TECHNOLOGY TRANSFER AND PRODUCTIVITY OF ORGANISED INDIAN INDUSTRIAL SECTOR SINCE 1991

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DECLARATION

This is to certify that the dissertation titled *Technology Transfer and Productivity of Organised Indian Industrial Sector Since 1991* is based on my original research work under the supervision of Professor Amaresh Dubey and Dr Purva Yadav. My indebtedness to other works or publications has been duly acknowledged herein. This study has not been submitted in part or full for any other diploma or degree of any other University.

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Chapter 1 Introduction and Background

1.1 Introduction

Production is a very complex process that is of utmost importance for the progress of an economy. Within production, the different methods of producing final goods are called techniques, and the set of all techniques available to a firm is its technology (Gomulka, 1990). Thus, a technological change or progress, is defined as an enlargement of the technology set available with the firm. Technology paradigm, defined as a configuration of design that specifies the framework in which production takes place, is shaped by the form of acquisition of technology and its usage (Narayanan, 1998). And it is important for any strategy that intends to introduce or study the effects of any newer technologies within a system, to consider the inter- linkages as well as interactions between different technological paradigms including the existing ones (Dosi, 1988).

Technology is a crucial input in the process of industrialisation and development of countries. In the present era of liberalisation of trade regimes and greater economic integration that attempts to increase international competitiveness, importance of technology as a determinant of growth is too significant to be ignored. The rate of assimilation of technological progress is certainly shaped by different factors that are external and internal to a firm. Such a technological change can happen in two forms- innovation and invention. These two phenomena may involve one of the two processes of either 'technology generation' or 'technology transfer', which are both significant for a growing economy for achieving higher production and maintaining increased growth levels. Among the two processes, the latter has sought more importance in developing economies in terms of increasing industrialisation progress to sustain growing needs. Hence, technology transfer is a crucial part of the industrialisation process for an economy, more so, for a developing economy like India.

Limitations of the primary and tertiary sectors for being employment inelastic, puts even more pressure on development of manufacturing sector to in turn help spur the overall growth of an economy. Industrial sector is also important from the point of view of foreign exchange earnings. Technology transfer is essential for effective industrialisation. Thus, it has been one of the prime objectives of Indian government to improve growth trends in the industrial sector, and also cater to employment generation in the labour surplus economy.

1.2 Statement of Problem

It is pertinent to look at the divergence in the intended objectives of the reforms of 1991 and their actual outcomes. The literature is divided over the achievements and failures of the reforms. Though designed for a better performing industrial sector of the economy, the results on the whole indicate towards an inadequacy accruing to these reforms. This dissertation is an attempt to look at the process of industrialisation from the perspective of capital, and to investigate the possible reasons for the inadequate growth in productivity of Indian firms.

We look at the various trends and patterns in productivity of Indian industrial firms and try to point out factors that influence their total factor productivity. These factors have been chosen in a manner so as to describe their process and extent of technology transfer process. These various modes of technology transfer are then pinned against the firm's expenditure on research and development and the decision of a firm to undertake investment in R and D, to find out the nature of relationship between the various channels through which a firm acquires technology. It is assumed that such a relationship can either be complementary or that of substitutes. This is also important because such question will help us answer which mode of technology transfer will yield more outcome and thereby influence the productivity of a firm in a positive manner. Such an exercise will point out towards appropriate and optimum policy implications that might result in better performance of the industrial sector, thereby giving further shape to the underlying aspirations of the 1991 economic reforms.

Improved performance of the industrial sector in India is crucial also from the point of view of profitability and absorption of the large labour surplus that India has. The primary and the tertiary sector have their own limitations in terms of providing employment to the greater proportion of the Indian population. With the economy coming at the cusp of demographic dividend in the next few years, it is pertinent to look at this problem in a holistic manner and the secondary sector offers plenty of beneficial opportunities for a growing Indian economy. The present study focuses on this issue and tries to formulate three research objectives.

1.3 Review of Literature

The review of the literature in this study shows that there has been a variety of studies and research that have focussed on international generation, transmission and diffusion of technology. It is important to look at this vast range of literature and review it in order to establish a research gap and hence derive a link between what has already been done and what this study's contribution can be to the ongoing discussion on industrialisation and its relationship with the process of technology transfer. This is pertinent also due to the huge importance accruing to the Indian industrial sector and its contribution to the overall growth of the giant market that is the Indian economy.

The literature review presented henceforth has been structured into two broad parts: the theoretical conceptualisation and the empirical evidence. Empirical findings have been looked in both the arenas of international as well as Indian research done in the field of industrial sector. Also, an attempt to draw upon the policy lessons and concerns has been made, so that a concrete research gap can be established owing to the failure or successes of changes in policy outlooks of the various national governments.

1.3.1 Theoretical Conceptualisation

The history of technology has been contextual with the history of industrial structures associated with such technology (Dosi, 1982). An addition of an efficient technique moves the production possibility frontier or production function of a firm, outwards, thus defining the presence of technological progress within the firm (Gomulka, 1990). Ever since the first Industrial Revolution that happened in the eighteenth century, manufacturing has come to be regarded as the most important instrument of economic growth. Development theory has historically emphasised upon the structural shift from agriculture to industrial sector, in order to explain growth. However, the recent times questions this notion because of the importance amassed by services sector in the most advanced economies of today. This idea raises concerns for developing economies like India, as to what appropriate strategy for development may be adopted to map themselves across other economies of the world.

When included in the trade theory, such notion describes the growth phase of the 'product cycle' that involves specialisation of the production process for large scale production, typically reducing the unit costs drastically, in order to set in a 'virtuous cycle' (through further reduction in price, increased demand, increased output and even further reduction in price) (Vernon, 1966). International trade, especially important for developing economies with limited resources and dependence upon foreign technology, is considered as a very crucial source of transmission, adoption and generation of technology (Coe and Helpman, 1995; Barro, 1997; Frankel and Romer, 1999).

Schumpeter (1943) developed upon the technology and innovation stimulus for growth and development of an economy. He was essentially one of the first economists to recognise the importance of innovation in providing cost and quality advantages. This is also indicative of the importance of economies of scale (measurable through size of the firm) in terms of technological efforts undertaken by a firm (Narayanan, 1998). Such economies of scale also enable greater manoeuvrability in the use of technology for the firms, thereby enabling them to gain comparative advantages.

Traditional neo- classical theory of economic growth mainly emphasised on a production function that contains labour and capital as inputs, taking technological change to be exogenous (hence, called the exogenous theory of growth), and prevailed in the 1950s and 60s. This school predicted the property of convergence that said that countries that have lower real per capita income, will in time have higher growth rates, as assumption of diminishing returns to capital was applicable to the production function.

Neo- classical approach saw technology as a short run cost to be figured in the production function for optimum firm size (Layard and Walters, 1978), as an ingredient for determining the optimum growth path of manufacturing firms (Morris, 1964) and as a significant variable for determination of the dynamic equilibrium of production for a firm which is also influenced by its surrounding 'environment' (Solow, 1971). Thus, the main thrust for economic growth had to arrive from outside, mainly from progress in technology (Solow, 1997). But this model also suffers from limitations because it emphasises the flexible functioning of market. Such an assumption theoretically permits use of the then prevailing best practice technology, and ignores the slow nature of skill acquisition and development of a technology regime (Basant, 1997).

In the 1980s, development within theorisation of economic growth led to the emergence of New Growth Theory with Romer and Lucas being the most crucial proponents. Technological progress and increasing returns to scale were included in the growth model with the advent of theory of endogenous economic growth (Narayanan, 2004; Mazumdar, 2005). This was possible through sustained increase in investment in capital- both physical and human. Lucas (1990) suggested that disparity in productivity of different nations were so because of the diversity in their skill levels and their technological capability. This theory gives importance to technological innovations as a factor in the growth of an economy (Grossman and Helpman, 1991) which leads to indirect effects of such technological change (also known as technology 'spillovers') that further lead to higher growth rates for the economy (Aghion and Howitt, 1998).

The strategic management research also establishes that technology is an important determinant of competitiveness of industries (Prahalad and Hamel, 1997).

In the context of 'technology gap'[1], presence of foreign owned firms and disembodied technology import reduces the gap over time and the reduction is observed to be more for firms that invested in learning or R&D (Kathuria, 2000). Stiglitz et al (2013) also holds this view, particularly for poor countries that resort to imitation and import of technology from abroad, rather than opting for R& D and innovation.

Kenneth Arrow (1962) defined acquisition of knowledge as a form of learning which has the same connotation as that of technical progress made by a business entity. This paper brought to life the now common phrase of "learning by doing" that implies that learning is a culmination of experiences which are gained in the process of solving problems or finding new solutions thereby resulting in greater efficiency in operations. He mainly proposed this idea in the context of skills acquired by labour. However, this simple idea can be applied to any production unit as well as any macro- economic model as well. This can also be assumed to be another form of embodied technical progress that imparts efficiency to the overall level of investment and hence, economic growth.

Technological progress is a valuable concern for policymakers when both policy making and technology transfer are functions that translate knowledge into power (Bar- Zakay, 1971) especially in case of developing economies which are short of funds and hence have to be more vigilant about the available resources at their disposal. Archibugi and Michie (1995) makes a case for 'techno-globalism,'[2] a term used to describe the phenomenon of 'globalisation' experienced by invention and innovation, stating that over the 1980s, industrial R&D had increased in importance compared to other R&D for all OECD countries. Firms have indeed explored opportunities to develop 'global research strategies' and 'networks' in order to partake their own innovation programmes (Casson, 1991) emphasising that a firm's internal learning as well as accumulation of skills has a crucial role to play in its overall efficiency (Iyer, 2009).

'Technology regime' of an industry, defined as a combination of different factors that capture the industrial as well as the policy environment and knowledge, affects the technology strategy adopted by a particular firm (Basant, 1997). Such technological strategies lead to technological

[1] Defined as the gap between the productivity of the most efficient firm in the industry and any other firm in the same industry. It is also hypothesised in the same paper, that there is a positive relation between the width of the gap and the productivity growth of the firm. The paper, however, dealt with the phenomenon of spill overs from multi-national corporations to the local Indian manufacturing firms.

[2] Increasingly international generation, transmission and diffusion of technologies.

capabilities that in turn determine competitiveness at both national and firm levels in developing economies (Siddharthan and Rajan, 2002). The increasing technological gap between the first and the third world economies has been acknowledged as one of the crucial causes of the widening disparity between the two sets, since a large percentage of world's R&D expenditure is bagged by the advanced countries (Chaudhuri and Moulik, 1986). However, all isn't lost since developing world has had the advantage of importing technologies directly from the developed part of the world.

The primary channels for international technology transfer, discussed in the literature are, direct foreign investment, international strategic alliances, licensing, and 'embodied' transfers through the import of technology- intensive goods (Mowery and Oxley, 1995). Embodied technology includes the transfer of knowledge incorporated in the designs of machinery inputs or in the skills of workers. Disembodied technology on the other hand, is transferred through contracts, product designs, patents, copyrights etc. Such kind of accumulation of capital is facilitated through different means of technology transfer, one of them being the direct foreign investment.

Total Factor Productivity (TFP) has been identified as an explanatory variable of growth of different countries (Howitt, 2000). TFP can be understood through two different methods: non-parametric and parametric. Through the former method, Solow residual of the residual of a production function which is given, is calculated when all factors of production are taken together. The parametric TFP is however calculated as the residual in the estimation of the underlying production function.

FDI, represents not simply a pure transfer of capital, as was highlighted in neoclassical models, but it also facilitates the transfer of a 'package' in which capital, management and new technology are combined (Findlay, 1978). FDI is sought because it augments resources that can be invested in order to improve technological standards, efficiency and competition within the industry. Presence of FDI in an industry improves the average productivity and even the skill levels due to the ownership and internationalisation benefits associated with the MNCs (Caves, 1974; Dunning, 1973). Eclectic theory of ownership- location- internalisation (OLI) framework by Dunning (1993) also establishes the importance of technology and includes it under the ownership advantages of the firm over that of the rivals. However, the actual extent of rate of technical diffusion of technology depends upon the prevailing levels of technology and learning capabilities of the firms (Aitken and Harrison, 1999).

Capital flows through FDI also have the potential to stimulate innovation that can further help in transfer of technology within the host country (Grossman and Helpman, 1991). Both theoretical as well as empirical literature have supported the argument that trade openness allows better technology to come in the host country through imports that in turn lead to better productivity as well as increase in efficiency of process of production (Barro and Sala-i-Martin, 1995).

Levine and Renelt (1992) on the other hand, also proposed a different position where openness of trade can also lead to increased foreign investment that may in turn discourage domestic investment. The final outcome on productivity of the firm thus depends upon these opposing forces.

There are numerous theories and studies on trade and growth of MNEs however, there has been a slight dearth of such literature from the perspective of developing countries that is usually dominated by export competitiveness and FDI inflows with a focus on importance of technology as a factor that determines the direction of trade (Bhat and Narayanan, 2011; Iyer, 2009). Technological spillovers are observed from the perspective of production externalities within as well as across industries (Kathuria, 1998). According to Lall (1981), great deal of technological progress in an economy takes place in the form of minor innovation that occurs as such countries import and assimilate newer technologies. Such countries then go on to specialise in technologies that are best suited to their respective capabilities as per their own comparative advantages.

Exports also lead to competition and thus encourage investment in better and more productive organisations and technologies (Mitra et al, 2014). Exporting firms are found to be better equipped, productive, larger sized, intensive in skill and capital and more wage paying (Bernard and Jensen, 1995, 1999). Balassa (1988) also established that exports help in improving productivity of firms thereby leading to improved economic growth. This also indicates that competition in the global economy makes the host capable of investing in more productive technological regime (Rodrik, 1988; Krugman, 1994). This has also led to a "learning by exporting" argument that says that meritorious learning effects are produced when domestic firms are exposed to advanced technology in the foreign markets (Bernard and Jensen, 1999).

Structural variables such as size and age of the firm are also important sources of economies (cheaper raw materials, specialisation of machinery as well as that of managerial capacity, superiority in marketing of finished products, capability to spend higher amounts of resources on research and innovation, efficient transportation services) and diseconomies of scale (resulting from inefficiently large management). Size of the firm is also an indication of its market power (Nagrajan and Barthwal, 1990). Alternatively, size of the firm can also be measured by either total assets or the total sales revenue. Larger firms are also believed to be more productive and efficient as compared to small firms as they are able to avail all technical advantages available to the smaller firms as well, in addition to the ones conducive to their own size (Mehta, 1955).

1.3.2 Empirical Evidence

After having looked at the theoretical background of the subject, this study now turns to the empirical side of the literature, to look at the experiences of different nations (India included) in terms of their trajectories of industrialisation and the effects of adoption or creation of technology. This part will also help in looking at the successes and failures of different economies in terms of the various means of adoption of technology and its diffusion into the domestic economy. This section is further divided into two main sub- parts: International context and the Indian context.

1.3.2.a International Context

Many studies go on to find the impact and experience of technology transfer in different economies, most of which, analyse the linkages between firms' productivity and technology spill overs in the context of developed economies.

Experience of many economies hold testimony to the necessary development of manufacturing sector to facilitate forward movement in overall economic development. Japanese manufacturing sector growth in the 1970s and 80s was replicated by South Korea and China later on in the 1980s and 90s respectively, based on incentive to R&D, particularly in manufacturing as one of the main factors of such growth (Bhat, 2014).

It is known that technology can be exploited in foreign markets in both embodied and disembodied forms (Archibugi and Michie, 1995). The same study also establishes a complimentary relationship between technical partnership in the form of joint ventures, a form of technology transfer, and financing of in- house R&D.

Griliches (1979) establishes that R&D activities are a main source of productivity growth of a firm. This expenditure is regarded as the expenditure on creation of the firm's own technology base as compared to the use of any 'imitated technology' (Griliches, 1979). Such conclusion of drawing up to spillover effects from R&D expenditures on firms' income gains has also been explained by Grossman and Helpman (1990) and Romer (1986). On investigation of the role of R&D in transfer of technology in case of manufacturing performance, most studies found a positive relationship between R& D and TFP growth (Griliches and Mairesse, 1990; Wang and

Tsai, 2003). The impact is however, found to be small in case of many developed economies (O'Mahony and Vecchi, 2009).

Quite intensive use of inputs, improved organisational and technological progress led to increase in total factor productivity to output growth in manufacturing sector of Finland by 38% in the period 1973-1990 as compared to the period 1960-1973 (Okko and Gunasekaran, 1996).

Extending the theory of embodiment hypothesis to also include the impact of disembodied technology as source of economic growth, Hulten (1992) says that such investments when result in improvement of quality of product goods, show a great contribution to productivity growth, based on the analysis done for US manufacturing industries from 1949-1983.

Cross- country analysis by the UNCTAD (1999) established a positive relationship between FDI and manufactured exports. Such a relation was found to be stronger in case of developing economies and in low and high- tech industries. Sjoholm (1999) and Greenaway et al (2004) are also of the opinion that increased competition resulting from foreign firms is the most important channel for spillovers from exports thereby also making a case for efficient use of technology in order to compete with the rival firms.

Knowledge spillovers from the presence of foreign firms has largely been inconclusive in the existing literature (Kathuria, 1998). Positive spillover effects have been established in case of Australia by Caves (1974), in Canada by Globerman (1979), in Mexico by Blomstrom and Persson (1983) and on different OECD countries by Nadiri (1991). On the opposite side, are results shown in case of European countries by Cantwell (1989), Morocco by Haddad and Harrison (1993), Venezuela by Aitken and Harrison (1999) and on Uruguay by Kokko et al (1996).

Imports of capital and intermediate goods have been considered as great stimulants of productivity through enhancement of technology from first world countries (Goldberg et al, 2010).

Importance of exports and their contribution to the productivity and efficiency of firms has been widely established through different research studies. Such results were empirically found by Kraay (1999) in case of China; by Baldwin and Gu (2003) for Canada; by Blalock and Gertler (2004) in case of Indonesia and by Fernandes and Isgut (2005) for Colombia. However, inconclusive results were also produced in search for such relationship between exports and productivity growth (Bernard and Jensen, 2004; Wagner, 2007). On the other hand, opposite relation was also detected by Greenaway et al (2004 (a)) and Damijan and Kostevc (2006) for Swedish and Slovenian manufacturing sectors respectively.

We now look at the empirical studies that are specific to the Indian industrial sector in the research literature on technology transfer.

1.3.2.b Indian Case

The period from 1950-51 to 1980-81 saw economic growth average close to 3.5% per year, with per capita GDP averaging to a meagre 1.5% a year (Acharya, 2002; Bhat, 2014). Indian industrial structure inherited the colonial legacy that did not see much changes till even the second Five Year Plan (Bhat, 2013). However, a break from such record low growth was observed in the 1980s, based on a clear acceleration of growth across all sectors, owing to an array of long overdue economic reforms that encompassed external sector liberalisation, industrial deregulation, and taxation reforms and with slight commercialisation of the public sector (Acharya, 2002; Ahluwalia, 1991; Nagaraj, 1990). Further reforms were introduced in the form of the New Economic Policy of 1991 that brought in a variety of reforms, targeting different sectors and areas that inarguably needed a makeover. Technological paradigm shift was tried in India, as in many developing economies, through enhanced foreign equity participation (intra-firm transfer), in- house R&D efforts, technology imports through licensing (disembodied technology imports) and import of capital goods (embodied technology). The 1991 reforms were specifically targeted for the Indian manufacturing sector as it offers better prospects for accumulation of capital, technical improvement and job creation (Kathuria et al, 2010; Sen, 2009). The economy saw quick growth recovery in the nineties as well as the early 2000s (6.1% by Acharya, 2002; Chaudhury, 2002). Surge in export growth, investment boom, confidence in governmental policy signals, improvement in terms of trade for agriculture, expansion of capital inflows and freer access to foreign technology were some of the gains from the economic reforms of 1991 (Acharya, 2002; Bhat, 2014; Bhat, 2013).

However, these benefits petered out after the gains of early nineties due to ‘unfinished’ reforms and innate bottlenecks in key sectors such as infrastructure, financial sector and industrial policy and it was this stagnation that has continued to affect Indian economy till today (Bhat, 2013; Goldar and Kumari, 2003). Since the focus of this study is to look at the impact of technology transfer process on the overall productivity of the Indian industrial sector, this literature review compiles the empirical findings of studies done with focus on the Indian scenario.

