of firms. But, aggregating these models will not necessarily yield a model of the same form as implied by the disaggregated version. Using aggregate data to estimate models describing firm behaviour will also introduce aggregation bias. Finally, if a dynamic model is being estimated with aggregated data in that the composition of firms in the industry or country at time $t$ and $t-1$ will not be the same. This means that changes over time reflect both changes in composition and changes in behaviour and that using lagged values as regressors or instruments may become invalid (Pischke, 1995).

Griliches and Ringstand (1971) pioneered the use of longitudinal micro level data (i.e., micro level panel data) in their study of scale elasticities using Norwegian Census of Manufactures. As Griliches (1991, p.9) points out:
effects on productivity could be deduced from inter-industry comparisons over time and space”.

The wide popularity for micro level panel data is because they contain large and statistically representative samples and they allow the linking of data from supplementary surveys. In India, Centre for Monitoring Indian Economy (CMIE) provides such establishment level data for different years. The RBI also has unpublished information about corporate firms over a number of years. This study also estimates a multifactor production function using panel data for Indian manufacturing industries.

In the present study, the relationship between the extent of foreign ownership and firm level productivity is tested using cross sectional establishment level data for 1129 manufacturing firms for the year 2000. The same establishment level data, over a period of nine years (from 1992 to 2000 – a period after 1991 liberalisation) is used to test the role of FDI in technology capability building and spillover generation. Such type of micro-level data may be useful to control for fixed differences in productivity levels across industries, which might affect the level of foreign investment. The selection and construction of database for the study is explained in Section 4.3.2.

4.3.2 Database Selection and Construction

The data for this study is taken from the Prowess (an electronic database for Indian corporate firms listed in the Bombay Stock Exchange (BSE)) provided by CMIE. Prowess is the establishment level data that is collected and compiled from the annual reports. Only manufacturing
establishments are taken for this study that includes firms from the following seven industries: chemical, food processing, machine and machine tools, metals, non-metallic minerals, textiles and transportation. All the three hypotheses tested use this data. However, for Hypothesis I only data for the year 2000 is considered. For Hypothesis II and III, the data is taken for the period between 1992 to 2000 (i.e., the period after 1991 liberalisation). For the selected firms information on gross output, labour input, gross fixed assets, payment for technology licensing, imports of capital goods, exports, etc are available. Some supplement information has been taken from the Annual Survey of Industries (ASI) provided by Central Statistical Organization (CSO), Government of India.

The study has selected firms that come under the NIC\(^7\) 2-digit classification as given in Table 4.2. A balanced panel data is used, comprises of firms that were existing and in operation before the initial year of the study, i.e. 1992. The initial data set consisted of 1397 firms. Those firms that have not reported the information required for the study in any year of the study period (1992-2000) are removed from the sample. After executing this truncation procedure, a sample of 1365 firms was left.

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\(^6\) Prowess provides information about foreign equity participation of the firms only for the latest year. Since Hypothesis I test for the association between foreign equity share and firm's productivity, this non-availability of information on foreign equity participation for previous years allows only to perform a cross sectional analysis.

\(^7\) NIC means National Industrial Classification.
Table 4.2 National Industrial Classification (NIC) Codes and Description for the Sample selected for the Study

<table>
<thead>
<tr>
<th>Industry</th>
<th>Industry Code</th>
<th>Description of Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Processing</td>
<td>20-21</td>
<td>Manufacture of Food Products</td>
</tr>
<tr>
<td>Textiles</td>
<td>23</td>
<td>Manufacture of Cotton Textiles</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>Manufacture of Wool, Silk and man-made Fibre Textiles.</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>Manufacture of Jute and other Vegetable Fibre Textiles (except Cotton)</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>Manufacture of Textile Products (including Wearing Apparel).</td>
</tr>
<tr>
<td>Chemical</td>
<td>30</td>
<td>Manufacture of Basic Chemicals and Chemical Products (Except Products of Petroleum and Coal).</td>
</tr>
<tr>
<td>Non-metallic minerals</td>
<td>32</td>
<td>Manufacture of Non-metallic Mineral Products.</td>
</tr>
<tr>
<td>Metal and Metal products</td>
<td>33</td>
<td>Basic Metal and Alloys industries.</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Manufacture of Metal Products and parts. Except Machinery and Equipments.</td>
</tr>
<tr>
<td>Transportation</td>
<td>37</td>
<td>Manufacture of Transport Equipment and Parts.</td>
</tr>
</tbody>
</table>