Economic reforms forced domestic firms to review and analyse their technology strategies (Basant, 1997; Chaudhuri and Moulik, 1986). In a study that relates technological regime with policy regime for India for the period 1980-81 to 1995-96 for automobile industry, foreign

equity participation turned positive vis-à-vis growth of the firms, in the period after liberalisation compared to being negative in the period before liberalisation (Narayanan, 2004).
A panel data analysis of Indian manufacturing firms from 1974- 75 to 1981-82 by Basant and Fikkert (1996) looks at the productivity growth in this period (prior to liberalisation policies) and finds evidence of international as well as domestic R&D spillovers. Mitra et al (2014) also found out that a firm's productivity and efficiency (in terms of trade openness) are significantly affected by infrastructure endowment, technology transfer and R&D in a liberalised Indian manufacturing sector for the period 1994- 2008.
Measure of total factor productivity (TFP) as an indicator of the growth of the firms and their progress is appropriate in case of gauging the overall efficiency of the firm, rather than trying to look at the contribution of a particular input to the production process. Also, contribution of TFP to output growth of the firm is one indicator for the contribution of innovative and technology related activities to economics growth (Mowery and Oxley, 1995). Banga (2004) estimated TFP growth using the 'time- variant firm specific' technical efficiency approach (parametric approach) wherein a Cobb- Douglas representation of technology is used where the Hicks- neutral productivity factor, Ae^h, is allowed to vary across firms and over time. 'h' here is a function of unobservable differences across firms, productivity and policy changes common to all industries and a random variable that takes into account the random shocks (Cornwell et al, 1990). Kumar and Paul (2019) modified the traditional total factor productivity estimates after incorporating imperfections in product and labour market in the post 2008 period for the Indian organised manufacturing sector.
It is also suggested that economic growth is better indicated by change in total factor productivity rather than the erstwhile popular indicator of change in the level of capital stock (Easterly, 2001).
Process of technology transfer was looked into Indian manufacturing tractor industry, where Chaudhuri and Moulik (1986) divided the entire process into sub- processes of adaptation, utilisation and development. They focused upon the change in stances of the firm in adapting to and adoption of foreign technology in a highly regulated policy environment that had prevailed during the 1970s.
Basant (1997) employs a multinomial logit model to find the determinants of choices for technology transfer made by Indian firms in non- electrical machinery and chemicals industries, while making use of the following variables: firms' size, foreign equity, capital and material imports and foreign or domestic technology spillovers. Evidence suggested that

chemicals industry was less reliant on foreign technology purchase as compared to the industrial machinery manufacturing firms.

Plethora of studies have been carried in order to look at the trends in productivity levels that have even compared the levels of pre and post reforms productivity. Those citing a fall in productivity in the post reform period might have been a consequence of technology obsolescence and slow adoption of available new technology owing to a J- curve trend (Virmani and Hashim, 2011; Ghosh, 2010; Das et al, 2017).

Kathuria (1998) made use of stochastic production frontier and panel data to find out that foreign firms' presence leads to higher productivity levels of domestic firms. The study however failed to show a significant relationship between productivity growth and disembodied technology import in case of Indian manufacturing sector for the period, 1975-76 to 1988-89.

Narayanan (1998) in his analysis of Indian automobile industry for the period 1981- 1990 (period before the 1991 reforms but after the 1980s measures of a break from the erstwhile licensing- quota- raj system) concluded that the success of a firm's productivity is evident from complementing the efforts to import technology with development of in-house R&D generation.

R& D has generally and historically been negligible in case of Indian economy, despite its reiterated importance across literature. Because of such small proportion of R&D expenditures, many studies have failed to find a significant relationship between R& D and TFP growth (Basant and Fikkert, 1996; Raut, 1995; Sharma, 2012).

It is also hypothesised that larger size of firms favours growth because they are able to undertake investments for further production (Baumol, 1959 and Basant, 1997; Lall, 1981), also giving them advantages vis-à-vis different brand loyalties and price setting power (Krugman, 1979) and capability to absorb any fixed costs of entry into a market and exploitation of economies of scale therein (Ruane and Sutherland, 2004). Though Banga (2004) found the impact of firm size on its technical efficiency to be ambiguous in nature.

Age of the firm signifies its accumulated knowledge and skill in production (Joseph and Reddy, 2009) making firms with longer age of operation to have gained and accumulated higher amount of skills and reputation (Kumar, 2007). However, Narayanan (1998) found out that newer firms were far successful at accomplishing paradigm shifts in technological regime in case of Indian automobile industry in the 1980s. This may be so mainly because of the intra-firm technology transfer between the foreign and domestic firms in a liberalised economy.

According to Acharya (2002), sustained growth of exports typically empowers positive growth of the economy through enhanced demand, productivity and technology levels. This in turn also affects and improves FDI inflows. Lall (1981) also argued that India has been a leading exporter of industrial technology among the developing economies and this has largely been a result of the efforts of the Indian government to foster learning in technology especially in the capital goods sector. Trade policies of the 1990s and 2000s have changed the composition of Indian exports in a manner that has led to growth in industrial exports (Hasan et al, 2006). However, evidence was also found that suggested negative relation between export productivity and trade openness in case of India (Das, 2003; Subrahmanian et al, 1996), while Sharma and Mishra (2011) failed to find any significant relation between exports and TFP.

Competitive imports also help spur domestic productivity in an economy. Similar results were put forward by Iyer (2009) who had analysed the backward and forward linkages caused by foreign firms in order for spillovers to occur, causing productivity improvements in the Indian manufacturing industry. Chawla (2007) also holds testimony to the success of manufacturing sector through foreign technology transfer via imports of foreign investment and inputs. Narayanan (1998) also credits imported technology in the 1980s that led to easy entry of new firms and diversification as well as introduction of new products in the Indian automobile industry where technological upgradation happened through liaisons with foreign firms that entered after de-regulation of the market.

Foreign equity participation is also considered to be a mode of intra-firm technology transfer and know-how (Bhat and Narayanan, 2011; Narayanan, 1998).

Deolalikar and Evenson (1989) also found out that structure of the industry, firm size and the status of its ownership has a strong influence on the decision of Indian firms to invest in their own R&D and purchase of technology through licensing agreements. And this decision is affected by the foreign technology that positively affects both manners of technology adoption. Banga (2004) also analysed the impact of Japanese and US FDI on productivity growth of firms in electrical and chemical industries in the post- reforms period and established that firms witnessed efficiency growth as well as technological progress in the period 1993-94 to 1999-2000.

Goldar et al (2003) and Siddharthan and Lal (2003) also found significant spillover effects from foreign firms on the efficiency and labour productivity of Indian firms, respectively.

Improvement and further research over the earlier theories of economic development also led to the conclusion that capital is not very productive by itself, but is central to the learning processes and productive structures associated with different methods of production and division of labour (Prendergast, 2010). Capital intensity was found to be positively related with productivity growth of a firm over time (Banga, 2004; Basant, 1997) and on the quality of products and export capabilities (Sjoholm, 1999). This may also induce adaptive R&D especially under a policy regime that motivates 'import substitution' and 'indigenisation' (Basant, 1997).

Meanwhile capital intensity has gone up in the Indian manufacturing sector in the decade since the reforms, which may indicate an upgradation in technology that might also mean substitution of capital for labour (Chaudhury, 2002). On the other hand, Francis (2016) blames the inadequacy of government policies, despite the liberal FDI regime in the period after liberalisation, in case of Indian electronic industry, where no policy measures could ensure positive spillover effects between foreign- invested firms and domestic supplier base.

Import of capital goods and raw materials brings with them latest technology embodied within such imports (Joseph and Reddy, 2009). Though Pradhan (2004) found that foreign technology imports did not have a significant impact on Indian manufacturing industries.

Persistence of low technology intensive exports and slow shift from low to medium- low technology intensive exports are also however observed for the Indian manufacturing sector for period 1990-2011 (Preeti et al, 2015).

Export growth has been found to be meagre since the mid- 1990s to the early 2000s, that shows greater reliance on import of basic and capital goods (Chaudhury, 2002). This is not a great condition to be in and might spell disaster unless complemented with sufficient investments in R&D at home. An analysis related to increased capital flows, which was an intended outcome of the 1991 reforms, showed that capital inflows had however not resulted into either industrial production or growth of the economy, owing to the inadequacy of the reforms to properly channelize such inflows to impact export growth or productivity of the Indian economy in a significant manner in the post reform period (Mazumdar, 2005). This was in stark contrast to the experience of different East Asian economies that saw high economic growth in wake of improved capital inflows through liberalisation.

Even the decision of a firm to choose outward FDI, is positively influenced by technology sourcing, particularly by, in- house R&D (Bhat and Narayanan, 2011). This has come to be regarded as a strategic variable in influencing development of an economy since FDI provides developing economies with technologies and managerial skills required for them to achieve rapid growth (Javed and Javed, 2018).

There has been an increasing trend of widening of emerging sources of technology transfer other than the US and UK, that were later on joined by Japan and Germany, which in turn faced competition from countries like Taiwan, South Korea, Israel, Hong Kong, South Africa, Mexico, Brazil, Mainland China, Singapore and many more (Kumar, 1997). The imported technologies were successfully adapted through local R&D programmes and then transformed into export comparative advantages (Chaudhuri and Moulik, 1986; Lall, 1981).

This trend is accompanied by rising expenditures on R&D of these countries in the decades after 1970s which is suggestive of the hypothesis of a complementary relationship between R&D and technology transfer. There is also an observation that R&D activity associated with the developing economies has been more of an adaptive kind, as compared to the more creative and innovative type of the industrialised economies (Kumar, 1996; Siddhartan and Rajan, 2002).

It is also observed that developing countries frequently need to complement imports of technology with subsequent in- house R&D development (Kumar and Siddharthan, 1994). Firms do not just pursue new process and product innovation directly, but also make efforts in direction of developing their own capabilities to bring in incremental progress in the overall production system (Cohen and Levinthal, 1989).

The relationship between in- house R&D and technology transfer in case of the developed economies (USA, Western Europe, Japan), has largely been complementary in nature, while elsewhere, it is found to be mostly that of substitutes (Mowery and Oxley, 1995; Archibugi and Michie, 1995). The reliance on either mode of technology acquisition, however, varies from economy to economy. While Deolalikar and Evenson (1989) found a positive relation (complementary relationship) between purchased technology and inventive activity in Indian manufacturing for the period 1960-70, Basant and Fikkert (1996) established R&D expenditure and technology purchase expenditures as substitutes. The results were found to be ambiguous- neither perfect substitutes nor perfect complements in Basant (1997).

The research literature also highlights few suggestions to corroborate the intended benefits of the 1991 reforms. As per Bhat (2014), inadequate efforts in developing indigenous technology or acquisition of it has maintained a stable material resources intensity in years after the reforms. Thus, a technology development and fund for the same, focus on skill development, and incentivisation to adopt knowledge and innovate are suggestive for better industrial growth. There is also a need to integrate development of both industrial and services sector because of their interdependence. Efforts may be made to remove the 'dependency syndrome' vis-à-vis foreign collaborators, by arranging for technical consultancy services (Chaudhuri and Moulik, 1986).

Even though the reforms focussed on a more liberalised economy, many challenges continue to plague the Indian industry till date. The characteristic problem of "missing middle"[3], low productivity and deficiency in technology, drawbacks at the front of 'doing business' due to a list of labour laws, and the overall inadequate contribution of manufacturing in employment generation as well as national income are few problems that are yet to be resolved (Mohanty, 2014). Upgradation of technologies that are already available and creation of newer techniques can be a fruitful step in that direction. Integrated industrial clusters have helped in cases of East Asian economies including China, Japan and South Korea where differently endowed firms collaborated resources and technologies. Investment in infrastructure suitable for facilitation of such linkages and agglomerations were also promoted by their respective governments. A similar approach may be considered by the Indian economy.

1.4 Rationale and Scope of Study

The above literature review highlights the length and breadth of the work that has been done on the subject, and also the centrality of the argument that industrial sector continues to be of huge importance for any economy irrespective of its phase in its development trajectory.

Most of the empirical literature focuses on the MNCs' contribution and its spill over effects and diffusion of technology and its impact on the growth of the sector in general. This ignores the innate characteristics of the local industries that might enable them to gain comparative advantage through some technology paradigm change.

There is also a lack of work that approaches the question of industrial policy for the entire manufacturing sector. Most of the papers, were very specific and thus, restrictive in nature because they picked up a few industries and looked at the impact of process of technology transfer on the growth of the firm.

Very few research has been devoted to the period after liberalisation, that looks at the question of technology transfer in a policy-oriented manner and thereby differentiates between the strategy of firms that pursued technology transfer, and those, that did not do so. It is also pertinent to look at the magnitude of the success achieved by such firms, and whether there are

[3] Indian manufacturing is characterised by a very large 'unorganised' sector (which employs between 5-9 employees; characterises small enterprises- majority of household units; and is generally less productive) and a very small 'organised' sector (that employs at least 500 employees; is capital or skilled- labour intensive hence exhibiting high productivity), thereby missing the intermediate sized enterprise sector. This phenomenon has been announced as a major cause for slow growth of Indian manufacturing sector and its productivity and employment generation ability (Mazumdar and Sarkar, 2009; Krueger, 2009).

firms that did not pursue such strategy, and have still been placed high up on the ladder of total factor productivity.

Within the literature on innovation and capital accumulation, most studies have focussed on the importance of FDI, while side-lining the other modes of technology transfer. Equally important are in- house R&D investment as well as other means of embodied and disembodied technology inputs for the productivity of the firms. The inquiry about which mode has led to better outcomes in terms of growth, also becomes centrally important and may be emphasised for improved policy initiatives.

There is thus, a need to look at the causes of stagnation of Indian industrial sector and the reasons for the delayed industrialisation in the last two decades, from the point of view of capital, as the 1991 reforms mostly banked upon the free movement of market and capital accumulation for the overall progress of the economy.

1.5 Research Objectives

In light of the above stated research gap obtained from the literature review done so far, this study is an attempt to look at the impact of technology transfer process on the Indian industrial sector. The study focusses on the period after liberalisation, 1991-2018, for the entire industrial sector as well as the 13 different industries that we have taken up in our study. The main objectives of the study are as follows:

1. To estimate and investigate the trends in Total Factor Productivity of firms in Indian industrial sector.
2. To investigate whether technology transfer has led to any change in the productivity of the firms or not. And to look at the probable factors that affect the total factor productivity of the firms.
3. To look at the nature of the relationship between in-house R& D (technology generation or creation) and technology transfer, for firms that undertook technology transfer: whether the relationship is complementary or that of substitution.

All the above research objectives were addressed with respect to the full sample as well as the 13 industries in our analysis for the entire period of our study, from 1991 to 2018.

1.5.1 Hypotheses

The analysis is based on the following hypotheses:

Hypothesis 1: Total Factor Productivity of firms has undergone changes in the 28- year period analysis of the study.

Hypothesis 2: Technology transfer has affected the overall productivity of the firms and has led to positive growth of the firms that actively pursued technology transfer process through various different channels.

Hypothesis 2: There is a complimentary relationship between in- house R& D and technology transfer process, for a firm to successfully grow.

1.6 Organisation of the Study

Chapter One: Introduction and Background of Study

Chapter Two: Data and Research Methodology

Chapter Three: Industrialisation and Liberalisation: Case of Indian Economy

Chapter Four: Estimation and Trends of Total Factor Productivity of Firms

Chapter Five: Total Factor Productivity and Technology Transfer: An Analysis

Chapter Six: R and D and Technology Transfer: Complement or Substitutes?

Chapter Seven: Conclusion and Policy Suggestions

References

Chapter 2 Database and Research Methodology

This chapter focuses upon the methodology used in the study. This study is a quantitative examination of the total factor productivity of Indian industrial firms based on secondary data collected from Prowess (CMIE) database. This chapter outlines the steps in the analysis and the quantitative techniques used in the study.

2.1 Data Sources

The two most widely used databases in industrial sector research in India are Annual Survey of Industries (ASI) and the Prowess database of Centre for Monitoring Indian Economy (CMIE). As pointed in the earlier chapter, this study focuses on impact of technology transfer process on the Indian industrial sector (firm level) during the period after liberalisation i.e., from 1991 to 2018. Since the study looks at both time and cross- section (firms) parameters, panel data analysis is employed (further described later in the Chapter in Section).

Between ASI and CMIE, the choice for data source was made in favour of CMIE because of various rationales such as:

i. The prime objective of the study is to look at the process of technology transfer, for which financial data of the firms is needed. Since ASI does not provide such data and CMIE is a good source for firms' financial data, Prowess was used.

ii. Another major reason for using Prowess is the availability of a proxy for 'Labour' (L) variable. In this study, 'Emoluments' have been used as a proxy for L since data for number of employees was very scarce. Such a methodology is also supported in literature. Alternatively, ASI could have been used to prepare the data on L, by using the data on Average Wage Rate for a particular industry [total emoluments paid by the firm divided by average wage rate for that industry would have given the total labour employed in the firm]. But such an exercise was avoided to keep the study simple. Also, mapping of the two databases was in itself very difficult to do, hence resorting to another database such as ASI was avoided in entirety.

iii. ASI does not provide the name of the company, while Prowess does. Even if we tried to map the two datasets- ASI's Company Code with Prowess' Company name, it would have been difficult and may have led to many missing values.

iv. Prowess data is available for the entire period after liberalisation, is regularly updated, and normalised for inter- temporal and inter- company comparisons, making it more user friendly with the ProwessIQ interface.

Thus, one single data source for firm level financial data- Prowess database was chosen to keep the study simple and with minimal differences in the methodology of variables used.

2.1.1 Prowess Database

The data source for the study samples is the Prowess Database. It is arranged and collated by the Centre for Monitoring Indian Economy (CMIE) that organises the financial performance of about 51,000 companies and is the "most comprehensive database available on Indian business entities". [4] The data so collated is based mostly on the Annual Financial Reports of the companies in the database, information from stock exchanges (in case of listed companies), the information available with the Ministry of Corporate Affairs, and that by firms filed on the stock exchanges with details of their securities' prices.

The database provides seamless data since 1989- 90, which is regularly updated as per the changes in the details of the companies. The database is thus a good source of information on companies that are still active and the data is available in a structured manner (presentation and arrangement of data in a conventional and useful format), arranged by CMIE itself. This structured format is of essentiality here, as this is the main basis of information availability for the firms and the related fields of such firms. The Prowess website also clarifies that the data is not only restricted to registered companies and covers other companies as well. The data is easily accessible through a software that can be installed on a laptop or a computer. The user interface of the software has rightly been called 'Interactive Querying' (hence the name, ProwessIQ) as it is curated in a manner that enables a user to easily build a query (with use of over 80 Query Triggers[5]) and download data in proper tabulated manner and store it in a manner as a researcher may need.

The Prowess data is regularly normalised for easy inter- temporal as well as inter- company comparisons. This feature of the database makes it even more user friendly and research friendly. Thus, the complete post- reforms period in India is covered in this database that is updated every day with regular updates from companies.

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[4] As per the Prowess CMIE website in November, 2020. https://prowessiq.cmie.com/

[5] Tabs or options that enable the user to cite the data that he/she wants. Such data has already been classified into different queries or questions that can be put forward using the Query Triggers.

The panel ID given to the firms in this database is the CMIE Company Code which is uniquely assigned to each company. Thus, this code is an important indicator of the companies' identity and is also useful in case the user wishes to map the data from Prowess onto the data from some other source or sources.

CMIE database broadly classifies companies into two groups on the basis of their ownership as being owned by the government or by a private entity. This classification is based on the ownership in terms of management control and share of equity in the company. Ownership by government can either belong to the Central or the State governments. On the other hand, ownership can be classified as private if it belongs to either of the four categories within the private sector- Indian (business entities owned by Indians), foreign (businesses owned by foreigners and foreign governments) or cooperatives and joint sector (includes business entities owned by government and private sector in cohesion).

Every company or business entity in Prowess is related with an industry. Prowess has developed a broad set of industry groups based on the classification of products and services of the companies. Very loosely, the division is between financial (mainly banks and NBFCs) and non-financial services (manufacturing, electricity, construction, mining etc) at the apex level of classification. These categories are further broken down into a total of 197 industry groups. All such classifications are based on the detailed division of products and services of the business entities in the database.

Every business entity in the database is mapped on to a code known as the National Industrial Classification 2008 (NIC) code which is a numeric code that classifies all economic activities in India and is maintained by the Central Statistical Organisation (CSO) of the Ministry of Statistics and Programme Implementation (MoSPI). This mapping is done in an indirect manner such that the NIC code is matched with the main activity of the company. So, initially the main activity of the firm is matched with the CMIE industry classification and then this CMIE classification is mapped to the NIC code. The sample in the study is based on the 2008 NIC code, which is the most recent classification available at the time of writing.

2.1.2 Other data sources

Prowess data base is the single data source for firm level data used in this study. All variables have been arranged and transformed in a manner suitable for answering our research questions. The study also makes use of data on Wholesale Price Index (WPI), published by the Ministry of Commerce and Industry, Government of India. WPI captures the price of goods traded between various companies. This index is built from the perspective of the producer and not the consumer and hence captures the price which is paid by wholesalers and manufactures. We have used WPI based on the new series with base year 2011-12. Few variables used in the study, such as Sales, Labour and Capital were deflated using the WPI for all commodities. Many studies in literature had also used CPI (Consumer Price Index) to approximate the value of labour employed by the firms. However, since the CPI values with respect to Industrial Workers (CPIIW) weren't available for the entire period of our analysis from 1991-2018, WPI was used to deflate the value of labour.

The study uses Sales of the firm as a proxy for the firm's output, and it is further used to estimate different production functions. These production functions are then used to later estimate the Total Factor Productivity of firms. This value of sales turnover of the firms was deflated by using WPI with base 2011-12.

In order to approximate the number of labour (L) employed by a firm, a proxy was used since Prowess database had a majority of missing values for variable on Number of Employees. It seemed pertinent and in consonance with the literature, that we approximate the value of labour by the compensation paid to the workers of the firms. This variable was also deflated using WPI as per the new series of 2011-12 base year.

For the variable of capital (K), the study approximated capital by 'real gross fixed assets' of the firms. This approximation is also in consonance with the research literature on Indian industrial firms. Gross Fixed Assets of the firm were deflated for suitable and meaningful estimation, by the all commodities WPI with base year 2011-12.

Other variables were constructed and transformed in a manner meaningful to the analysis. The description of the variables used in the study has been done in Chapter 4.

2.2 Methodology

The study is a quantitative analysis based on secondary data collated from Centre for Monitoring Indian Economy (CMIE) using ProwessIQ. This study focusses on the period after liberalisation i.e., from 1991- 2018 and the analysis is done for the entire organised industrial sector for the said period.

Since the study uses both time (1991- 2018) and cross- section (firm level) parameters in the analyses, panel data regression method is employed throughout the study to investigate the 3 research objectives as enlisted in Chapter 1.

The methodology followed in the study may thus be summarised in the following steps:

a. The first step (Chapter 4) involves calculation of Total Factor Productivity (TFP) of the firms. Most measures of productivity in economics research literature have been based upon the analysis of the remaining residual which is left after accounting for the growth in output as a result of the growth in respective inputs (labour and capital). Thus, residual growth of output or the total factor productivity may be the result of change in technology employed by a firm. Since this residual is immeasurable, the TFP growth cannot be computed using the growth in perceptible inputs such as labour and capital. Further, since 1991 reforms may have changed the levels of productivity of the firms even without changing their technology, it is important that such growth needs to be accounted in order to look at the effects within the liberalised economy (Kumar and Paul, 2019).

In this study, three different methods have been explored for the calculation of TFP wherein each method has its own merits and demerits, as highlighted in the Section 2.2.2 of this Chapter. The Ratio Method, Cobb Douglas Production Function Approach and Levinsohn and Petrin (LP) method are the three ways in which TFP was calculated for this study.

b. In the second step (Chapter 5), the analysis employs panel data regression method to investigate research objectives 2 and 3. For the second objective (to investigate if technology transfer has led to any change in the productivity of the Indian industrial sector), panel regression is done with total factor productivity (TFP) of the respective firms (as estimated in Step 1 above- Chapter 4) as the dependent variable, along with different explanatory variables related to technology regime of the firms such as- R and D expenditure, import of capital goods, raw materials, expenditure on royalties etc, and other firm specific variables such as firm size, age, foreign equity participation, export orientation etc. This objective is of importance as it will indicate about the various factors that affect the TFP of a firm and thus, has policy implications as to which factors may be paid more attention to, for a better and improved performance of the firms.
c. Next objective (Chapter 6) is to look at the nature of relationship between R&D expenditure and technology transfer process in a firm. This third objective will involve a panel regression (Heckman 2 step estimation process) with R&D expenditure of the firms as the dependent variable and rest of the technology and firm specific variables as the independent variables.

Following sections describe the tools and methodology used in the study, in detail.

2.2.1 Panel Data Regression Analysis

A dataset that follows a given sample of individuals over a long period of time, thereby providing multiple observations about each such individual in the sample for those many years is known as longitudinal or panel data (Hsiao, 1985). Thus, a panel data has two dimensions:

a time series dimension and a cross sectional dimension. One might expect that examination of a panel dataset might be more complicated. However, this is usually not the case. On the contrary, panel data estimations are far more beneficial and provide more information than that produced by pure time series or cross-sectional datasets individually.

This kind of data has many advantages from the point of view of research. Such dataset gives a large number of data points thereby increasing the degrees of freedom and reducing the collinearity among the independent variables. This in turn improves the efficiency of the estimates that are obtained in the process of regression operations using this dataset. This dataset has many advantages over conventional time series or cross-sectional data. Panel data allows a researcher to be able to answer many important research questions that cannot be addressed with cross sectional or time series data set.

Cross sectional dataset is unable to provide many micro dynamic as well as macro dynamic effects upon regression. On the other hand, a time series dataset also suffers from the inability to provide dynamic coefficients too. Panel data thus has the advantage of allowing us to utilise the inter-individual differences in the explanatory variables thereby reducing the problem of collinearity (Hsiao, 1985).

Use of panel data also enables a researcher to construct and test more and more complex behavioural models. This exercise cannot be performed with datasets that are primarily cross sectional or time series.

Panel data also allows us to control for missing or unobserved variables that might have some influence on the independent variables in the model. This is so because panel data utilises information on account of both intertemporal dynamics as well as the uniqueness of the individual entities that are being investigated.

As per Baltagi (1995), panel data is bound to have heterogeneity in the dataset since it relates several individuals across time. However, panel data estimation techniques acknowledge this heterogeneity by accounting for variables that are specific to individuals.

We have made use of panel data in our analysis because a cross sectional dataset would have been unable to estimate the total factor productivity of the individual firms in our analysis. This analysis will allow us to make dynamic predictions about the different samples and sub-samples used in our study.

Panel data estimation technique makes use of fixed effect and random effect estimates for better analysis of the dataset.

The fixed effects model has an underlying assumption that the individual specific variables are correlated with the explanatory variables and don't change or change at a constant rate with time. Thus, it is assumed that any change they cause to the individual in consideration is the same.

The random effects model on the other hand assumes that the individual specific variables are uncorrelated with the explanatory variables. The error term in the random effects model comprises of two components: the cross section or individual specific component and another, the combined time series and cross section error component (Gujarati, 2003).

The Hausman Specification Test is a tool that helps us make a choice between the fixed effects and random effects models. The underlying hypothesis of this test is that the fixed effect model is applicable (Johnston and DiNardo, 1997) while the alternative hypothesis implies that the random effect model is more appropriate. Thus, if the effects in the panel data estimation are uncorrelated with the explanatory variables, then the random effect estimators shall be consistent and efficient and may be used for interpreting results of the regression. It'll be the opposite case if the effects are correlated with the independent variables.

Further confirmation can be done by using the Breusch and Pagan Lagrangian Multiplier Test or LM Test. This test helps in choosing between the random effects model or the Ordinary Least Square (OLS) model. It is based on the underlying null hypothesis that OLS estimators are consistent (Johnston and DiNardo, 1997) while the alternative hypothesis suggests that random effects estimates are more suitable for usage of interpretation of results of the regression.

2.2.2 Productivity Estimation

Productivity is a crucial concept in the context of measuring the economic growth. It is essential that an economy be productive in order to raise and maintain a required level of standard of living for its population. However, despite the heavy importance of this concept, the definition as well as measurement techniques for productivity estimation are still vaguely defined. Experts in various fields have defined and curated the meaning and interpretations of this concept in their own perspectives suitable to their own needs (Sardana and Vrat, 1987). Thus, there has been a constant struggle between the many methods and estimation techniques available in the literature to ascertain the level of productivity.

The basic motivation for a firm to operate in market is to deliver valuable utility to the consumers and still be able to earn a profit. While operating at an efficient scale, the firm thus needs to efficiently use its available resources. This efficiency is hinted by the ability of the firm to utilise its available resources to produce better output. Such a ratio of the output produced by a firm with respect to its inputs is known as its Productivity. Higher productivity also causes an increase in profits by reducing the cost incurred in production (Goswami, 2006). Such a ratio can be analysed either at an aggregate level of the inputs or, this exercise can also be done for individual inputs. Such separate measurement of the respective input would give the productivity of the firm with respect to the optimum utilisation of the input in consideration. The measure of productivity calculated in this manner is known as Partial Factor Productivity. Similarly, the measure of productivity that looks at the efficiency of aggregate input is known as Total Factor Productivity (TFP). This is one approach towards measuring productivity of an organisation.

TFP not only helps out in analysing the productivity of inputs, like labour and capital, but it also indicates the productivity that is caused by the combination of such factors of production. The unexplained residual, other than the productivity caused by the growth of inputs is caused by TFP growth. As per Ahluwalia (1991), this admits the efficiency caused by any technical progress during production, and in addition, it also includes the effect of 'learning by doing' embedded in the labour and capital thus employed. TFP growth has special significance in case of developing economies due to the paucity of resources available to them that needs strategized usage in order for efficient production. In an analysis by Mitra (1999), it was concluded however that speedy productivity growth rarely coincides with industrialisation in case of developing economies, like India.

Largely defined as the rate of transformation of total inputs into total output, TFP was introduced as an important concept in the economics literature by Tinbergen (1942) and Stigler (1947). Solow later on extended the concept and made it a functional point of reference from the point of view of empirical research. His approach came to be known as the growth accounting approach. Following are the three methods that we have used in estimating TFP in our study. The selection of these methods was done on the basis of the limitations posed by the dataset in our hand. Many variables like prices of output, inputs, as well as the share of inputs in value added etc, that are required in many other methods could not be availed in the dataset that we have used in our study. Thus, we restricted to the following three methods of estimation of TFP in our study.

2.2.2.a Ratio Approach

Productivity measured in the form of a ratio of output to that of inputs is known as the Ratio Approach of measuring productivity (Goswami, 2006). Thus,

$$Total\ Factor\ Productivity = \frac{Total\ Output}{Total\ Inputs} \tag{2.1}$$

Above expression would measure productivity of the firm with respect to all the resources that have been employed in production. The term Total Input here may include the sum of Labour, Materials, Capital, Energy etc utilised in the production of total output. Such a ratio can also be altered by attaching weights to the inputs relative to their weight in the total output. These weights can be the returns or prices on the respective unit inputs. Thus, labour can be weighted using the wage rate, capital can be weighted at the return on one unit of capital input, and similar weights can be attached to other inputs as well.

In case one wants to look at the productivity of the firm with respect to a particular input, then such a measure is known as Partial Factor Productivity. The expressions,

$$Labour\ Productivity = \frac{Total\ Output}{Labour} \tag{2.2}$$

$$Capital\ Productivity = \frac{Total\ Output}{Capital} \tag{2.3}$$

thus, respectively signify the productivity of labour and capital input, employed in the production of total output of the firm. Partial productivity indices thus refer to the ratio of output to each category of inputs for which data is available.

In the empirical literature on productivity, the most common partial productivity indices are those of labour and capital. However, this measure takes into consideration only one measure of inputs while ignoring the rest of the inputs thereby overestimating the level of productivity thus calculated.

The concept of partial factor productivity provides a distorted view of efficiency and thus, the idea of total factor productivity gained more currency especially in case of production function where many inputs are used to produce many outputs. Thus, TFP is an overall indicator of how well an organisation makes use of all the available resources and inputs to produce the goods and services. In this manner, TFP can be said to be a sum of partial productivities that measures the efficiency with which all the inputs are utilised and combined to produce goods. the advantage of the ratio approach to measuring TFP is that it doesn't require an underlying assumption about the form of the production function of the entity for which TFP is to be calculated.

2.2.2.b Cobb Douglas Production Function Approach

The production function which has been employed most frequently in empirical work is the Cobb Douglas production function. The output (V) is expressed as a function of labour (L) and capital (K) in the following manner:

$$V = A\, K^{a}\, L^{b} \qquad (2.4)$$

where, A is said to be the efficiency parameter, and the coefficients a and b measure the output elasticities of capital and labour respectively. The sum of these two coefficients gives the information about the returns to scale of production[6]. If the sum of a and b is greater than 1, then there are increasing returns to scale, implying that increase in output is by a greater proportion than the increase in inputs. If their sum is equal to one, then constant returns to scale are said to prevail. Output of the firms increases in the same proportion as the inputs are increased. However, if the sum of a and b is said to be less than 1, then the production is occurring at decreasing returns to scale.

Marginal productivity of the various inputs in the analysis can be obtained by differentiating the Equation (1) with respect to the individual inputs.

We have transformed the model into logarithmic form so as to estimate the output elasticities of labour (b) and capital (a) and predict the efficiency parameter of the samples. Taking log of Equation (2.4) we get,

$$\log V = A + a \log K + b \log L \qquad (2.5)$$

This regression is then estimated to find out A, which is the efficiency parameter and gives the total factor productivity measure of the respective firms.

Solow's (1976) methodology also makes use of Cobb Douglas production function.

2.2.2.c Levinsohn and Petrin (LP) Method

Since the 1980s, many factory or plant level datasets started getting collected and arranged in a manner suitable for researcher. Around the same time, this data was increasingly made available to the researchers.

[6] Response of output to proportionate changes in inputs.

In the years prior to the evolution and availability of detailed datasets, Solow productivity residuals mainly dominated the estimation of TFP and related those measures to the change in aggregate demand or economic growth of an economy.

Petrin and Levinsohn (2012) attempted to extend the aggregate Solow residual (Solow, 1956; Hulten, 1978; Basu and Fernald, 2002) estimation to plant level data thereby developing the relationship between aggregate demand or value added and TFP. This method couples data on input expenditures with estimates of production function elasticicities (Petrin, 2018). This method estimates the total factor productivity of the firm by summing up the productivity changes arising from allocation of individual inputs as well as the TFP changes within the plant from such combination of different inputs. This in turn adds up to the final aggregate demand of the firm and thereby gives better approximations of the TFP of the firm.

The earlier methods mainly looked at the TFP residuals that did not fully add up to the change in aggregate final demand and thus led to very misleading inferences about the causes of economic growth in question.

The LP method mainly resolves the problem associated with the correlation between unobservable productivity shocks and the level of key inputs of the plant. Firms that are profit maximising, will try and respond to positive productivity shocks by increasing the level of output which would imply increase in the use of inputs (Petrin et al, 2004). Opposite will happen in case of negative productivity shocks. In order to account for the unobservable shocks, Olley and Pakes (1996) used investment as the proxy for these shocks in their estimations.

Levinsohn and Petrin (2003) on the other hand, introduced intermediate inputs as the required proxies to account for unobservable productivity shocks in the system. They argue that such proxy is more efficient as intermediates will meticulously adjust with the productivity shocks in a more seamless manner. The same paper also claims that there is evidence of 'lumpiness' in investment ie, there are substantial costs in adjustments with respect to investment and thus, investment is not an efficient proxy to account for response to productivity shocks. This simultaneity problem is suggested to be solved by introduction of intermediate inputs in the analysis. Another problem related to the investment proxy is the "zero investment" reporting that is done for this variable in most of the plant level datasets in many economies, especially that of the developing countries. This implies that the Olley and Pakes (1996) method is only suitable for firms that report non-zero investment. Number of such firms is going to be very less and the datasets thus will be highly truncated. This problem doesn't arise with use of intermediates inputs as the proxy in the LP model because almost all firms will report positive or non- zero intermediate inputs.

Another advantage of this method is that it is less costly to adjust to the unobservable productivity shocks as compared to the adjustments that will need to be brought in case of using investment proxy.

The model in this method is described as follows. The production function of the firm is featured as a function of primary inputs, intermediate goods and technical efficiency.

The production function is assumed to be Cobb Douglas such that

$$y_t = \beta_0 + \beta_l l_t + \beta_k k_t + \beta_m m_t + \omega_t + \eta_t \tag{2.6}$$

where, y_t is the log of output of the firm. We have taken sales turnover that have been deflated by Wholesale Price Index (WPI) as the proxy for output in our study.

l_t and m_t are freely variable inputs in the model with the former being referred to as log of labour and the latter signifies the log of intermediate input (raw materials in our study). k_t is the log of variable capital.

The error term in this model has two components: ω_t and η_t. The former component is the transmitted productivity component and it impacts the firm's decisions. It is unobservable component and exercises impact on the choices of inputs made by the firm. η_t is the uncorrelated error term with respect to the input choices in the model.

The variable m_t is assumed to depend on the variables k_t and ω_t.. This can be expressed as:

$$m_t = m_t(k_t, \omega_t) \tag{2.7}$$

It is further assumed that the demand function for intermediates as stated above, is monotonically increasing in ω_t. Such that the above demand function can be inverted as:

$$\omega_{t.} = \omega_{t.}(k_t, m_t) \tag{2.8}$$

This expression presents the unobservable productivity shock solely as a function of two observed variables in the model. It is also assumed that this unobservable productivity follows a first order Markov process[7] such that

[7] a random process in which the future is independent of the past, given the present value.

$$\omega_{t.} = E[\omega_{t.} | \omega_{t.-1}] + \varepsilon_t \quad (2.9)$$

where, ω_t is described as an innovation to the unobservable productivity shock and it is assumed to be uncorrelated with k_t but is free to be correlated with l_t.

LP method estimation can be done in two forms: when the output variable is in form of gross revenue or when it is in form of value added. Since we have used Sales turnover as the output in our study, we have used the gross revenue model of LP estimation.

The estimation process transforms the output in a manner such that it is expressed in terms of labour, capital and intermediate inputs only.

$$y_t = \beta_0 + \beta_l l_t + \beta_k k_t + \beta_m m_t + \omega_t + \eta_t \quad (2.6)$$

$$y_t = \beta_l l_t + \phi_t (k_t, m_t) + \eta_t \quad (2.10)$$

where,

$$\phi_t (k_t, m_t) = \beta_0 + \beta_k k_t + \beta_m m_t + \omega_{t.} (k_t, m_t) \quad (2.11)$$

In order to estimate y_t, first ϕ_t is estimated. This in turn is done after estimation of $\omega_{t.}$.

Wooldridge (2009) describes a generalised method of moments (GMM) framework to estimate the two-step nature of the LP estimation method. This framework is argued to have several advantages in terms of identification of variables, for example labour, in a manner that might itself be determined by the very nature of the production function and may itself be influenced by the unobserved productivity. Ackerberg et al (2006) proposed a hybrid model that makes use of both Olley and Pakes (1996) and LP methods and resolves this problem of identification of variables in the first stage of estimation of TFP using the LP method.

Petrin et al (2004) offered the command (levpet) that can be used for LP estimation of TFP in STATA software. Our analysis takes help of the same command for the specification of our model with sales of the firm as the output, labour and capital as the primary inputs and raw materials as the proxy for intermediate inputs in our study. This command was very helpful in predicting the TFP values of the LP method.

The measures of TFP obtained by using LP estimation technique were further used in our analysis to solve the second and third research objectives of our study as we ascertain that out of the three methods that we have used in estimation of TFP, the LP method is most suitable and provides appropriate estimations of the TFP for the firms in our sample.

2.2.3 Heckman 2 Step Procedure Estimation (Heckit Model)

In order to examine our third research objective, we make use of the Heckman specification tool (Heckman, 1976). As the name suggests, this estimation technique is done in two steps. This is a blessing of a statistical tool in quantitative research and helps in correcting the bias emerging from non-randomly selected data (for example, in our analysis we estimate the various samples- full sample and sample for different industries).

The first step of Heckit estimation in this study, is done by modelling the probability of deciding in favour of undertaking R and D investment by the firm as the dependent variable and regressing it over the various independent variables specific to the firm and its technology regime. This step is called the 'selection model' because it estimates the factors affecting the probability of making a decision in favour of the dependent variable and thereby selecting the firms of our interest.

The next step involves the 'outcome equation' because this step estimates the magnitude of the variable for which decision was made in the selection model in the first step. In our study, the 'outcome model' regresses the R and D intensity (ratio of expenditure on R and D to the total sales) of the firms which undertook the decision of spending on R and D in the first step. This model thus estimates the various factors that influence the intensity of research and development expenditure for the firms in the sample.

Chapter 3 Industrialisation and Liberalisation: Case of the Indian Economy

This chapter strives to contextualise the importance of industrialisation and its trajectory in the Indian economy. This chapter is also a historical account of the various policies and politico-economic scenario prevalent in India since its independence in 1947. We also attempt to make case for the scope of our study.

3.1 Industrialisation led Development

The optimal industrial structure of a country is shaped by its stage of development and innate characteristics, which further develop its comparative advantages across different industries (Lin, 2010).

For India, the process of industrialisation has undergone many changes, regularly shaped by the various industrial policies that were taken up since independence. The reform era has put forward an industrial sector that has been moulded by major policy changes.

De-licensing as well as withdrawal of restrictions on foreign investment (Aghion et al, 2008), reduction in tariff rates as well as quantitative restrictions on imports of intermediate and capital goods (Topalova and Khandelwal, 2011), introduction of fiscal incentives as well as financial benefits to encourage innovation and R&D (Sharma, 2012) were few steps that were taken in the direction of a liberalised economy in 1991.

Even though, technology transfer had always been a part of the industrial scheme of the economy, most significant has been the new economic reforms policy of 1991 that formally enlarged the expanse of this process, from arm's length purchase of technology through lump sum and royalty payments, to intra- firm technology transfer through foreign direct investment (FDI) and to technology transfer through imported capital goods. Structural changes have occurred in this sector in recent decades. However, these changes have not been fast enough to change the pace of development of the overall economy. Industrial sector drives exports and creates productive employment, business opportunities and further capabilities on which growth takes place. But this has not happened in an adequate manner in the Indian economy. Share of manufacturing towards GDP has been low, stagnating in the mid- teens for over a decade now (2010- 2018).

There are studies that show either no improvement or decline in total factor productivity growth of manufacturing sector in the decades following the reforms (Trivedi et al, 2000; Goldar and Kumari, 2003; Sharma and Sehgal, 2010).

R& D expenditure has been too low to spur growth within the sector, forcing the technology in the sector to remain at the basic or intermediate levels (Bhat, 2014). This adversely affects fresh investment and hence necessitates development of infrastructure and application of newer technology, fostering innovation in frontier technologies.

As the literature shows us, more and more firms have started focussing on in- house R&D investment for technology generation, rather than being dependent on foreign technology imports. Changes in the FDI policy of India (removing the ceiling on FDI in different sectors in order to ease the investment demand), especially in the last decade has been highlighting the immense importance laid on spurring the industrial sector growth of the economy.