Two more truncation rules are employed to clean the data. Since outliers may be a cause of measurement errors in any of the variables, a cleaning process is used as suggested by Hall and Mairesse (1992) and adopted by Basant and Fikkert (1996). Based on this process, 171 firms (i.e., 12.5 per cent of the sample) for which the capital-labour ratio is outside of three times the inter-quartile range (the difference between the 75 per cent value and the 25 per cent value) above or below the median are removed. Since there is a duality in Indian industries – firms belonging to small scale are regulated through different procedures than medium and large sized firms. In order to keep the focus on medium and large sized firms, all firms having a paid-up capital of less than Rs.10 million have been removed. This leaves a final sample of 1129 firms with observations for nine years (1992-2000) making a total of 10161 panel observations for the study.

In order to understand the role of ownership (domestic or foreign) on the productivity and technological performance in different industries, sample firms in each industry sector have been classified into two groups: domestic controlled/owned firms (referred as domestic firms) and foreign controlled/owned firms (referred as foreign firms). The criteria used for this classification is the one given by RBI,\(^8\) which considers firms with foreign equity participation of 25 per cent or more as foreign controlled/owned firms.\(^9\) Using the RBI classification criteria there are 874 domestic firms (around 77

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\(^8\) Reserve Bank of India (RBI) is the Central Bank in India.

\(^9\) It is assumed that the control/ownership of the sample firms haven’t had any major change during the analysis period, 1992-2000. This assumption is valid, since the foreign ownership more or less remains the same for many years unless there is some legal enforcement or some drastic change in firm’s policy. Also, after the 1991 liberalisation, new joint ventures and fully subsidiaries are usually incorporated as new firms. Theses firms are not included in the analysis since all the sample firms covered in this study are incorporated before 1992. Usually there is not much change in the equity ownership of these firms. Therefore, we assume that the control/ownership of the firms remained the same for whole sample period. (Also see Kathuria (2001), p.632.).
per cent) and 225 foreign firms (around 23 per cent). A detailed sectoral classification of all the firms along with their ownership is given in Table 4.3. The sample firms cover a wide range of manufacturing industries: 16.9 per cent sample firms are from chemical industry, 4 per cent from food processing, 25.2 per cent from machinery, 11.5 per cent from metals, 4.3 per cent from non-metallic minerals, 8.4 per cent from textiles and 29.8 per cent from transportation.

Table 4.3 Sectoral and Ownership Classification of Sample Firms selected for the Study

<table>
<thead>
<tr>
<th>Industry</th>
<th>Domestic-owned</th>
<th>Foreign-owned</th>
<th>All Firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical and chemical Products</td>
<td>144 (16.5°, 75.4**)</td>
<td>47 (18.4, 24.6)</td>
<td>191 (16.9, 100.0)</td>
</tr>
<tr>
<td>Food Processing</td>
<td>34 (3.9, 75.6)</td>
<td>11 (4.3, 24.4)</td>
<td>45 (4.0, 100.0)</td>
</tr>
<tr>
<td>Machinery and Machine Tools</td>
<td>214 (24.5, 75.4)</td>
<td>70 (27.5, 24.7)</td>
<td>284 (25.1, 100.0)</td>
</tr>
<tr>
<td>Metal and Metal Products</td>
<td>111 (12.7, 85.4)</td>
<td>19 (7.5, 14.6)</td>
<td>130 (11.5, 100.0)</td>
</tr>
<tr>
<td>Non-metallic Minerals</td>
<td>40 (4.6, 83.3)</td>
<td>8 (3.1, 16.7)</td>
<td>48 (4.3, 100.0)</td>
</tr>
<tr>
<td>Textiles</td>
<td>87 (9.3, 91.6)</td>
<td>8 (3.1, 8.4)</td>
<td>95 (8.4, 100.0)</td>
</tr>
<tr>
<td>Transportation</td>
<td>244 (27.9, 72.6)</td>
<td>92 (36.1, 27.4)</td>
<td>336 (29.8, 100.0)</td>
</tr>
<tr>
<td>Total</td>
<td>874 (100.0, 77.4)</td>
<td>255 (100.0, 22.6)</td>
<td>1129 (100.0, 100.0)</td>
</tr>
</tbody>
</table>