Manufacturing sector has historically been recognised as the main catalyst of enhanced performance to catch up with the better performers across the global economy, through progress in technology, innovation, economies of scale in production and spill overs in knowledge (Murphy et al, 1989; Kaldor, 1966).

3.2 History of Industrialisation in India: Story Through Policy Making

Independence from colonial rule brought life to many dreams in the Indian subcontinent. These dreams as well the ideals undertaken to realise these dreams have undergone various transformations with the changing policy reforms to improve the Indian economy. India now seeks to join the $5 trillion club of national income.[8]

Abject poverty, illiteracy and sharp social differences in addition to severe deindustrialisation was writ all over the India that got independence in 1947. It was these concerns that cast doubts on India's endurance as one consolidated nation after it was reborn in 1947. Angus Maddison's popular work on economic history shows that India's share in world income was slashed from 22.6% in 1700 to about 3.8% by 1952 (Maddison, 2003).

As the first Prime Minister of the newly independent nation, Jawaharlal Nehru undertook an economic model wherein a dominant role was allocated to the State as the facilitator of finance as well as entrepreneurship for all economic activities in the country. Such a strategy was

[8] a policy strategy to make India a $5 trillion economy by 2024 was made by Prime Minister Narendra Modi during presentation of Budget 2019.

presented in the form of Industrial Policy Resolution of 1948 which adopted a mixed economy model for India.

The Bombay Plan which was proposed by eight big industrialists in the then economy aspired for a model that protected the indigenous industries that were still taking birth. This was stated to be done with a substantially powerful public sector, with occasional interventions by the State. But it was soon realised that state and public sector were going to be required for leading role in progress of the economy.

On November 26, 1947, the first Union Budget was presented under the leadership of R.K. Shanmukham Chetty and it made many interventions on behalf of the State in defence of fiscal federalism.

Subsequently, the Planning Commission was set up in 1950 to supervise the different economic activities such as planning, allocation of resources, their distribution as well as implementation and execution of all such plans in a strategic manner. The five-year plans were cited to be formulated on the lines of planning process being carried out in the USSR. Thus, planning in India was substantially centralised and was done on the ideals of economic and social welfare. India's first five-year plan sought to adhere to learnings of the Harrod- Domar Model to give a boost to Indian economy through higher savings and investments (Harrod, 1936; Domar, 1946). The plan was successful with achieving more economic growth than the targeted growth rate.

The second five- year plan was received with much doubt as well as uncertainty. With its slogan of promotion of heavy industrialisation through dependence on deficit financing, it was criticised mainly because such a policy would have been troublesome for a young economy like India, that needed time to prepare the ground for industrial development. Launched in 1956, the second five- year plan was based on the Mahalanobis model[9] that advocated adoption of a strategy of rapid industrialisation with prime focus on capital goods and heavy industries. The second five- year plan along with the Industrial Policy Resolution of 1956 laid down the ground for development of Indian public sector and invoked the infamous license raj. Industries were organised in three broad groups with basic and strategic industries essentially placed under the yoke of public sector. The second group comprised of industries that were largely to be owned by the state. The third set comprised of the consumer goods industry that was largely

[9] Named after its architect Prasanta Chandra Mahalanobis. He was the chief adviser to the Planning Commission from 1955 and founded the Indian Statistical Institute for economic research in India. He is regarded as the father of modern statistics in India.

left to the control of the private sector. This private sector however was controlled and directed as well as regulated by a strict system of licences.

The second five- year plan also led to the development and building of the 'temples' of modern India and Jawaharlal Nehru called them to be. These 'temples' of modern India were the multi-purpose hydel projects taken up in several parts of India. The developmental of dams led to expansion of power and steel industries in India. The Indian Institutes of Technology and the Atomic Energy Commission were the other 'temples' of modern India.

After Nehru's death in 1964, Lal Bahadur Shastri came to the helm of affairs and addressed the economic weaknesses of India that were exposed in the Indo-China war of 1965. He welcomed decentralisation and gave a larger role to the private enterprises and foreign investment. At the same time, he also attempted to slash the role of the Planning Commission. The threat of a massive famine in the 1960s gave lessons and appropriate focus was given to food security. It was then that primacy was given for an agricultural revolution in the form of Green Revolution of 1965 with employment of high yield varieties of seeds and agricultural implements. Taking cue from this, a White revolution was also brought about in the dairy sector with the cooperative movement led by Verghese Kurien.

With many economic as well as political upheaval and loss of two prime ministers in quick succession led to a hiatus in the planning process. India Gandhi came to the fore and devalued rupee that led to a general price rise. This jolted the strength of the Congress party for the first time in history of India. Gandhi, faced with this challenge, in order to garner better control, nationalised 14 banks in 1969. This was done on the argument that big businesses were hoarding credit flow that needed to be allocated to agriculture in time of crisis. This move had mixed effects on the economy. On the one hand, nationalisation of banks led to acceleration of credit available to agriculture and other priority sectors, financial savings also gained a fillip and more branches were opened in rural areas. But, such centralisation of economic power led to loss of competition and increase in inefficiencies in the system. These banks operated only to please the political bosses instead of taking care of the profitability of the financial sector of the economy. Such complacency in the banks, over so many decades, has resulted in huge dud loans[10] in the Indian public banking sector today.

In 1966, Indira Gandhi undertook the policy of devaluing Indian rupee by a sharp 57% in order to counter the balance of payments crisis that was left at the end of the second five - year plan. This meant that the economy had to run constant trade deficits because Indian economy wasn't

[10] Loans whose payments have been defaulted.

open for foreign investment and exports that could have served as an additional source of income for the economy. Contrary to the expectations, the devaluation of rupee resulted in inflation. The economic situation was further deteriorated by imposition of Emergency in India. Congress lost power and the Janata party government imposed the first demonetisation in India in 1977 by withdrawing the high denomination currency notes in a crackdown on illicit wealth. Strikes were legalised and trade unions were reinstated. Many foreign multinationals shut their operations in India because of the Foreign Exchange Regulation Act of 1973 that limited the equity owned in Indian enterprises by any foreign company to 40%.

Return of Indira Gandhi in 1980 was marked by economic reforms that pledged to boost economy's competitiveness by introduction of fiscal reforms, removal of price controls, reduction in import duties, revamp of the public sector enterprises and delicensing of the domestic industry. This was the beginning of the license quota raj in India.

After Indira Gandhi's assassination in 1984, her son Rajiv Gandhi ascended to the role of Prime Minister of the country. Being a young minister, he was driven to make India self-sufficient without its reliance on foreign aid and loans. Exemption limits for income tax were raised and the direct taxes to be paid by companies were lowered. He also brought the information technology and telecom revolutions in India. This period is marked by dominance of large business enterprises that were basically hereditary in nature.

Indian economy has generally been cited as an economy with high fiscal deficit (government spending being more than its income). Much of this expenditure is on defence, pensions, subsidies, cost of borrowings and social sector expenditure (which constitutes only a minute proportion). Most of the capital owned by government is locked up in its own companies and holdings, which suffer from huge inertia to make any sale. This continues to happen till date.

There were signs brewing up that pointed towards the 1991 economic crisis when Indian stock market plummeted. The country had pledged its reserves of gold to secure a loan from the International Monetary Fund (IMF) in order to sail through the balance of payments crisis. The Narasimha Rao led government took the charge and with advice from finance minister Manmohan Singh, a raft of economic reforms was launched that also aimed at dismantling of the license Raj.

3.3 Liberalisation of Indian Economy: A Breakthrough. Is it?

The economic growth miracle of India has been attracting attention from across different corners of the globe majorly because of its wide-ranging reforms that were introduced in early

1990s. This was also a period when most of the industrialising economies were opening themselves to the exposures of the global economy. However, not every economy had a favourable experience with their policy of liberalisation of economy.

As per UNCTAD report (2012), one aspect that imparts success to the Indian liberalisation experience is the manner in which the reforms were introduced in the economy. It wasn't a sudden policy action, rather, small carefully calibrated steps were undertaken in the process of opening of the economy, especially on the front of external liberalisation. This risk aversion has been mentioned as the tag of "reluctant globaliser" for India, in the same report. India still continues to maintain high tariff rates in case of many products and still has placed many restrictions on the investment that can be undertaken by a foreign business entity on Indian soil. For more than four decades of maintaining a strategy of self-reliance, Indian economy was forced to open up because of the timely balance of payment crisis in 1991. These wide-ranging reforms covered the macro-economic aspects in a holistic manner, ranging from trade and industrial policy framework with bent on employment-oriented industrialisation strategy to maintaining and resolving the exchange rate regime as well as the fiscal and current account imbalances of the Indian economy. Delicencing of the industrial sector that began in 1984-85, was majorly restricted to a few sectors. The 1991 policy expanded this coverage to other major industrial sectors of the economy.

The economic reforms policy was termed as the LPG policy that strove for – liberalisation, privatisation and globalisation of the Indian economy.

In 1999- 2000 Budget, the then finance minister Yashwant Sinha took upon the charge of disinvestment in public sector enterprises and downsizing the government. Rationalisation of interest rates was also done that gave a boost to the housing sector in the Indian economy. The new policy also tried to curb the trade deficit by inviting more foreign direct investment and improving exports (for which, rupee was devalued in order to expand trade). Thus, greater interaction with the global economy was encouraged with a swift shift to market friendly policies.

India also shifted to the regime of flexible exchange rate in 1993 with exchange rate being determined by the market forces. This altered the monetary policy regime also in the Indian economy. Capital markets became more liberalised to welcome foreign investors. Tariffs and quotas were reduced to encourage freer trade.

3.4 Industrial Sector as it Stands Today

The first decade of the 21st century, following the economic reforms, was marked by acquisitions of firms and business entities by flourishing Indian industrial sector. The waters of Indian economy were rocked by the Great Recession of 2008, but Indian economy was quick to jump back on its feet because of its very nature of gradual liberalisation and trade openness. Within eight months of the arrival of the new government in 2014, the Planning Commission was replaced by the NITI Aayog (National Institute for Transforming India). It was argued that Planning Commission had lost its significance as a guiding light for economic policy making. NITI Aayog now serves as the government's think tank and helps it in formulating medium- and long-term strategies, later breaking them into annual aspiration and targets with prior consultation with the Indian states.

The Insolvency and Bankruptcy Code, 2016 was formulated to take care of the sick companies in Indian economy. Errant promoters are now shown the door and defaulters of loan are kept in check as well as supervised by the principles laid under the IBC, 2016.

The Good and Services tax (GST) is another step in the direction of making Indian industry a more efficient sector. This is also in line with the aim of improving the 'ease of doing business'[11] and overall efficiency of the industrial sector.

Industrial sector is so crucial for an industrialising nation like India, that it is correctly called as the backbone of the economy. This sector provides considerable employment to people with varied skill sets. This is sector makes the economy more competitive in the global market. It is also essential to build adequate infrastructure for rapid industrialisation as well as urbanisation of the economy. This sector makes significant contribution to the national income, employment, investment, exports demand and research and development of the Indian economy. Despite the immense importance of this sector, Indian industry suffers from stagnant growth or low growth rate for past decade. It is grappling with the problem of competition from low priced consumption goods from many emerging economies and China; the credit availability in this sector is amiss because of the surmounting crisis in the public sector banks; devaluation of Chinese currency and many internal problems caused by the demonetisation as

[11] A phrase that gained currency by the Ease of Doing Business report, prepared by the World Bank that ranks economies in order of their performance on 10 different dimensions. It is published annually and guides the economies of the various aspects that need improvement in order to ensure greater efficiency in their growth performances.

well as GST introduction in the economy. It is now yet to be seen how India will face the challenge put forward by the Corona virus pandemic of 2020.

There might be different reasons for the stagnation of industrial sector. And it is the responsibility of researchers to keep looking through various means and methods and try and find out appropriate policy actions in order to secure higher growth levels for this sector. This is what we aim to do through our study. This study is restricted to the regime of technology transfer and capital of the industrial firms and how the productivity of the firms can be enhanced by emphasising on appropriate variables.

Chapter 4 Estimation and Trends of Total Factor Productivity (TFP)

This chapter outlines and discusses the results obtained in quest of the first research objective of this study. This chapter begins with description of the variables and their transformations that have been used in our analyses in later chapters of this study. We discuss the three methods of estimation of TFP, describe the inferences drawn from each of those methods and try and find out a pattern in the TFP of the complete sample as well as that of the 13 industries that we have undertaken in our analysis.

4.1 Variables and Description of Data

The data source for the financial information of the industrial sector (firm level) as used in this study and earlier described in the Chapter 2, is the Prowess database, compiled by the Centre for Monitoring Indian Economy (CMIE). The sample used for analysis comprises of 2,661 firms out of the total 22,000 firms that were downloaded from the prowess website. Data downloaded in monetary value terms is in Rs Million value.

Data was cleaned or sorted on the basis of the intuition that the analysis will comprise of firms that have been in existence prior to the 1991 reforms. This restriction was posed mainly on the account of the argument that the analysis would make sense if we look at the performance of those firms that have been in existence since before the reforms had come into existence. This would in turn meaningfully ascertain the trends as well as the factors responsible for the productivity of the firms for the entire period after the reforms had already been in place. Thus, after removing all the firms that were born after 1991, sample was further cleaned on the basis of data availability for the variables Sales, Labour and Capital. This was done because these three variables will act as the basic variables from which TFP will be calculated. All those firms that had large missing values for these variables were eliminated from the sample. Those with fewer missing values were retained in the sample, as that doesn't pose grave problem for the analysis since STATA ignores the missing values while operating on the data.

It is pertinent that we use the variables at constant prices and hence, all the variables that are to be used in the regression, need to be deflated with appropriate price indices. Since Sales, Expenditure of Raw Materials, Compensation to employees (proxy for Labour) and Gross Fixed Assets (proxy for Capital) have been used for the estimation of production function and thereafter, the total factor productivity of the firms, these variables have been deflated using the general or all commodities' Wholesale Price Index (WPI). WPI was obtained from EPWRF website that collates data on different variables of economic importance. This WPI was first concorded at the 2011-12 series (the latest available series) and thereafter it was used to deflate the variables stated above. Most of the literature talks about deflation of value added or output values of different industries, by their respective WPI available. This study however, uses the general WPI for all industries because of the difference in industrial classification in the two databases from which WPI and the variables have been collated. WPI is formulated by the Ministry of Commerce and Industry, Government of India.

On the other hand, the variables to be used in the analysis have been obtained from the CMIE database that is built and compiled from the Annual Reports, feeds from Stock Exchange, Financial Statements, and many different sources. Thus, it was difficult to categorise industries based on the criteria listed out by Ministry of Commerce and Industry and thereby use the respective industry's WPI to deflate the variables of that same industry in the data obtained from Prowess.

Few studies have also used Consumer Price Index to deflate the variable for Labour. This study abstained from doing that precisely because of two reasons. One, the data availability for CPI was scarce for period prior to 2006. And the second reason for not using CPI is because its inclusion would have led to differences in values of other variables that had been deflated at 2011-12 series whereas CPI was not available to fit the same series. Hence, all the variables listed above have been deflated by using the All Commodities WPI values that have been concorded at 2011-12 series (latest available at the time of writing).

This study includes the entire industrial sector (organised sector, since Prowess database contains firms in the organised sector). As per the database, the Manufacturing industry includes: Food and Agro based products; Textiles; Chemicals and Chemical products; Consumer Goods; Construction Materials; Metals and Metal products; Machinery; Transport equipment and Miscellaneous Manufacturing industries. In our study, we have analysed each of these industries as separate samples also. Mining, Electricity and Construction and Real estate industries have also been included in our analysis, but these are categorised outside the Manufacturing industry and these industries have also been analysed as separate samples while discussing results for different samples. Thus, in entirety this study is an analysis of a total of 14 samples.

Table 4.1: Variables used in the study and their description.

Sl. No.	Variable	Description
1	ageyr	age of the Firm (Year or the time variable minus the year of incorporation of the firm)
2	ln_sales	log of deflated value of sales of the firm. This variable gives the size of the firm
3	L	Deflated value of compensation to employees. Taken as the proxy for Labour (Rs Million)
4	K	Deflated value of Gross Fixed Assets. Proxy for capital employed by the firm (Rs Million)
5	rm1	Deflated value of expenditure on raw materials (Rs Million)
6	ln_rm1	log of deflated value of expenditure on raw materials of the firm
7	ln_L	log of deflated value of compensation given to employees of the firm
8	ln_K	log of deflated value of gross fixed assets of the firm
9	royalties_i	expenditure on royalties/ sales
10	rnd_i	expenditure on research and development/ sales
11	X_i	Exports of goods/ Total sales Here, exports of goods have been taken up without the inclusion of exports of services by the firms. Both exports and sales values are as given in Prowess.
12	m_raw_i	Import of Raw Materials/Sales Import of raw materials also includes the import of stores and spares and thus indicates the total import of raw materials.
13	m_k_i	Import of Capital Goods/Sales Both values have been taken as given in Prowess.
14	d_f	Dummy variable for foreign ownership =1 if the firm is categorised as private foreign under Ownership category in Prowess =0 otherwise
15	royalties1	royalties_i*100
16	rnd1	rnd_i*100
17	X1	X_i*100
18	mraw1	m_raw_i*100
19	mkg1	m_k_i*100
20	for_eq	Foreign promoters' shares as percentage of total shares in the firm
21	DRD	Dummy Variable for presence of R and D. =1 if rnd_i is not equal to 0, or if the expenditure on research and development of the firm is not equal to 0 i.e. the firm undertakes some sort of R and D activity =0, otherwise
22	TFP1	TFP calculated for the complete pool of data as per the ratio method; for all firms belonging to all the industries in the sample for the period 1991-2018
23	TFP1_man	TFP calculated for manufacturing industry as per the ratio method
24	TFP1_food	TFP calculated for the food and agro based industry as per the ratio method
25	TFP1_tex	TFP calculated for the textiles industry as per the ratio method
26	TFP1_chem	TFP calculated for the chemical industry as per the ratio method
27	TFP1_cons	TFP calculated for the consumer goods industry as per the ratio method
28	TFP1_const	TFP calculated for the construction materials industry as per the ratio method
29	TFP1_met	TFP calculated for the metals and metal products industry as per the ratio method
30	TFP1_mach	TFP calculated for the machinery industry as per the ratio method

Sl. No.	Variable	Description
31	TFP1_trans	TFP calculated for the transport and transport equipment industry as per the ratio method
32	TFP1_min	TFP calculated for mining industry as per the ratio method
33	TFP1_elec	TFP calculated for the electricity industry as per the ratio method
34	TFP1_creal	TFP calculated for the construction and real estate industry as per the ratio method
35	TFP1_mman	TFP calculated for the miscellaneous manufacturing industry as per the ratio method
36	TFP2	TFP calculated for the complete pool of data as per the Cobb Douglas Production Function approach; for all firms in the sample, for the period 1991-2018
37	TFP2_man	TFP calculated for the manufacturing industry as per the Cobb Douglas Production Function approach
38	TFP2_food	TFP calculated for the food and agro based industry as per the Cobb Douglas Production Function approach
39	TFP2_tex	TFP calculated for the textiles industry as per the Cobb Douglas Production Function approach
40	TFP2_chem	TFP calculated for the chemical industry as per the Cobb Douglas Production Function approach
41	TFP2_cons	TFP calculated for the consumer goods industry as per the Cobb Douglas Production Function approach
42	TFP2_const	TFP calculated for the construction materials industry as per the Cobb Douglas Production Function approach
43	TFP2_met	TFP calculated for the metals and metal products industry as per Cobb Douglas Production Function approach
44	TFP2_mach	TFP calculated for the machinery industry as per Cobb Douglas Production Function approach
45	TFP2_trans	TFP calculated for the transport and transport equipment industry as per the Cobb Douglas Production Function approach
46	TFP2_min	TFP calculated for the mining industry as per the Cobb Douglas Production Function approach
47	TFP2_elec	TFP calculated for the electricity industry as per the Cobb Douglas Production Function approach
48	TFP2_creal	TFP calculated for the construction and real estate industry as per the Cobb Douglas Production Function approach
49	TFP2_mman	TFP calculated for the miscellaneous manufacturing industry as per the Cobb Douglas Production Function approach
50	TFP3	TFP calculated for the complete pool of data as per the LP method
51	TFP3_man	TFP calculated for the manufacturing industry as per the LP method
52	TFP3_food	TFP calculated for the food and agro based industry as per the LP method
53	TFP3_tex	TFP calculated for the textiles industry as per the LP method
54	TFP3_chem	TFP calculated for the chemical industry as per the LP method
55	TFP3_cons	TFP calculated for the consumer goods industry as per the LP method
56	TFP3_const	TFP calculated for the construction materials industry as per the LP method
57	TFP3_met	TFP calculated for the metals and metal products industry as per the LP method
58	TFP3_mach	TFP calculated for the machinery industry as per the LP method
59	TFP3_trans	TFP calculated for the transport and transport equipment industry as per the LP method
60	TFP3_min	TFP calculated for the mining industry as per the LP method
61	TFP3_elec	TFP calculated for the electricity industry as per the LP method
62	TFP3_creal	TFP calculated for the construction and real estate industry as per the LP method

Sl. No.	Variable	Description
63	TFP3_mman	TFP calculated for the miscellaneous manufacturing industry as per the LP method

Largely, there are 74, 508 observations in the panel data. It is a strongly balanced panel, as declared by STATA.

The summary statistics for all the variables have been detailed out in the Table 4.2 below with description of the variables' mean, standard deviation and range of its observations. The number of observations has also been mentioned alongside each variable with its description. The sample consists of 2,661 business entities. The analysis is done for a period of 28 years from 1991- 2018. All regressions done in this study have been performed on strongly balanced panel data.

4.2 Summary Statistics of Variables

The descriptive statistics of the variables used in our study has been summarised in Table 4.2. The table lists out the number of observations, mean and the standard deviation of the respective variables in our sample. Range of the values that these variables take, has also been described in the table.

It is observed that the oldest firm in our sample is 155 years old, as on 2018. All the variables are as described in Table 4.1 above. Electricity industry displays the least number of observations for estimation of TFP as per the LP method. This problem created a hindrance in estimating results for the third research question of our analysis for this industry sample.

All samples- full sample as well as industry samples, were found to be strongly balanced panel data sets in STATA and thus, are appropriate for meaningful analyses.

Table 4.2: Summary statistics of variables used in the study

Sl. No.	Variable	Observations	Mean	Std. Dev.	Range
1	ageyr	74,508	35.41	21.96	1 – 155
2	ln_sales	40,692	6.57	2.20	-2.47 - 15.43
3	L	74,508	225.49	1825.27	-300 - 92740.38
4	K	74,508	2572.53	24014.05	-0.09 – 1209676
5	rm1	74,508	1692.91	26514.45	-54.03 - 2304278
6	ln_rm1	38,172	5.87	2.14	-2.47 - 14.65
7	ln_L	38,206	3.90	2.10	-2.47 - 11.43
8	ln_K	43,119	5.90	2.19	-2.47 - 14.01
9	royalties_i	10,108	0.12	2.50	0 – 161
10	rnd_i	10,495	0.006	0.04	0 - 2.47
11	X_i	20,382	1.16	99.06	0 - 13082.29

Sl. No.	Variable	Observations	Mean	Std. Dev.	Range
12	m_raw_i	40,694	0.19	10.66	0 - 1603.31
13	m_k_i	13,098	0.41	25.18	0 - 2732.4
14	royalties1	74,508	1.66	92.46	0 – 16100
15	rnd1	74,508	0.09	1.57	0 - 247.62
16	X1	74,508	31.93	5181.29	0 – 1308229
17	mraw1	74,508	10.58	788.17	0 - 160331.3
18	mkg1	74,508	7.22	1055.94	0 – 273240
19	for_eq	6,619	21.66	26.88	0 - 97.45
20	TFP1	43,810	2.31	77.63	-76.66 - 13123.14
21	TFP1_man	40,184	2.36	80.97	-76.67 - 13123.14
22	TFP1_food	5,091	2.46	42.91	-0.42 - 2546.53
23	TFP1_tex	6,009	1.29	14.32	-0.001 - 638.5
24	TFP1_chem	8,622	2.94	56.21	0 - 3622.33
25	TFP1_cons	2,114	12.48	322.30	0 - 13123.14
26	TFP1_const	2,426	0.80	2.97	-76.67 - 60.25
27	TFP1_met	5,087	1.58	27.15	-61.05 – 1741
28	TFP1_mach	5,590	1.03	3.01	0 - 144.96
29	TFP1_trans	3,127	1.02	2.15	0 - 50.42
30	TFP1_min	810	0.86	1.01	0 - 14.13
31	TFP1_elec	423	0.76	0.72	0 - 6.83
32	TFP1_creal	2,243	2.10	15.99	0 - 709.5
33	TFP1_mman	2,268	1.93	30.07	0 - 1011.33
34	TFP2	36,791	2.05	20.21	8.78E-05 - 3015.86
35	TFP2_man	33,771	2.06	20.96	8.78E-05 - 3015.86
36	TFP2_food	4,272	2.40	6.58	0.0004 - 289.00
37	TFP2_tex	5,006	1.82	6.42	0.0002 - 248.32
38	TFP2_chem	7,253	2.01	16.21	0.0007 - 1129.46
39	TFP2_cons	1,808	5.02	80.84	0.001 - 3015.86
40	TFP2_const	2,036	1.16	1.69	8.78E-05 - 49.03
41	TFP2_met	4,169	2.30	8.68	0.0003 - 444.45
42	TFP2_mach	4,777	1.69	8.86	0.001 - 310.59
43	TFP2_trans	2,695	1.50	2.37	0.002 - 36.70
44	TFP2_min	672	1.76	12.74	0.009 - 326.02
45	TFP2_elec	346	1.21	1.30	0.005 - 9.44
46	TFP2_creal	1,865	2.07	5.62	0.001 - 132.64
47	TFP2_mman	1,892	1.46	2.80	0.0003 - 56.59
48	TFP3	35,003	2.82	26.41	0.002 - 2481.62
49	TFP3_man	32,346	2.39	16.62	0.002 - 1460.26
50	TFP3_food	4,033	3.15	33.03	0.04 - 1460.26
51	TFP3_tex	4,834	1.93	14.88	0.08 - 987.42
52	TFP3_chem	6,912	2.62	14.74	0.002 - 662.55
53	TFP3_cons	1,712	3.48	18.64	0.002 - 413.81

Sl. No.	Variable	Observations	Mean	Std. Dev.	Range
54	TFP3_const	1,969	1.90	2.05	0.01 - 46.02
55	TFP3_met	3,989	2.10	9.48	0.07 - 286.81
56	TFP3_mach	4,602	2.22	10.94	0.01 - 328.86
57	TFP3_trans	2,613	2.07	11.94	0.03 - 464.59
58	TFP3_min	618	4.98	17.02	0.24 - 249.89
59	TFP3_elec	311	18.96	130.42	0.03 - 1488.63
60	TFP3_creal	1,607	7.46	78.51	0.04 - 2481.62
61	TFP3_mman	1,803	2.07	6.41	0.02 - 108.14

4.3 TFP Estimation

The first objective of this study pertains to examination of TFP of firms- its trends as per the various methods of measuring TFP. We have employed three methods (as described in Chapter 2) to calculate TFP of firms in the different samples of our study. We then go on to make a case for selection of LP method estimated of TFP for the further two research objectives of our study. This section mainly looks at this concern and discusses the results obtained in the process.

Total Factor Productivity of the firms has been attempted to be looked at in three different ways that have been borrowed from the available literature on this subject. The Ratio method, the Cobb Douglas Production Function approach and the Levinsohn and Petrin (LP) method have been employed for calculation of TFP. We now discuss the estimates as well as the trend in TFP that these measures cause for the entire period of our study, from 1991- 2018.

4.3.1 Ratio Method

This method is the most common and simple method of calculation of TFP of any business entity. As explained in Chapter 2, this ratio method is simply a ratio of total output to the sum of total inputs of a firm. As stated earlier, all the monetary values that have been used for analysis are in Rs Million terms.

Total output of the firm has been taken in the form of Total Sales of the firm. Total inputs have been arrived at by summing up the total expenditure on raw materials, labour and capital. All these variables have been deflated by using Wholesale Price Index for different years at the 2011-12 series.

Table 4.3 below, describes the trends in TFP for the complete pool of data (2,661 firms) and the TFP indices for different industry samples i.e., manufacturing; food and agro based products; textiles; chemicals and chemical products; consumer goods; construction materials; metals and metal products; machinery; transport equipment; mining; electricity; construction and real estate and miscellaneous manufacturing. These are the mean values of TFP in their respective categories (categorised into columns) as calculated by STATA, for all the firms in that industry in a particular year. This exercise was done for all the years in consideration.

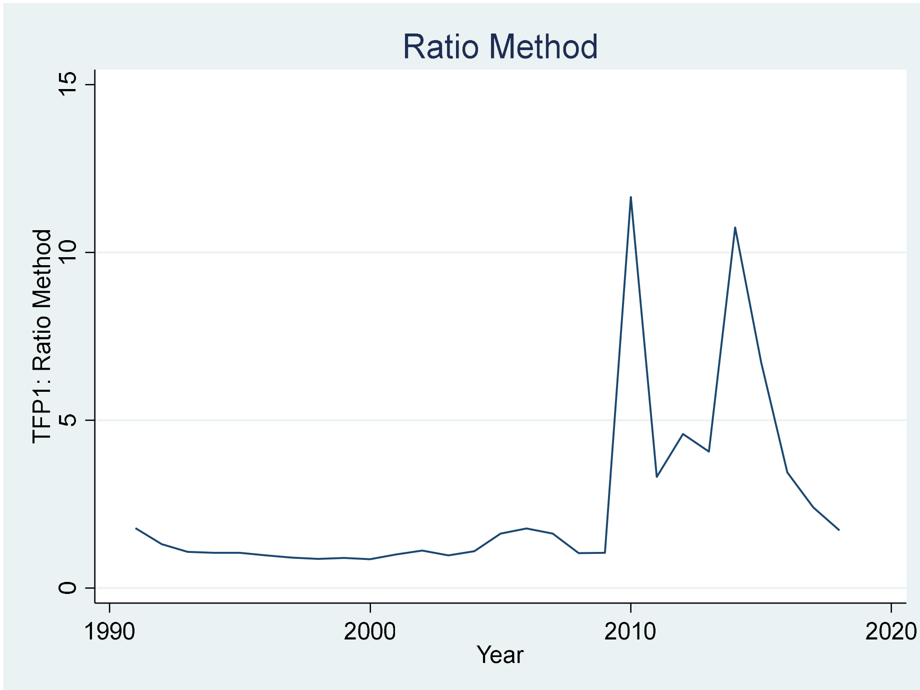
It is worth noting that construction materials industry has been the only industry that saw negative TFP values, that too for the last two years of analysis. Rest, all industries saw positive TFP indices for the entire period of analysis.

Table 4.3: Trends in TFP calculated for various industries, as per the Ratio Method

Year	TFP1	TFP1_man	TFP1_food	TFP1_tex	TFP1_chem	TFP1_cons	TFP1_const	TFP1_met	TFP1_mach	TFP1_trans	TFP1_min	TFP1_elec	TFP1_creal	TFP1_mman
1991	1.778	1.798	3.285	2.862	1.127	1.715	0.785	2.482	0.934	0.879	0.875	0.754	1.986	0.861
1992	1.302	1.303	1.351	2.609	1.111	1.647	0.838	0.897	0.938	0.862	0.735	0.768	1.642	0.867
1993	1.070	1.056	1.510	0.895	1.073	1.553	0.787	0.952	0.952	0.893	0.700	0.813	1.559	0.852
1994	1.044	1.022	1.134	0.872	1.130	1.312	0.838	1.081	0.947	0.911	0.675	0.722	1.650	0.865
1995	1.050	1.022	1.202	0.820	1.077	1.312	0.813	1.188	0.918	0.915	0.711	0.777	1.748	0.861
1996	0.968	0.954	1.159	0.811	1.018	1.174	0.808	0.952	0.884	0.902	0.704	0.825	1.375	0.801
1997	0.902	0.890	1.133	0.781	0.898	1.204	0.735	0.801	0.854	0.872	0.722	0.787	1.226	0.763
1998	0.868	0.853	1.080	0.714	0.874	1.465	0.690	0.753	0.795	0.798	0.662	0.742	1.255	0.670
1999	0.894	0.821	0.923	0.681	0.869	1.344	0.660	0.747	0.779	0.836	0.637	0.700	2.307	0.697
2000	0.858	0.838	0.930	0.709	0.905	1.412	0.649	0.780	0.770	0.796	0.643	0.680	1.311	0.712
2001	1.003	0.993	0.981	0.868	0.981	0.885	1.149	0.954	0.886	0.983	1.079	1.020	1.129	1.691
2002	1.114	1.101	0.879	0.816	1.173	0.933	0.732	1.965	0.927	0.845	1.049	1.258	1.205	1.711
2003	0.973	0.960	0.888	0.814	1.093	0.929	0.719	1.130	0.911	0.973	0.948	1.027	1.089	1.184
2004	1.097	1.092	0.861	1.079	1.038	0.864	1.617	1.235	1.121	1.055	0.953	1.091	1.101	1.193
2005	1.622	1.625	0.848	1.219	2.823	1.027	1.418	1.359	1.892	1.027	1.441	0.628	1.877	1.418
2006	1.775	1.825	0.889	0.715	5.412	0.960	0.979	0.841	0.967	0.827	1.040	1.176	1.280	0.839
2007	1.618	1.648	0.810	0.700	4.254	1.112	1.431	0.703	1.250	1.098	1.121	1.118	1.371	0.915
2008	1.034	1.004	0.806	0.800	1.092	0.773	0.652	1.264	0.958	0.847	0.812	0.628	1.754	1.956
2009	1.051	1.034	0.796	0.821	1.034	0.724	0.661	1.350	0.995	1.330	0.759	0.525	1.612	1.771
2010	11.654	12.466	1.076	0.813	4.206	205.865	0.579	1.103	1.133	1.166	0.764	0.685	2.555	1.195
2011	3.305	3.382	1.049	0.794	8.107	0.671	0.608	1.296	0.982	1.505	0.718	0.678	2.398	15.879
2012	4.586	4.802	0.823	3.680	3.064	36.804	0.801	1.486	1.578	1.918	0.632	0.681	1.732	16.009
2013	4.059	4.218	0.910	3.833	2.441	33.288	0.740	5.372	1.649	1.244	0.997	0.594	3.342	1.179
2014	10.748	11.563	10.815	1.536	15.922	83.879	0.755	11.249	1.127	1.213	1.332	0.641	2.362	1.018
2015	6.738	6.607	23.279	1.430	13.310	0.930	0.858	1.321	1.176	1.364	1.309	0.828	12.054	1.182

2016	3.447	3.589	6.348	1.225	9.167	1.378	1.535	1.157	1.108	1.267	0.978	0.632	2.530	1.691
2017	2.400	2.396	6.703	1.376	3.942	1.923	-0.346	1.106	1.083	1.152	1.023	0.664	3.269	0.978
2018	1.710	1.763	1.320	1.260	4.163	1.248	-0.162	1.149	1.134	1.291	1.298	0.567	1.142	0.998
Average	**2.524**	**2.594**	**2.635**	**1.269**	**3.332**	**13.869**	**0.797**	**1.667**	**1.059**	**1.063**	**0.904**	**0.786**	**2.138**	**2.170**

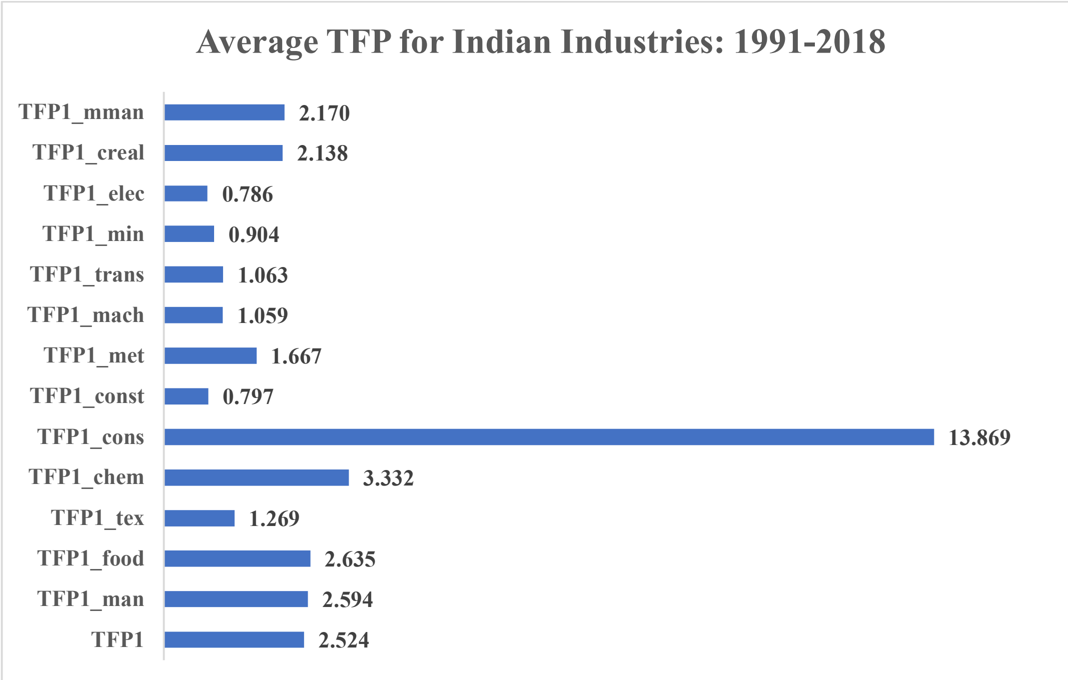
Figure 4-1: Trend in TFP of overall industrial sector (complete panel of data of all 2,661 firms) for the entire period of analysis 1991-2018, as per the Ratio Method.



Average annual growth of TFP was also calculated for the entire period between 1991- 2018 for the complete sample as well as the 13 different industries. If we look at the trend in the TFP of the overall industrial sector, as shown in ***Figure 4-1***, there were no major changes in TFP of the industrial sector, as per the Ratio method in the decade following the economic reforms of 1991. The trend however saw some upward movement in year 2004 which continued till 2006 and then started dipping and attained stagnation by 2009.

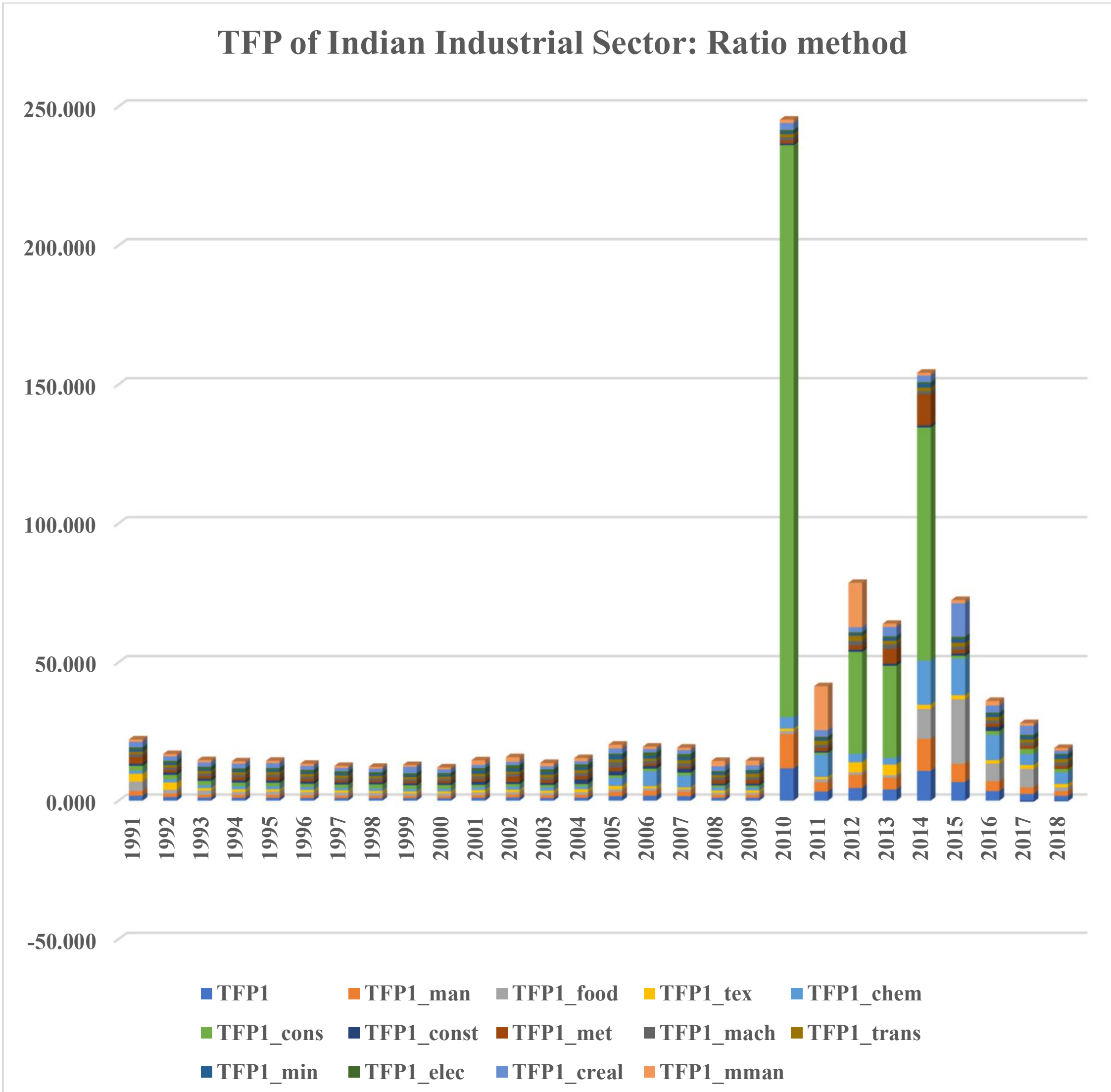
The graph spiked upward in 2010 and saw a dip by more than fifty percent of its value in the very next year. Thereafter, the situation has been sort of a roller coaster ride within sudden spike again in year 2014 that reduces and continue to do so till 2018.

Figure 4-2: Disaggregation of TFP of different industries in the period 1991-2018.