Source: Computed from sample data

Note: For definition of domestic and foreign-owned firms, refer text.
  * Row percentage
  ** Column percentage
4.4 VARIABLE DEFINITION AND CONSTRUCTION

4.4.1 Basic Variables – Output Variable

Value of Output \((Q_{ij})\) : The value of output is taken as the measure of output. To convert it into constant prices, the value of output is deflated by a two-digit, industry-specific, wholesale output price deflators obtained from the index numbers of wholesale prices of India.\(^{10}\)

A close look at the available literature shows that the choice of output measure was often dictated by the available data. Economists suggest that where possible, physical output with unchanging quality would be the best measure. In general, researchers rely on deflating nominal variables at the sectoral level (all establishments in an industry use the same deflators). But, using deflated production to measure productivity has one drawback, which is the same whether applied at the micro level or at the sectoral or aggregate level. Any quality improvement in output that is not reflected in the deflator will result in a downward bias in productivity. For instance, due to the unavailability of micro level prices, quality-adjusted industry deflators are applied to micro level data. But this would be acceptable only under perfect competition, because the price per unit of quality-adjusted output would be the same across firms. However, the empirical relevance of perfect competition is questioned because of the persistent dispersion of productivity or costs across firms. “Under monopolistically competitive markets with differentiated products, prices may differ across micro units. In this case, assuming constant prices implies that an establishment with higher than average prices will mistakenly be assigned higher productivity” (Bartelsman and Doms, 2000, p.576).

\(^{10}\) Index numbers of wholesale prices are obtained from Handbook of Industrial Policy and Statistics, 2000, Ministry of Commerce and Industry, Government of India.
Another choice facing the researchers is the use of gross production or value added as the output measure. For the economy as a whole, value added is the preferred output concept. It avoids double counting of intermediate inputs, such as raw materials, energy inputs and business services, and is comparable to the domestic or normal product as shown in national accounts. Some of the studies carried out for India have used gross value added as indicator of output (example, Kathuria, 2001; 2002). However, the value-added concept creates a problem for productivity studies because intermediate inputs are transferred from a “source” of output growth to an “explanation” of output growth. In contrast to value added, gross output allows symmetrical treatment of intermediate inputs, capital and labour. At the industry level, where purchase of intermediate inputs from outside the sector are much larger than at the aggregate level, the use of gross output is therefore the most appropriate concept for productivity measurement (OECD proceedings, 1996).

Value added may be more useful for making welfare statements at an aggregate level but less useful for understanding sources of productivity growth. Shifts in use of intermediate inputs relative to labour and capital over time may create biases in productivity measured with value-added output. As noted in Baily (1986), the more disaggregated the data, the greater the advantage of using gross production for productivity measurement (Bartelsman and Doms, 2000, p.576). Klein (1992) has argued that in studying the laws of production, the appropriate variable to be used is gross output rather than the value-added measure of output, especially when intermediate materials are used as factor inputs.
4.4.2 Basic Variables – Input Variables

Capital \( (K_j) \): A net capital stock is generated as a measure of the capital input. The database gives information on gross fixed assets (GFA), its components and depreciation. Usually, fixed assets of the enterprises are reported at their historical cost. Some firms have revalued these assets to present the current market value and this revaluation portion is reported separately in the database. We subtracted the value of capital under construction and revaluation portion, if any, from the reported GFA.

The capital stocks are reported at their purchase prices (i.e., the historical cost of the capital). In order to bring them into 1991-92 constant prices (the initial year of data set) capital formation price indices are constructed and used as a price deflator from the series for gross fixed capital formation in manufacturing obtained from National Account Statistics of India. An average age \((AA)\) of each firm’s capital stock has been calculated based on the following formula. The life of a machinery (i.e., the period in which the full depreciation of capital take place) is assumed as twenty years, as noted in the report of the ‘Census of Machine Tools 1986’ of the Central Machine Tool Institute, Bangalore (CSO, 1989). Then, under the assumption of straight-line depreciation method, capital depreciates at a rate of 5 per cent per annum. Thus, average age of the firm would be,

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11 The procedure followed to construct capital stock, man-days worked and R&D stock is more or less similar to the procedure used by Basant and Fikkert (1996) and Kathuria (2001).

12 Both Basant and Fikkert (1996) and Kathuria (2001) assume that full depreciation of capital stock takes 16 years. This study has also computed capital stock using this assumption and found hardly any difference in the results. Therefore, we follow the assumption of 20 years as the life of a machinery based on the report of Central Machine Tool Institute.

13 The new name of the institute is Central Manufacturing Technology Institute.
\[ AA = \left( \frac{AD_{92}}{GC_{92}} \right) \times 20 \]  

(4.6)

where \( AD_{92} \) is the accumulated depreciation in 1992, the first year of data, and \( GC_{92} \) is the gross capital in 1992.

This average age, \( AA \) is used to construct a price deflator of capital (\( DC_i \)) for each firm’s capital stock in order to deflate from the year 1991-92 – \( AA \) to the year 1991-92. Then, the net capital stock of each firm \( i \) in 1992 would be,

\[ NC_{92} = \left( \frac{GC_{92}}{DC_i} \right) \times (1 - 0.05)^{AA} \]  

(4.7)

Similarly, net capital stock for 1992-93 at 1991-92 prices would be

\[ NC_{93} = \left( \frac{NC_{92}}{PC_{93}} \right) \times (1 - 0.05) + \frac{(NI_{93})}{PC_{93}} \]  

(4.8)

where \( NI_{93} \) is the net investment in 1992-93 and \( PC_{93} \) is the price deflator for capital for 1993, which is same for all firms. The same formula is used to get net capital stock for the subsequent years, till 2000.

**Labour (\( L_i \)):** The firms report the total wages paid to the employees. In order to estimate mandays worked, these total wages are divided by the average wage rate of the industry to which each firm belongs. The average wage rate is calculated by dividing the total labour costs by total hours worked for the relevant industry groups from the ASI data available at the two-digit industrial classification.
Materials (M): The material variable includes all the raw material expenses and the energy consumed in the process of production. The series on material consumed is deflated using an industry-specific material price index that is constructed by taking weights from the input-output transaction table (1989-90). At first, the material components for each industry have been identified and then their proportions to total material consumed, in value terms, have been calculated. Using these figures as weights, the Wholesale Price Indices (WPI) of various inputs has been combined to construct the appropriate material price index for each industry.\footnote{See Mitra (1999), and Basant and Fikkert (1996) for details}

4.4.3 Technology Variables

Learning by Experience ($\text{AGE}_t$): Learning by experience from production is usually thought of as proportional to the learning period and is proxied by the age of the firm. In some studies, cumulated production of the firm over time is considered to reflect this learning factor (Berndt, 1991; Gustavsson \textit{et al.}, 1996). Kathuria (2001) uses the learning curve as the ratio of accumulated depreciation to the value of total plant, machinery and equipment. In this study, the age of the firm is used to represent learning by experience.

Learning by Exporting ($\text{EXPINT}_{it}$): It is assumed that as the export intensity of a firm increases, its exposure to advanced technology available abroad also increases. Many a times the exporter has to adhere to the (high) technological standards of the importing country. Therefore, it is believed that export intensity improves the technological knowledge and skill of the firm. Firm’s interaction with the foreign buyers and the consequent learning from
them is represented by this variable. Export intensity is measured as the ratio of exports to total sales turnover.