Trend in average TFP for the Indian industrial sector has been disaggregated for different industries for the period in consideration and it is visible from ***Figure 4-2*** that in the entire period of our analysis, the consumer goods industry holds the maximum share of TFP among all industries in the economy with an average TFP of 13.86 in the entire period. Chemicals and chemical products industry comes second with an average TFP of 3.33. Manufacturing (2.59) and Food (2.63) industries are very close to the overall sector's average TFP (2.52). Construction materials (0.79), electricity (0.78) and mining (0.90) industries have the lowest TFP in the said period of analysis. Other industries fall in between these two ranges of TFP values.

Figure 4-3: Trends in TFP as per the Ratio method in each year from 1991-2018.



Trend analysis was also approached from the point of view of looking at the progress of TFP of different industries in each year of analysis. This is shown in Figure 4.3. The maximum average TFP was registered in year 2010 wherein, again, consumer goods industry was placed with the highest average TFP among all the industries in consideration. The next year saw a sudden dip in the average TFP of all the industries, but manufacturing industry stayed on top in the share of average TFP in that year. Subsequently, later years also saw greatest share of consumer goods industry again in the overall average TFP among all the industries, with a spike in year 2014. In the years after 2014, there has been a downward trend in the average TFP of all the industries, accompanied with consumer goods industry losing its prominence. This period also saw a dominance of food and agro based industry's share in the overall average TFP of the Indian industrial sector.

4.3.2 Cobb Douglas Production Function Approach

This approach is also very common in the literature on total factor productivity. In fact, many other methods also employ the use of Cobb Douglas Production Function in order to estimate TFP. The chapter on literature review (Chapter 1) and also chapter on methodology (Chapter 2) have already talked about this method in detail.

In order to estimate TFP for the firms in our panel data, we regressed the log value of Sales (output) on the log values of labour and capital. Thereafter, the calculated TFP values were predicted in the appropriate form (anti log of the TFP calculated using OLS estimation technique of panel data) using STATA. The following regression equation was estimated for the entire sample of all firms:

$$ln\_sales = \beta_0 + \beta_1 \, ln\_K + \beta_2 \, ln\_L + \varepsilon_i \quad (4.1)$$

where all the variables are as described in this chapter earlier. The variables have been taken in log form for easy estimation in STATA. The values of TFP thus received for the firms in sample were then converted into anti-log for suitability of prediction of TFP in a more meaningful format.

Following results were obtained from the above regression and estimation of Cobb Douglas Production Function:

Table 4.4: Estimation Results for Cobb Douglas Production Function.

Dependent Variable= ln_sales	Coefficient	Standard Error	P value
ln_K	0.391	0.004	0.000*
ln_L	0.553	0.004	0.000*
Constant	2.096	0.018	0.000*

All the estimated regression coefficients were found to be significant at 95% level of significance (indicated by *). The values in the second column of the above table are the standard errors of the variables as produced in STATA. This model was able to explain 73% of the total variations in the predicted values of TFP as per the Cobb Douglas Production Function assumptions. The model was found to be overall significant (significant F statistic) with a total of 36, 791 observations.

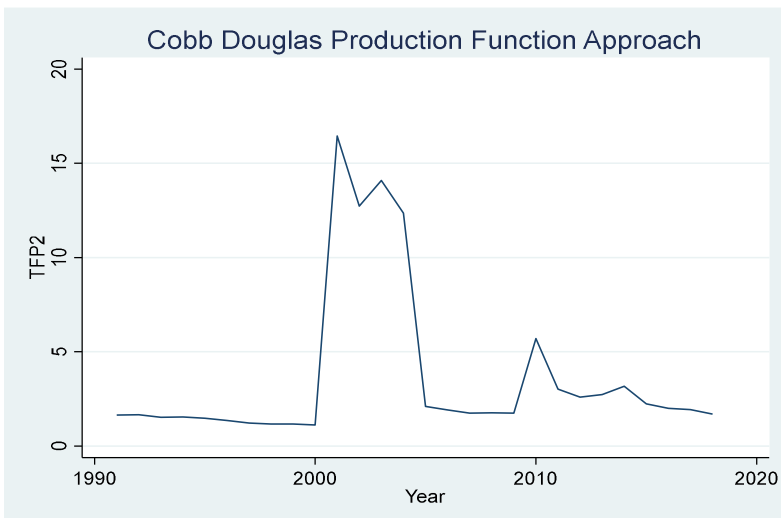
TFP values for respective industries were thereafter sorted by introducing conditions appropriate for the relevant industry and then the mean values of TFP were calculated for each industry, for every year from 1991-2018. These values have been tabulated in

Table 4.5.

Table 4.5 lists out the mean TFP values calculated for all the firms in a particular year, for different categories of industries (listed as columns in the table). This exercise is repeated in order to look at the trend in TFP values for different industries considered in our analysis. The table does not show any negative TFP values for any industry in any year. This is in contrast to the table of TFP as per the Ratio method.

And, also here there are missing values for electricity industry for years 2001, 2003 and 2004. This might be because of higher proportion of missing values in order to estimate the TFP for this industry in the stated years.

Figure 4-4: Cobb Douglas Production Function Approach: Trend in TFP of overall industrial sector (complete panel of data of all 2,661 firms) for the entire period of analysis 1991-2018.



Average annual TFP as per the Cobb Douglas Production Function approach for the entire industrial sector were also plotted against time variable as shown in the figure above. These are annual average TFP values for all the firms in the sample in each year of our analysis from 1991 to 2018. As the figure shows, annual average TFP values follow a pattern of stagnation since 1991 to 2000.

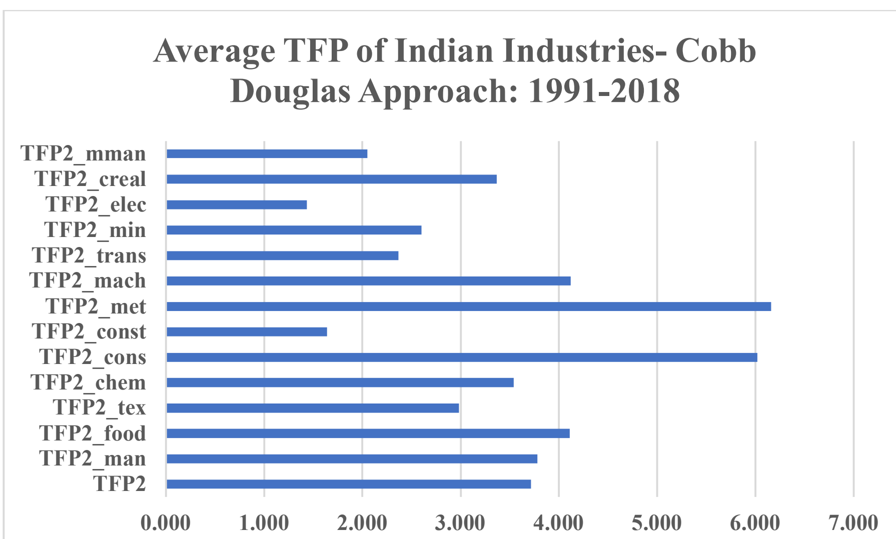
Table 4.5: Trends in TFP calculated according to the Cobb Douglas Production Function Approach.

Year	TFP2	TFP2_man	TFP2_food	TFP2_tex	TFP2_chem	TFP2_cons	TFP2_const	TFP2_met	TFP2_mach	TFP2_trans	TFP2_min	TFP2_elec	TFP2_creal	TFP2_mman
1991	1.648	1.650	2.095	2.122	1.633	2.101	1.075	1.971	1.166	1.093	1.441	0.878	1.727	1.052
1992	1.661	1.681	2.239	2.139	1.556	2.054	0.998	2.141	1.175	0.990	1.267	1.026	1.549	1.055
1993	1.532	1.549	2.089	1.617	1.495	1.943	1.010	2.031	1.149	1.056	1.267	1.145	1.393	1.006
1994	1.547	1.571	1.978	1.608	1.552	2.021	1.116	2.066	1.186	1.128	0.804	1.039	1.418	1.047
1995	1.482	1.507	1.893	1.571	1.482	1.796	1.057	1.956	1.154	1.172	0.723	1.095	1.373	1.020
1996	1.362	1.386	1.831	1.451	1.371	1.645	1.005	1.733	1.043	1.108	0.695	1.126	1.224	0.902
1997	1.226	1.240	1.725	1.311	1.215	1.641	0.881	1.459	0.906	0.971	0.646	1.031	1.229	0.761
1998	1.165	1.170	1.659	1.092	1.185	1.835	0.854	1.388	0.826	0.856	0.575	0.974	1.335	0.749
1999	1.176	1.151	1.521	1.043	1.198	2.018	0.842	1.364	0.800	0.900	0.539	0.907	1.881	0.787
2000	1.116	1.121	1.535	1.064	1.120	1.717	0.859	1.353	0.775	0.860	0.528	0.885	1.287	0.847
2001	16.455	16.988	11.987	20.845	10.891	4.108	4.731	52.103	21.394	6.238	4.193		14.003	4.834
2002	12.729	13.433	19.013	5.297	12.293	4.649	3.892	21.549	23.451	7.890	4.304	4.130	7.084	5.060
2003	14.094	14.722	16.817	6.437	15.031	5.317	4.018	27.175	24.045	7.505	5.613		8.285	5.061
2004	12.365	12.545	15.309	8.119	11.327	7.154	5.489	26.534	12.958	9.036	5.599		14.085	3.612
2005	2.108	2.150	2.807	2.040	1.730	1.467	1.671	2.240	1.665	2.844	1.267	1.424	1.949	3.811
2006	1.921	1.934	2.403	1.547	2.736	1.721	1.203	1.910	1.540	1.504	1.370	2.045	1.939	1.422
2007	1.754	1.752	2.576	1.678	1.449	1.696	1.241	2.067	1.569	1.962	1.265	1.880	2.045	1.428
2008	1.771	1.757	2.488	1.788	1.433	1.505	1.201	2.030	1.506	1.569	1.293	2.192	2.255	2.383
2009	1.757	1.698	2.110	1.628	1.412	1.549	1.106	1.764	1.755	1.659	2.966	2.115	2.525	2.456
2010	5.710	5.613	2.214	2.151	4.696	61.930	1.106	2.031	1.777	1.589	24.082	1.260	3.501	2.557
2011	3.026	3.060	2.181	2.009	7.185	1.567	1.198	2.151	1.799	1.604	1.063	1.891	2.556	2.586
2012	2.600	2.610	2.503	1.777	2.097	14.299	1.953	2.158	1.815	1.892	1.059	1.921	2.017	1.888
2013	2.736	2.685	2.239	3.580	1.891	10.721	1.287	2.197	1.966	1.898	1.827	1.737	3.284	2.251
2014	3.167	3.201	2.187	2.321	1.899	23.226	1.225	1.997	1.640	1.923	1.796	1.630	3.077	1.860
2015	2.249	2.261	4.012	2.195	2.656	1.967	1.154	1.892	1.548	1.958	1.911	1.050	2.130	1.889

2016	2.000	1.929	2.011	1.956	2.511	2.287	1.195	1.877	1.471	1.708	1.466	0.879	3.249	1.797
2017	1.937	1.832	1.976	1.724	2.081	2.837	1.293	1.766	1.483	1.676	1.590	0.869	3.985	1.699
2018	1.697	1.697	1.690	1.415	1.978	1.778	1.261	1.561	1.817	1.721	1.621	0.771	1.901	1.634
AVERAGE	**3.714**	**3.782**	**4.110**	**2.983**	**3.539**	**6.020**	**1.640**	**6.160**	**4.121**	**2.368**	**2.599**	**1.436**	**3.367**	**2.052**

So, for a decade after the reforms, there were no significant changes in the TFP of the industrial sector. However, a sharp upward spike is observed in TFP in year 2001. This is the highest TFP of the sector observed in the entire period of analysis. This is also in contrast to the previous method of Ratio approach. There was no such upward movement in TFP in the Ratio method in this stretch of time period. This increase subsequently decreases and increases to decrease again till year 2004 before dipping in a sharp manner in year 2005. TFP continues to stagnate at this level till year 2009 and then increases slightly in 2010. This pattern is followed as was the case in ratio method, however the extent of this upward spike is lesser as compared to that of TFP trend in Ratio method. Hereafter, TFP analysis as per this method is in close approximation to that of Ratio method. However, the extent of upward as well as downward spikes in TFP in this method are relatively smaller that the latter method. So, in the period before 2009, TFP measures calculated as per the Cobb Douglas Production Function approach are more than those of the Ratio method. And in the period after 2009, both methods follow a close pattern but, TFP measures as per this method remain lower than those of the Ratio method.

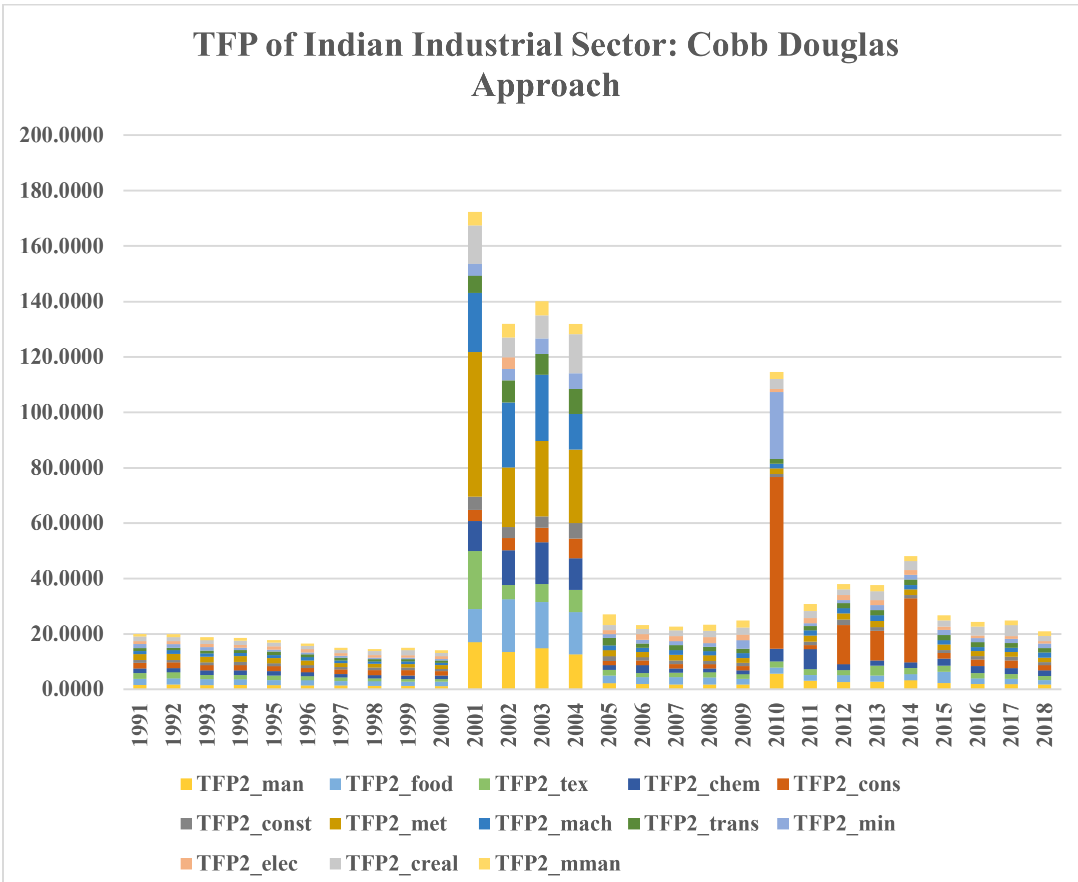
Figure 4-5: Cobb Douglas Production Function Approach: Disaggregation of TFP of different industries in the period 1991-2018.



The above figure shows the average TFP values for all the industries in consideration of our analysis. The above values were arrived at by averaging the TFP values of the respective industries for the entire period from 1991 to 2018. TFP values calculated as per this method are more distributed across the different industries. Metals and metal products industry registers the highest average TFP in the entire period with value 6.16. Consumer goods industry is close second with average TFP of 6.02. Food and agro based industry (TFP 4.11) and machinery industry (4.12) are the other industries with high average TFP.

Electricity industry (TFP 1.43) and construction materials industry lag behind with least average TFP in the period of analysis. This is similar to the result obtained in the Ratio method. Rest of the industries fall in between these two extreme categories.

Figure 4-6: Cobb Douglas Production Function Approach: Trends in TFP for all categories of industries in each year from 1991-2018.



The above figure displays the trend in TFP for different categories of industries for each year from 1991 to 2018. Maximum average TFP values were achieved in year 2001. This was also the first and biggest spike in average TFP of industrial sector as a whole too, in the period since the economic reforms. This streak in TFP continues till 2004. Metals and metal products industries appears to be the industry with highest average TFP in these years and owes the maximum share in TFP for these years. Machinery industry is a close follower with the second highest share in TFP in these years. Chemical, Food and Manufacturing industries seem to be closing up on the highest average TFP industries.

These trend sees a sharp decline in year 2005 which continues till 2009. In 2010, a sharp increase is observed in the average TFP of the industries wherein now, Consumer goods industry comes out as a winner with highest share of TFP measures in this year. This prominence of Consumer goods industry is also observed in the successive years till 2014. After 2014, it is again a mixed bag of TFP measures of different industries, that are quite close to each other with no industry gaining any significant prominence in comparison to others. The overall TFP values also see a declining pattern in the years after 2014 and continue to do so till the last year of our analysis.

4.3.3 Levinsohn and Petrin (LP) Method

Previous chapter have talked about this method of estimating TFP in a detailed manner. LP method is quite a recent method employed in calculation TFP for business entities or firms. It has its own advantages as well as disadvantages that have been detailed in last chapters.

This approach has been employed for more meaningful analysis as per the lessons observed from the literature review on total factor productivity estimation. The analysis was carried out using STATA software on the panel data of 2,661 firms for the period 1991 to 2018. The LP estimation can be employed by directly putting in the levpet command in STATA[12]. This will help predict the TFP values in appropriate format for meaningful application.

As stated earlier, this method takes into account the intermediate inputs like the raw materials, in addition to Labour and Capital, for estimating the total factor productivity of the entity. Since the intermediate inputs aren't readily available, a proxy is used in their place for estimation. Here, in order to calculate TFP, we have used raw materials as the intermediate good, in addition to labour and capital. Again, sales have been taken up as the proxy for output. All the variables are in log form for levpet command application.

The estimation is done in form of revenue accounting method as compared to the value-added method of LP estimation. This is primarily don on account of the logic that since we have taken sales as our proxy for output of the firm, it would be appropriate that the revenue estimation method is employed since sales are infact the revenue received on sale of products by the firm. Following regression model was estimated in STATA:

$$\text{ln\_sales} = \beta_1 \text{ ln\_K} + \beta_2 \text{ ln\_L} + \beta_3 \text{ ln\_rm1} + \varepsilon_i \qquad (4.2)$$

[12] Petrin et al (2004)

all the variables are as described earlier in this chapter and have been taken in log form as per the requirement of LP method estimation in STATA.

Upon regression, the following results were obtained:

Table 4.6: Estimation Results for LP regression model of TFP estimation.

Dependent Variable= ln_sales	Coefficient	Standard Errors	P Value
ln_L	0.246	0.010*	0.000
ln_K	0.201	0.058*	0.001
ln_rm1	0.709	0.046*	0.000

The above model was found to be overall significant (significant Chi2 value). It was estimated with total of 35,003 observations and 2,661 number of groups. All the estimates were found to be significant at 95% level of significance, as is indicated by the * sign attached to the standard error values of the coefficients placed under the estimates.

The predicted TFP values as per the LP method were then sorted and arranged for different industry groups. These TFP values were then averaged for all the firms in each year for the period 1991 to 2018. This information is tabulated in Table 4.7.

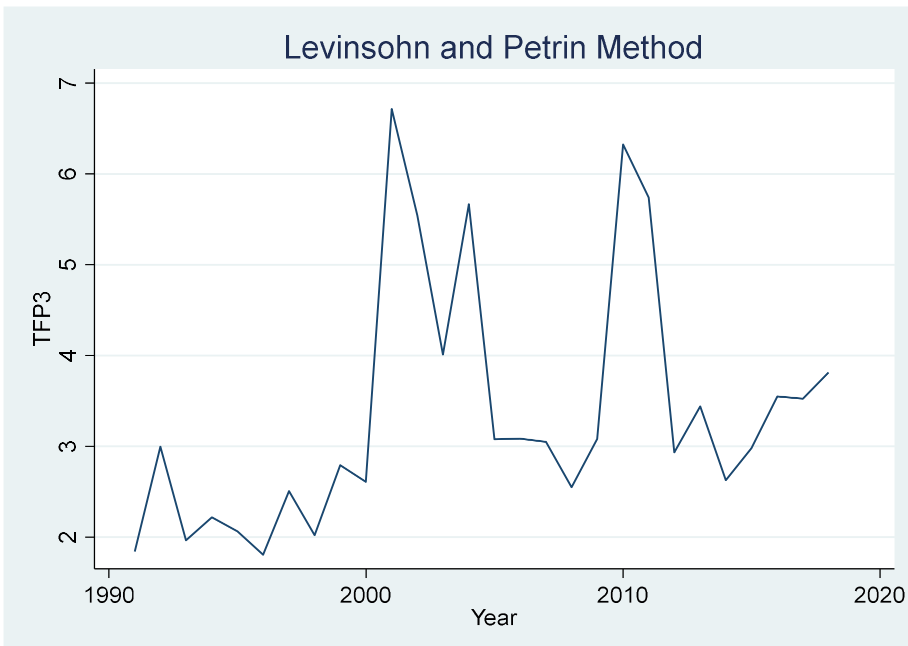
Table 4.7: Trends in TFP calculated as per the Levinsohn and Petrin (LP) method.