**R&D Stock of the Firm (RAD\(_\psi\))**: This variable represents the technological knowledge generated by the firm by its own efforts. This R&D stock variable is calculated from time series of R&D expenditure. Perpetual inventory method is used to construct the own technology stock of the firm,

\[
RAD_\psi = (1 - \delta)RAD_{\psi-1} + RD_{\psi-1}
\]  (4.9)

where \(RD_{\psi-1}\) is the expenditure on R&D at time \(t-1\), \(\delta\) is the rate of depreciation of technical knowledge. Following earlier studies (see Hall and Mairesse, 1995; Basant and Fikkert, 1996; Kathuria, 2001), this study also uses a depreciation rate of 15 per cent.

Many firms did not report R&D during the first year of our data, 1991-92.\(^{15}\) It is assumed in this study that these firms have not engaged in any R&D activities in preceding period also. Thus, the initial period R&D stock of these firms are assumed to be zero. To calculate the initial year R&D stock for the firms which have reported R&D expenditure in the first year of the sample data, it is required to know: (i) the number of years for which the firms have been doing R&D (i.e., the age of their R&D unit), (ii) the rate of growth of R&D expenditure, and (iii) the rate of depreciation of R&D stock. It has been argued in the literature that the effects of R&D investments persist for at

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\(^{15}\) Many a times, being relatively small amount, companies do not disclose expenditure on R&D separately. Therefore, for these firms we get the R&D expenditure as zeros. In order to convert these zero values into logarithmic format, we have assigned small values for them. This procedure can be justified on the fact that, in India some of the firms with R&D expenditures less than one per cent of total sales may not have reported their R&D expenditure in their annual reports but they did report their R&D expenditure details to the DST (See Raut (1995)).
most five periods (Griliches, 1979). Therefore, the age of a firm’s R&D unit is taken as five years. Hence, the initial year (1992) R&D capital stock of firm $i$ in industry $j$ is given as:

$$
RAD_{ij,1992} = RD_{1992} + (1-\delta)RD_{1992-1} + (1-\delta)^2 RD_{1992-2} + (1-\delta)^3 RD_{1992-3} + (1-\delta)^4 RD_{1992-4} 
$$

$$
= RD_{1992} + \sum_{r=1}^{4} (1-\delta)^r RD_{1992-r} 
$$

(4.10)

The rate of growth of private sector R&D expenditure during 1987-88 to 1991-92 is estimated to be 13 per cent from the R&D statistics published by Department of Science and Technology (DST). A depreciation rate of 15 per cent is used following most of the studies in this area of research. Taking these information, the above equation (16) can be rewritten to estimate the initial year of R&D stock as:

$$
RAD_{ij,1992} = RD_{1992} \left\{ \sum_{r=0}^{4} [(1-0.15)/(1+0.13)]^r \right\} 
$$

(4.11)

**Technology embodied in imported capital goods (CGy):**

Measuring foreign technology imported by technology licensing agreements alone underestimates the firm’s true technology imports, since much technology is transferred through machinery and equipments. Here it is assumed that foreign technology is embodied in the imported capital goods. The variable $CGy$ is constructed by dividing the import of capital goods by the sales of the company.
Foreign Disembodied Capital Stock (TPE$_{ij}$): Disembodied technology purchase in the form of expenditure on foreign patents, royalties, technical and consultancy fees, etc., from foreign countries have been used to measure foreign purchased technical capital stock. Here also the perpetual inventory method is used to construct the knowledge capital stock through technology purchase,

$$TPE_{ijt} = (1 - \delta)TPE_{ijt-1} + TP_{ijt-1}$$ (4.12)

where $TP_{ijt-1}$ is firm’s current expenditure on technology purchased in the form of licenses from foreign countries, and $\delta$ is the depreciation rate that is again assumed to be 15 per cent. Since the United States is the largest seller of technology to India, the technology purchase expenditure is deflated by the Rupee-US dollar exchange rate at the 1991-92 rates to bring it at constant prices.