Year	TFP3	TFP3_man	TFP3_food	TFP3_tex	TFP3_chem	TFP3_cons	TFP3_const	TFP3_met	TFP3_mach	TFP3_trans	TFP3_min	TFP3_elec	TFP3_creal	TFP3_mman
1991	1.842	1.695	1.967	1.777	1.677	2.377	1.998	1.416	1.523	1.221	3.236	3.748	4.133	1.719
1992	2.998	2.754	9.852	1.463	2.064	1.956	1.948	1.608	1.489	1.264	2.839	13.463	6.850	1.870
1993	1.966	1.802	2.388	1.480	1.993	2.032	2.094	1.568	1.437	1.309	2.504	3.130	5.355	2.166
1994	2.218	1.935	2.545	1.442	2.258	2.643	2.347	1.795	1.403	1.309	2.885	8.120	7.282	2.009
1995	2.064	1.852	3.369	1.291	1.711	2.339	2.244	1.510	1.481	1.255	3.487	9.252	4.641	2.093
1996	1.809	1.647	2.017	1.327	1.884	1.817	1.963	1.490	1.379	1.269	3.552	2.839	4.469	1.760
1997	2.509	1.612	2.130	1.433	1.592	2.233	1.803	1.390	1.258	1.190	2.862	64.994	7.115	2.237
1998	2.023	1.545	2.073	1.256	1.607	1.896	1.973	1.389	1.278	1.062	2.886	35.732	3.916	1.813
1999	2.792	1.647	1.738	1.292	1.791	3.784	1.632	1.411	1.401	1.085	2.880	77.577	7.979	1.868
2000	2.610	1.843	1.823	1.401	2.038	6.054	1.806	1.565	1.293	1.049	5.503	59.145	4.028	1.637
2001	6.716	6.469	4.090	3.665	3.131	2.718	3.092	13.916	11.039	2.160	16.713		4.658	15.124
2002	5.545	3.964	4.202	3.677	2.769	2.755	3.129	4.542	3.327	2.525	38.928	3.936	4.016	15.579
2003	4.013	3.549	4.283	2.277	3.435	2.735	2.914	5.314	3.486	2.727	13.391		4.457	3.134
2004	5.666	4.775	7.717	5.399	3.512	2.813	2.749	6.946	3.631	2.747	28.586		4.515	2.234
2005	3.079	3.062	1.776	1.774	2.952	5.971	1.891	9.102	1.832	1.726	8.049	0.950	1.992	2.274
2006	3.085	2.825	1.958	1.581	2.608	15.304	1.619	2.108	3.102	1.762	6.405	23.587	2.487	1.872
2007	3.052	3.015	1.851	1.669	2.929	11.750	1.676	2.084	4.869	1.883	7.604	1.312	2.683	1.797
2008	2.551	2.399	1.977	1.947	2.731	2.376	1.616	2.256	3.878	1.668	12.054	1.423	2.386	1.910
2009	3.082	3.012	1.869	2.859	2.825	10.381	1.458	3.175	3.110	2.211	9.939	1.261	2.856	1.973
2010	6.327	3.688	9.179	3.089	4.053	3.930	1.434	1.731	2.822	2.426	12.258	1.089	58.570	1.940
2011	5.741	3.826	10.079	2.117	4.263	1.986	1.442	1.935	3.130	3.167	10.601	1.225	43.224	3.562
2012	2.935	3.011	2.917	2.114	4.048	1.806	1.536	1.754	4.130	4.557	2.848	1.174	2.077	1.817
2013	3.440	3.489	1.699	9.357	3.777	1.681	1.698	1.856	2.816	2.750	2.933	1.075	3.042	1.504
2014	2.629	2.592	1.742	2.500	3.326	1.665	2.540	2.061	2.999	3.692	2.961	1.079	3.287	1.556
2015	2.982	2.499	1.880	2.046	2.879	1.915	1.576	2.563	2.526	4.671	3.232	1.116	11.285	1.718

2016	3.551	3.608	1.474	1.981	4.369	4.938	1.574	3.942	5.367	4.851	2.328	1.261	3.326	3.270
2017	3.527	3.474	1.458	2.470	6.519	5.309	2.090	3.820	2.416	3.018	2.324	1.181	4.915	1.559
2018	3.815	3.886	1.491	1.808	6.393	3.639	1.607	4.388	3.223	8.010	2.150	0.886	3.397	1.579
AVERAGE	**3.377**	**2.910**	**3.269**	**2.375**	**3.040**	**3.957**	**1.980**	**3.165**	**2.916**	**2.449**	**7.712**	**12.822**	**7.819**	**2.985**

Mean TFP measures for all the firms in the sample have been calculated and carefully arranged in Table 4.7 for all categories (different columns representing different industry in the table). This table also doesn't show any negative TFP values for any industry in any year of our study. This is similar to the values obtained in the Cobb Douglas Production Function Approach. However, here again we have missing values for the electricity industry for years 2001, 2003 and 2004. This is again because of very few observations to carry out regression exercise in order to estimate LP estimates for TFP prediction of firms in this industry.

Figure 4-7: LP Method: Trend in TFP of overall industrial sector (complete sample of all 2,661 firms) for the entire period of analysis 1991-2018.

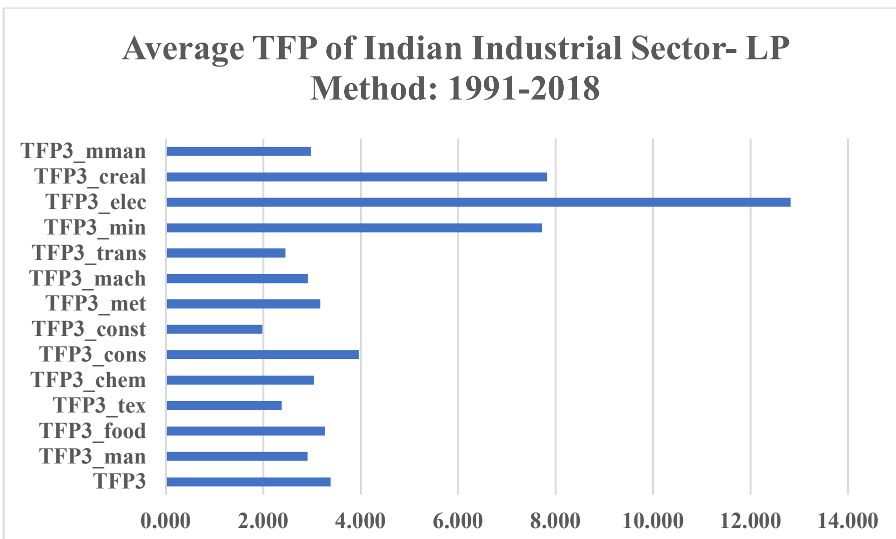


The above graph shows the time plot of annual average TFP measures calculated for the entire sample of our study. This graph is somewhat broadly similar in pattern to that of the Cobb Douglas Production Function method. However, this is a more sensitive and staggered graph as compared to the latter.

No major sharp changes are observed in the decade after the reforms. Small upward spikes are observed in years 1992- the year immediately after the reforms came into existence and thereafter, years 1997 and 1999 further saw increase in the mean annual TFP values of the Indian industrial sector. A sharp and higher upward increase was observed in 2001, which has been the year of highest TFP in the entire period of analysis. This is similar to the pattern followed in the previous method of TFP calculation. However, the extent of increase is smaller than that displayed by the previous method. This method follows a close pattern to that of the previous method, remaining lower in value for all years with respect to Cobb Douglas method, in the period after 2001 till year 2010. After 2010, in case of few years, this method yields results that are in exact contrast to those of the previous two methods. TFP increases in 2010 and decreases slightly successively by 2012. This decrease is gradual rather than a sharp rapid decline after 2010, as was the case in both the previous methods. Also, the increase in TFP in 2010 is almost of the same extent as that of 2001. This is also different in this method as compared to the last two methods that showed high sharp increases in TFP in year 2010.

After 2012, TFP slightly increases in 2013 and with a decline in 2014, TFP continues to gradually increase in years after 2015. This upward movement in graph is opposite to the results shown in the previous two methods that showed gradual decline in the TFP of the Indian industrial sector.

Figure 4-8: Levinsohn and Petrin Method: Disaggregation of TFP for different industries in the period 1991-2018.

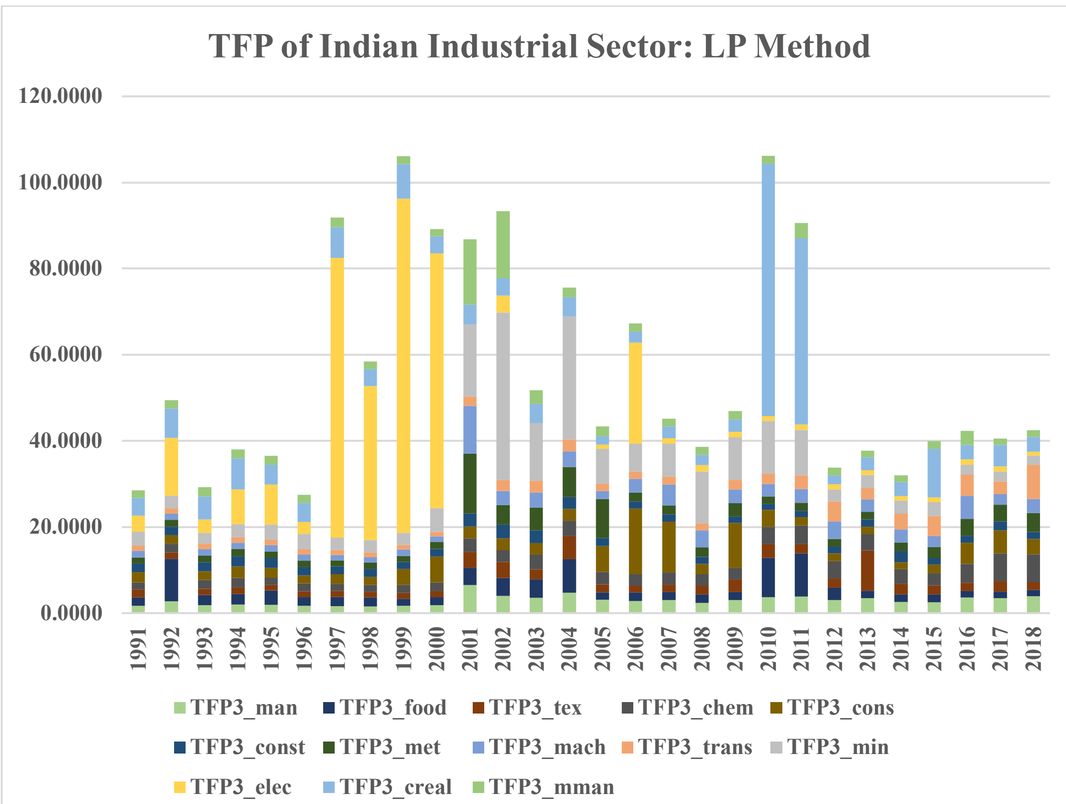


The above figure reflects the average TFP of all the industries, for the entire period of our analysis. Again, this method yielded TFP measures that are not very concentrated and limited to a few industries while others lag behind by a huge margin. However, few industries come out on top with higher TFP measures. Surprisingly, electricity industry locks the topmost position in terms of average TFP for the entire period with TFP of 12.82. This is surprising, because the last two methods classified electricity industry as one of the lagging industries with least TFP measures. Also, this industry was found to have a lot of missing values, thereby rendering very few observations to be put to use for calculation of TFP using LP estimation method. Other surprising element is also observed in cases of Construction and Real estate industry (TFP 7.82) and Mining industry (7.71), since both of them are placed after electricity industry in ranks of TFP measures. This also comes as a surprise after the last two methods, since both of these industries were placed in the mediocre range of average TFP values as per both Ratio and Cobb Douglas Production Function approaches of calculating TFP.

Consumer goods industry, which was placed with high average TFP measures as per the previous two methods, though continues to display a slightly high TFP value. However, this TFP falls in the mediocre range as per the LP method.

Construction materials industry with average TFP of 1.98 however, continues to be the industry with least average TFP as per the LP methods also. This is in consonance with the result obtained in the previous two methods. Rest of the industries are placed in between these two broad categories.

Figure 4-9: Levinsohn and Petrin Approach: Trends in TFP for all categories of industries in each year from 1991-2018.



The above figure displays the trend in TFP for different categories of industries for each year from 1991 to 2018 as per the measures of TFP obtained by using LP method of TFP estimation. As the above graph shows, average TFP increased overall within the next year of economic reforms. However, the levels saw an inverted U-shaped pattern in the subsequent years till 1996. 1997 saw a sudden increase in average TFP values that increased again in 1999 after a slight decline in the year in between.

It is noticeable that electricity industry was the most prominent industry in the period from 1991 to 2000. Construction and real estate industry follows as a close second to the former industry in this period. Rest of the industries were more or less maintaining their same average TFP during this range of time period.

This composition changes in the year 2001. Electricity industry is no longer the prominent industry, barring year 2006. This is also because this industry has missing TFP values for the three years- 2001, 2003 and 2004. This problem of large missing values also makes the results for this industry, less reliable.

So, beginning in 2001, Mining industry gains prominence and it continues to garner a significant share in the years after 2001 till 2011, after which its share decreases slightly. Mining industry gains significant share in average TFP in years after 2000 which continues to follow this pattern till 2012. After 2012, this industry also loses its share as a prominent industry.

Miscellaneous manufacturing industry gains fillip in its average TFP in year 2001, however this increase wasn't long lived and is lost in year 2003. In the years after 2003, this industry sees almost a stagnating average TFP for the rest of the period of analysis till 2018.

The construction and real estate industry that is quite visible in the graph since 1991, follows closely with the height of the bars in the graph. That is, it is in consonance with the pattern followed by the overall industrial sector. But major upward spike is seen in year 2010, but this progress was not to be seen after 2012. However, in the years after 2012, this sector still continues to register its visibility on the graph.

Food and agro based industry also follow the pattern of overall average TFP, it gains a higher share in 2001 which continues to increase till 2004. It increases again in 2010 after a brief stagnation in between. After 2011, the sector again sees a drop which continues to decline till 2018.

It is noticeable that transport industry has gained significant prominence in years after 2001, and continues to be visible on the graph till 2018. In fact, it has the maximum share in average TFP in 2018 among all other industries.

4.4 TFP Trends and Method Suitability

In the previous sections, the three methods of calculation of TFP that this study has employed, were discussed and the estimated results outlined the similarities as well as the dissimilarities in the results yielded by these approaches. Figure 4.10 below, briefly sums up the results for the entire period of 1991 to 2018 of the three methods.

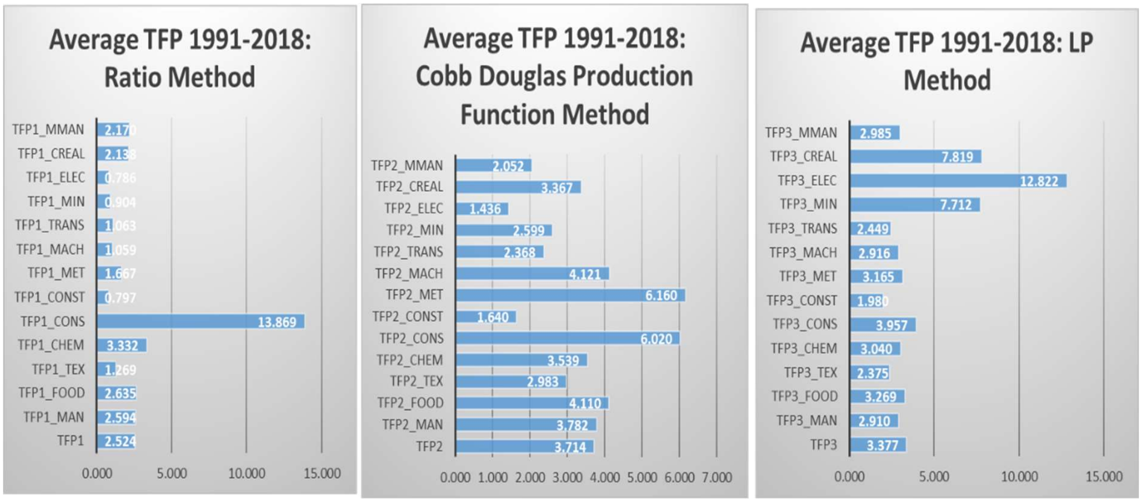
Whereas the Ratio method shows high concentration of TFP in consumer goods industry which stands as the only industry with high average TFP; the Cobb Douglas Production Function method of TFP calculation shows a mixed result with metals and metal products industry and consumer goods industry dominating the others in terms of high average TFP. The results as per the third method, LP approach again differ from the earlier two methods. LP method also shows a more distributed pattern of TFP as compared to the Ratio method. But here, other than the electricity, construction and real estate and mining industries, rest of the industries are broadly placed at the same level of average TFP.

If we compare the average TFP for the entire period, for all the firms, the Cobb Douglas Production Function approach gives the highest average TFP of 3.71. LP method estimation of TFP yields a close value of average TFP for the entire panel data with TFP measure of 3.38. Ratio method on the other hand gives the least average TFP of 2.52 for the complete sample.

The comparison between the three different measures of TFP is also done graphically as presented in Figure 4.11. We can see that TFP values as per the LP method lie somewhere in between the other two methods, and thus it can be said to be a balance of all the methods discussed in this study. The yellow trend line lies above the other two in the period 1991- 2000 and again in period between 2005- 2009.

2016 onwards, the TFP of industrial sector has been showing an upward movement as per the LP method. It is noticeable to see that the other two methods show a declining trend in average TFP in this stretch.

Figure 4-10: Average TFP for all industries as per the three different methods of estimation.

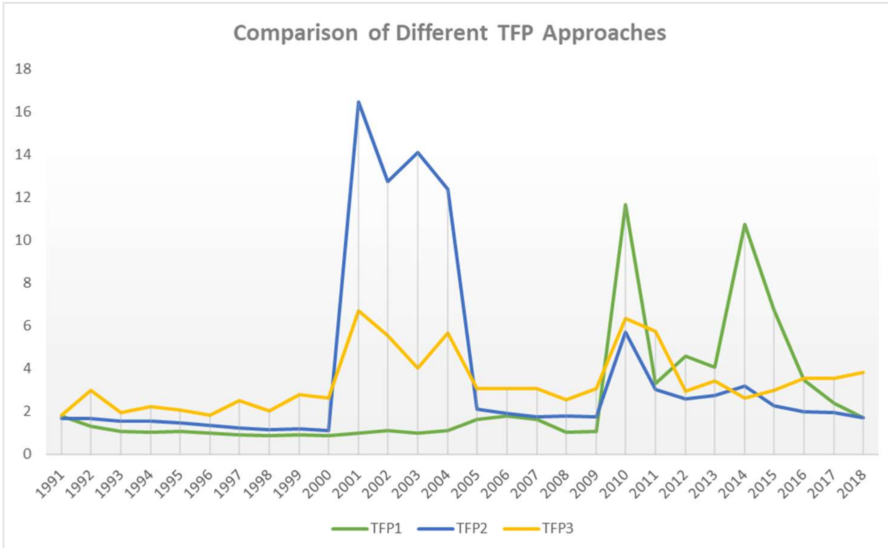


Also, the yellow trend line shows rather opposite results as compared to the results of the other two methods. For example, in the stretch of 1991 to 2000, while the other two trend lines show a stagnating pattern of average TFP, the LP method trend line shows spikes in this region of graph in Figure 11. It is also important to see that in the last decade of our analysis, the three trend lines show larger variations in results. Especially noticeable are the points at 2014, 2016 and the trend after 2016, where the yellow line shows opposite results to those of the other two trend lines. After 2016, the green and blue trend lines show a declining trend and converge in 2018, whereas the yellow trend line on the other hand shows an upward trend.

The blue trend line that shows the TFP measures calculated as per the Cobb Douglas Production Function approach. This blue line lies in between the other two measures in the period between 1991- 2000 and in the stretch between 2005- 2009. The blue trend line shows the highest average TFP measures in the period 2001-2004.

The ratio method on the other hand, shows a more or less stagnating pattern for almost two decades of our analysis, from 1991 to 2009. After 2009, the green trend line broadly lies above the other two trend lines in the figure.

Figure 4-11: Comparison of annual average TFP of the complete sample of 2,661 firms for the period 1991-2018.



Now, in order to select one method among the three methods of TFP calculation that we have employed in our analysis, it is important to look at the assumptions and the associated advantages of the methods. As per our literature review in this research, we had concluded that the Levinsohn and Petrin method is the most recent and appropriate method for estimating total factor productivity.

Following this logic, we are going to get ahead with adoption of LP method as the superior method among the three approaches to TFP estimation. Thus, we have used the results of LP method of TFP estimation in order to solve the other two research objectives undertaken to fulfil this research study. The second research objective takes the TFP of firms as the dependent variable and looks at various factors that may influence the TFP of a firm. The second research objective also looks at the effect of technology transfer on the TFP of a firm.