The initial period knowledge capital stock through foreign technology licensing is obtained as, $TPE_{ij1992} = \frac{TP_{ij1992}}{g + \delta}$, where $g$ is the rate of growth of foreign technology licensing during 1985 to 1991 computed from DST documents. $TP_{ij1992}$ is the initial year (1992) technology purchase expenditure incurred by firm $i$ in industry $j$. $\delta$ is the rate of decay assumed to be 15 per cent.

4.4.4 Spillover Variables

It is considered that knowledge generated by firms in an industry is spilled over to other firms in that industry. In that case, the firm will benefit not
only from its own knowledge generating activities but also from the various knowledge generating activities of other firms in that industry. In order to understand the knowledge spillovers from foreign firms to the domestic firms, three possible spillover variables are included in the basic estimation equation (4.5). The methods used to construct the spillover variables are explained below.

**Productivity Spillovers from Sales (SPSj):** The market share of foreign firms in the form of their sales can affect the output/productivity of domestic firms to a great extent. It is believed that the quality products of MNEs, which usually contains high technology/knowledge content, induce the local firms to be more quality conscious by adopting latest technology to protect their market shares. Technology may spillover to the domestic firms through these products either by imitation or reverse engineering or by using these products as inputs to their products. Therefore, productivity spillovers from sales \( SPS_j \) is constructed by taking the share of foreign firms’ sales in a particular industry to the total sales of that industry:

\[
SPS_j = \frac{SALES_{FOREIGN,j}}{SALES_{TOTAL,j}} \tag{4.13}
\]

**Spillover from Capital Stocks (SPCj):** Another possibility for spillovers is from the capital stocks of foreign firms. The capital stocks of foreign firms are generally considered as incorporating sophisticated technology that in turn makes them more efficient and productive. Close contacts with such capital stocks or purchase of such capital goods make the domestic firms also more efficient and productive. Therefore, the share of
capital stock of foreign firms in an industry to the total capital stocks in that particular industry is taken as a spillover generating variable. The variable is constructed as:

$$SPC_j = \frac{CAPITAL_{FOREIGN,j}}{CAPITAL_{TOTAL,j}}$$ (4.14)

**Spillovers from Technological Knowledge Stock (SPT)**: The technological knowledge stock variable for a firm, $i$ in an industry, $j$ (say, $KN_i$) is constructed by adding up R&D stock and the stock of technology purchased of that firm. The variable $SPT_j$ that denotes the technological knowledge spillovers from foreign firms is constructed taking the share of all foreign firms in a particular industry to the total technological knowledge stock in that industry.

$$SPT_j = \frac{KN_{FOREIGN,j}}{KN_{TOTAL,j}}$$ (4.15)

These three variables are not mutually exclusive always as a high foreign share may also imply more stock of foreign technology. On the other hand a high R&D by foreign firms may be an effort to increase their market share.

**4.5 CONCLUSION**

The trends in various technological indicators for domestic and foreign firms were given in this chapter with a descriptive analysis of sample
data using tables and figures. The question of whether technological capabilities vary among domestic-owned firms and foreign-owned firms in various industry groups was investigated. The analysis was carried out by comparing the technological performance of domestic and foreign firms taking four technology indicators, viz., R&D intensity, export intensity, capital goods imports intensity and technology import intensity. The analysis showed that domestic-owned firms are twice in size that of foreign-owned firms in terms of average output, net capital stock and employment. However, the technological performance of both these categories of firms in all the industries had almost similar trends and patterns. It is found that the technology capability building by these firms are more industry-specific.

There had been substantial growth in the R&D intensity and export intensity of both domestic and foreign-owned firms in India during 1992-2000. However, technology import intensity had declined in both categories of firms indicating the declining trend of dependence on technology imports through licensing after liberalisation. The capital goods import intensity for domestic firms also registered a negative growth while there was a small positive growth for foreign firms.