Chapter 5 Total Factor Productivity and Technology Transfer: An Analysis

This chapter is one of the crucial parts of the study as this chapter outlines the analyses undertaken to examine the second research question that helps in figuring out which factors, specific to the firms in the sample are able to relate the technology transfer process undertaken by the firm and its total factor productivity. This chapter describes and discusses the estimations and results obtained in pursuance of our second research objective.

5.1 Factors Affecting TFP of Firms

It is important to investigate the factors that govern and influence the spatial and temporal changes in productivity of the firms in Indian industrial sector. The research literature has been a diligent guide in pointing towards appropriate variables to be studied and looked at in our determination of the total factor productivity of the firms. Such a study is useful from the perspective of policy framework as this will help us in realising which variables influence productivity by a greater extent and hence, need to be enhanced in usage so as to further boost the productivity of the firms.

The objective of this part of the study is to look at the relationship between the level of TFP and the intensity of various factors that relate to the technology regime of the firm. This section gives shape to the second research objective of this study. The second research objective attempts to look at the various factors that are expected to affect the total factor productivity of the firms. In order to look at such factors, literature review has been the guiding light to pick out the probable determinants of TFP for a business entity. We have selected the variables in a manner such that we are able to find a relationship, if any, between the factors instrumental in the technology transfer process undertaken by a firm and its total factor productivity.

In order to so, we have employed the panel data regression methodology. It is appropriate because the data in our sample consists of both time series and cross-sectional elements. The 2,661 firms in our sample form the cross-sectional element of the data, and the time period from 1991 to 2018 constitutes the time series element in the analysis. This methodology has also been organised in Chapter 2 of this study. In order to look at our stated problem, the following regression model was estimated in STATA software:

$$TFP_{i,t} = \beta_0 + \beta_1 \text{ ageyr}_{i,t} + \beta_2 \text{ ln\_sales}_{i,t} + \beta_3 \text{ d\_f}_{i,t} + \beta_4 \text{ royalties\_i}_{i,t} + \beta_5 \text{ rnd\_i}_{i,t} + \beta_6 \text{ X\_i}_{i,t} + \beta_7 \text{ m\_raw\_i}_{i,t} + \beta_8 \text{ m\_k\_i}_{i,t} + \beta_9 \text{ for\_eq}_{i,t} + \varepsilon_{i,t} \quad (5.1)$$

All variables in the above regression model are same as described in the earlier section of this chapter. Under script (i,t) refers to the fact that that variable is for firm i at time t. The panel data was announced in STATA and it was found that the sample was strongly balanced.

Both fixed effects and random effects models were analysed and appropriate choice of model was made on the basis of Hausman Test and later confirmed with the results of Breusch Pagan Test or LM test. All of these statistical techniques have been described in Chapter 2.

For our analysis for full sample as well as that of different industries, the dependent variable is accordingly changed and is replaced by the TFP (calculated as per the LP method) relevant for the sample chosen for regression. The independent variables are either taken in intensity form or in percentage share form. This was done as per the need of the sample. Few samples didn't show results with variables in intensity form. This happened because of the problem of collinearity (as also indicated by the software). But regression results were produced with transformation of the variables (as it is also a remedy to the problem of collinearity). So, we were able to look at the relationship of our objective. This distinction is made in the discussion below, wherever a different model is specified. It would be appropriate to describe two models: one with independent variables in intensity form and another, with independent variables in percentage share form. The former is described as Equation (1) and the second model is described as Equation (2). Thus, Equation (2) will be:

$$TFP_{i,t} = \alpha_0 + \alpha_1 \text{ ageyr}_{i,t} + \alpha_2 \text{ ln\_sales}_{i,t} + \alpha_3 \text{ d\_f}_{i,t} + \alpha_4 \text{ royalties1}_{i,t} + \alpha_5 \text{ rnd1}_{i,t} + \alpha_6 \text{ X1}_{i,t} + \alpha_7 \text{ mraw1}_{i,t} + \alpha_8 \text{ mkg1}_{i,t} + \alpha_9 \text{ for\_eq}_{i,t} + \mu_{i,t} \quad (5.2)$$

In Tables 5.15 and 5.16, we present the summary of all the estimation results for the full sample as well as the results for different industries in our analysis. The Wald-chi square statistics were found to be significant at 1% as well as 5% level of significance for all the regression equations. This indicates that the regression models were significantly specified overall and the independent variables are able to explain for the variations in our dependent variables for the respective models. In this section, we present the estimation results for the regressions where the TFP of the concerned sample (full sample and industry wise samples) was regressed on different independent variables that may or may not exercise any influence on the TFP of the firm in the sample. Findings from the respective sample estimations have been described in the following sections.

5.2 Full Sample

The regression for the complete sample was done by estimation equation (5.1) with dependent variable TFP3 and the independent variables in intensity form. The estimates are shown in the Table 5.1 with the related standard errors being mentioned in the bracket under them. Similar pattern is followed for the industry samples also and in further chapter too.

Table 5.1: Estimation results for the full sample[13].

	Constant	ageyr	ln_sales	d_f	royalties_i	rnd_i	X_i	m_raw_i	m_k_i	for_eq
All Industries	2.389*** (1.007)	- 0.029*** (0.011)	0.070 (0.113)	0.828* (0.596)	10.501*** (1.546)	12.396 (17.346)	0.539* (0.535)	-1.052* (0.842)	0.625 (1.761)	- 0.021*** (0.005)

It is observed that age of the firm has a negative significant impact on its total factor productivity. That implies that younger firms tend to have high TFP. This is in consonance with most of the studies in our literature review.

Size of the firms appears to be irrelevant from the perspective of any effect on TFP.

Foreign private firms tend to have a positive influence on the TFP of the firm. Though this result is significant at 10% level of significance, it is important to see that presence of foreign entity gives a fillip to the TFP of a firm, thereby establishing a relation between technology transfer from the foreign parent company, and the TFP of the firm in India.

Expenditure on royalties, which is a form of technology transfer, is highly significant and positive. Thus, for the industrial sector as a whole, expenditure on royalties and know-how, helps with improvement in TFP of the firms.

Firms' own research and development expenditure on the other, though seems to be irrelevant in determining the TFP of the firms.

[13] ***indicates that variables are significant at 1% level of significance.

** indicates that variables are significant at 5% level of significance.

* indicates that variables are significant at 10% level of significance.

Firms that produce for exports seem to gain from the technology acquired in the process of production of goods that cater to the foreign demand. Thus, high export orientation seems to positively influence the TFP of a firm in a significant manner.

Import of raw materials for production yields as negative impact on the firms' productivity. This result is significant at 10% level of significance. This form of technology transfer thus, doesn't help with the motive of improvement of TFP of a firm in the Indian industry.

Import of capital goods on other hand, which is also a form of embodied technology transfer doesn't seem to have any influence on TFP of the firm in this sample.

Another important point to be noted is that the higher the share of foreign promoters to firm's total equity actually has a significant negative impact on its TFP. This variable is also taken as the indicator of foreign presence in our analysis. This is different from the variable about the ownership of firm where we have categorised firms as Indian or Foreign Private. The former then refers to the business entity that is wholly owned by a foreign party. The ownership variable was also significant in this analysis, however, that variable had a positive influence on the TFP of the firm.

Thus, for the full sample, technology transfer seems to have a mixed effect on the TFP of firm. While expenditure on royalties and ownership as foreign private firm and high export orientation leads to a positive influence on the TFP of a firm, at the same time, import of raw materials as well as presence of foreign promoters causes its TFP levels to decline. It is also noticeable to see that the firm's own R and D expenditure doesn't seem to significantly affect the TFP.

5.3 Industry wise Analysis

In this section we discuss the estimation results of the 13 industries, other than the full sample of our analysis. These regressions were estimated with TFP of that particular industry as the dependent variable and the related firm specific as well as its technology transfer related variables as the independent variables. For few of these industries Equation (5.2) was estimated in order to get meaningful results after transformation of variables in percentage forms. The distinction is subsequently made and discussed under each industry heading.

5.3.1 Manufacturing Industry

Panel regression estimation for this industry was done with Equation (5.1) and the results have been summarised in Table 5.2.

Table 5.2: Estimation Results for Manufacturing Industry.

Manufacturing	Constant	ageyr	ln_sales	d_f	royalties_i	rnd_i	X_i	m_raw_i	m_k_i	for_eq
	2.489*** (1.050)	-0.030*** (0.011)	0.069 (0.116)	0.783* (0.625)	10.440*** (1.590)	11.440 (18.494)	0.531 (0.549)	-1.071* (0.875)	0.652 (1.807)	-0.020*** (0.005)

As expected from the literature review, younger firms are more likely to register higher TFP as compared to the older firms. This result is highly significant and is indicative of the fact that of all the firms that have been in existence since before the 1991 reforms, the firms that lesser in age have been able to take greater advantages of the perks offered by the reforms.

Size of the firm is not statistically significant variable in our analysis.

If the firm is categorised as Foreign Private in the database, it is highly likely that it will have greater TFP as compared to the Indian firms (private as well as government owned). This result is significant. However, opposite result is observed in case of firms that have higher foreign equity shares in this industry. This result statistically significant. Thus, Indian manufacturing firms that have foreign presence are likely to have low TFP. However, firms that are completely owned by foreign enterprises are likely to have high TFP. This is noticeable because this result shows the discrimination by foreign business entities between their own firms and the Indian firms. They are more likely to invest more and cause greater TFP in firms that they own completely.

Any expenditure on royalties and know-how, is expected to positively influence the TFP of a firm in this industry. This is highly significant result and emphasis may be laid on this expenditure as it increases the TFP of a firm to a great extent. Thus, those firms that participate in technology transfer process, are more likely to gain high on TFP ground, if they invest in royalties. Import of raw materials though tend to have negative significant influence on the TFP of a manufacturing firm. Thus, firms may refrain from using this channel of technology transfer. Import of capital goods is not likely to affect the TFP of a firm as this result isn't statistically significant in our analysis.

R and D expenditure undertaken by such a firm is not a statistically significant variable in our analysis. Same result is secured for export orientation variable also.

5.3.2 Food and Agro Based Products

The estimation for this industry was also done by using Equation (5.1) as described before in this Chapter.

Table 5.3: Estimation results for the Food Industry.

Food and Agro Based	Constant	ageyr	ln_sales	d_f	royalties_i	rnd_i	X_i	m_raw_i	m_k_i	for_eq
	-2.675	0.003	0.181	-3.993	21.997	366.312	3.953	10.813	-42.995	0.021
	(9.529)	(0.126)	(0.839)	(12.102)	(29.900)	(444.246)	(26.603)	(15.100)	(60.680)	(0.057)

Results from the regression indicate that none of the variables were found to be statistically significant in our analysis at even 10% level of significance. However, we can still discuss the results with significance of the signs of the independent variables.

Technology transfer through expenditure on royalties and know- how; export orientation and import of raw materials is likely to cause an upward movement in the levels of TFP of the firms in this industry.

However, import of capital goods causes TFP levels to decline. This might be so because this industry is largely primary and hence labour intensive. Thus, capital goods import might not reflect best on the TFP of the firm. Rather, it would be interesting to look if any change in skills of the labour employed in this industry can lead to any change in its TFP levels.

The influence of ownership variable and presence of foreign equity are again in opposite directions in this industry too. Firms with high foreign equity in this industry are likely to gain on TFP levels. But the firms that are privately owned by foreign entities are likely to lose market in this industry. This is indicative of the fact that foreign firms are still struggling to get market space in case of Food and Agro based products.

Investment in R and D has a great impact on the TFP of a firm here and it comes out as the strongest cause for TFP improvement of the firm in this industry. This might be indicating that own research in this industry may be more emphasised in order to gain higher TFP levels.

Firm specific variables like age of the firm display a positive relationship with TFP. Thus, older firms are more likely to have high TFP as compared to the younger firms. Also, larger firms will tend to have more TFP levels as compared to smaller firms in this industry.

5.3.3 Textiles Industry

Estimation for this industry is done by regressing Equation (5.2) as described above.

Table 5.4: Estimation results for the Textiles Industry.

Textiles	Constant	ageyr	ln_sales	d_f	royalties1	rnd1	X1	mraw1	mkg1	for_eq
	5.590***	-0.0251*	-0.295*	11.383***	0.155	-0.051	-0.011	-0.028*	-0.001	-
	(1.616)	(0.021)	(0.188)	(4.546)	(0.228)	(0.112)	(0.012)	(0.026)	(0.059)	0.172***

										(0.049)

It is seen from the Table 5.4 that younger and smaller firms are more likely to gain higher TFP as compared to older and larger firms in this industry. This is indicative of the importance of small and medium scale enterprises in this industry in India.

Privately owned foreign firms are more likely to have high TFP as compared to Indian firms. Also, higher share of foreign equity in a firm will negatively impact the TFP in this industry. Only import of raw materials is supposed to have significant influence on TFP of the firm. But the impact is negative and thus, import of raw materials for this industry may not be encouraged.

Rest of the variables have insignificant influence on TFP of textile firms. Though expenditure on royalties is the only channel of technology transfer that seems to positively influence TFP of the firm.

5.3.4 Chemicals and Chemical Products Industry

The results for this industry were produced by regressing Equation (5.1) with TFP of this industry taken as the dependent variable in our analysis.

Table 5.5: Estimation results for the Chemicals Industry.

Chemicals and Chemical Products	Constant	ageyr	ln_sales	d_f	royalties_i	rnd_i	X_i	m_raw_i	m_k_i	for_eq
	3.324* (2.372)	0.206*** (0.042)	-2.081*** (0.347)	-5.630** (3.13)	16.250 (27.151)	-32.199 (65.176)	19.419*** (5.756)	-11.201* (8.601)	-12.543* (10.718)	0.289*** (0.062)

Older firms are more likely to have higher TFP than newer firms in this industry. Also, bigger firms seem to have a disadvantage in term of size as they are more likely to stuck with low levels of TFP as compared to that of smaller firms in Chemicals industry.

Firms with higher foreign equity are more likely to have higher TFP here. On the other hand, it is also shown that firms that are completely owned by a foreign entity are likely to have less TFP than the Indian firms.

Imports of raw materials and capital goods seem to have a negative influence on TFP of the firm. Thus, these channels of technology transfer may be refrained from.

Export orientation has strong significant positive influence on the TFP of a firm here. Thus, more and more production for exports may be encouraged in order to have better TFP levels.

Expenditure on royalties though statistically insignificant, will most likely have a positive influence on the productivity of the firm. Also, firm's own expenditure on R and D causes a negative impact on its TFP. Though this result is statistically insignificant.

5.3.5 Consumer Goods Industry

This industry was analysed by using Equation (5.2).

Table 5.6: Estimation results for the Consumer Goods Industry.

	Constant	ageyr	ln_sales	d_f	royalties1	rnd1	X1	mraw1	mkg1	for_eq
Consumer Goods	1.734*** (0.388)	-0.015** (0.007)	-0.003 (0.043)	0.852** (0.389)	0.042*** (0.017)	0.006 (0.130)	0.002 (0.003)	-0.005** (0.003)	0.021 (0.031)	-0.001 (0.003)

Expenditure on royalties seems to be the major mode of technology transfer for this industry in our analysis, that has led to higher TFP of the firms. Import of raw materials on the other hand, led to a decline in the TFP levels of the firms. It is also shown that newer firms have been more likely to register higher values of TFP, also, smaller firms might have given scope of better TFP levels. But the latter result is statistically insignificant.

In case the firm is owned by a foreign private entity, it is likely that it has greater TFP measure than the Indian firms.

Investment in own R and D, export orientation and import of capital goods on the other hand are likely to encourage higher TFP in our analysis, but these results have been statistically insignificant. Presence of foreign equity in a firm is also a likely cause of low productivity levels, however, this result is insignificant too.

5.3.6 Construction Materials Industry

Equation (5.2) was again taken as the template for estimation for this industry.

Table 5.7: Estimation results for the Construction Materials Industry.

	Constant	ageyr	ln_sales	d_f	royalties1	rnd1	X1	mraw1	mkg1	for_eq
Construction Materials	3.294*** (1.016)	-0.007** (0.004)	-0.234** (0.111)	1.779*** (0.342)	26.801*** (1.822)	-48.657 (43.649)	-0.318 (0.463)	-0.889 (1.048)	-6.499 (6.411)	-0.021*** (0.003)

Greater presence of foreign equity in a firm in this industry is likely cause a decline in the TFP of the firm. Expenditure on royalties on the other hand, might have been the major source of technology transfer for this industry that has led to positive influence on the TFP. In case the firm is privately owned by a foreign entity, it is likely to register high levels of TFP. Similarly, firms that were relatively younger in our analysis were able to secure higher TFP than the older firms. Even smaller firms have been more likely to have better TFP levels as compared to the bigger firms.

Other channels of technology transfer like investment in r and D, export orientation of the firm, import of raw materials and import of capital goods appear to have a negative influence on the level of TFP of the firms. These last results however, are statistically insignificant in our analysis.

5.3.7 Metals and Metal Products Industry

This industry was also analysed by using Equation (5.2) in our analysis.

Table 5.8: Estimation results for the Metal Industry.

	Constant	ageyr	ln_sales	d_f	royalties1	rnd1	X1	mraw1	mkg1	for_eq
Metals and Metal Products	-25.536*** (8.368)	-0.168 (0.171)	5.259*** (1.010)	0 (omitted)	0.223 (0.819)	0.305 (2.166)	0.0003 (0.005)	-0.087 (0.092)	-0.067 (0.430)	-0.168** (0.085)

Bigger firms are more likely to have high TFP values in this industry. This is expected also because metals industry is important from the point of view of the development aspirations of an economy and such industry needs high amounts of investment that can be undertaken by bigger firms in a more efficient manner as compared to small firms.

Presence of higher proportion of foreign equity is likely influence the TFP of the firm in a negative manner in this industry. Thus, the development of this industry may be undertaken with regards to this estimation result. This seems to be the only statistically significant mode of technology transfer available to this industry.

Rest of the variables were found to be statistically insignificant. Younger firms are more likely to succeed with higher TFP levels than older firms. also, expenditure on royalties; R and D of the firm and its export orientation are likely to cause a positive influence on the TFP of the firm. On the other hand, import of raw materials and capital goods are highly likely to cause a decline in the value of its TFP.

The variable about ownership of the firm was dropped during estimation because of collinearity.

5.3.8 Machinery Industry

Regression results were produced for this industry by using Equation (5.1) in our analysis.

Table 5.9: Estimation results for the Machinery Industry.

Machinery	Constant	ageyr	ln_sales	d_f	royalties_i	rnd_i	X_i	m_raw_i	m_k_i	for_eq
	4.460*** (1.595)	0.023* (0.017)	-0.170* (0.144)	0.037 (1.097)	5.183** (2.795)	- 140.270*** (43.259)	-0.711 (1.838)	-3.799** (1.999)	-31.376 (31.024)	- 0.032** (0.017)

It seems that investment in R and D hasn't been useful for this industry. Thus, the firm here needs to utilise its funds elsewhere rather than investing in research and development. Expenditure on royalties seems to have been the only favourable mode of technology transfer for this industry. Import of raw materials too is likely to have caused a decline in TFP levels of the firms. Same is the case with higher share of foreign equity in the firms in this industry.

Export orientation and import of capital goods seem to have led to a decline in TFP of the firms, but these results weren't found to be statistically significant in our model.

Same is the case with ownership variable, but it seems to have a positive impact on TFP of the firm.

Also, older firms have been more likely to have higher TFP in this industry that the younger firms. This industry is more likely to produce smaller firms with better TFP levels as compared to the bigger firms.

5.3.9 Transport Equipment Industry

Again, Equation (5.1) was used to guide us to analyse this industry in our quest for addressing objective 1. This is one industry, whose regression estimation yielded all statistically significant results.

Table 5.10: Estimation results for the Transport Equipment Industry.

Transport Equipment	Constant	ageyr	ln_sales	d_f	royalties_i	rnd_i	X_i	m_raw_i	m_k_i	for_eq
	0.901*** (0.294)	0.011*** (0.002)	- 0.052** (0.028)	- 1.399*** (0.143)	8.956*** (0.943)	- 9.396* (5.533)	3.216*** (0.656)	- 1.369*** (0.483)	- 0.935*** (0.379)	0.016*** (0.002)

Greater presence of foreign equity in the firm of this industry causes a positive significant influence on its TFP. However, firms that are privately owned by foreign business entities aren't likely to garner much gain in in their levels of productivity than the Indian firms.

It is also evident that older firms are more likely to have higher TFP than the younger firms in our analysis. Also, smaller firms will be able to register more TFP than bigger firms here.

Expenditure on royalties and know-how and high export orientation of the firms have led to higher TFP in our period of analysis. But import of raw materials hasn't been a cause of higher TFP in this industry. Thus, this channel of technology transfer may not be encouraged in this industry. Greater import of capital goods hampers the TFP of the firms in this industry.

It is also seen that investment in own R and D is most likely to decrease the productivity of this industry. Thus, emphasis may be laid on the other modes of technology acquisition in case of this industry. This result is important because automobile sector, which is a technologically driven industry and is also a source of high GDP for Indian economy, is a part of this industry in our analysis.

5.3.10 Mining Industry

Equation (5.2) was used to look at the relationship between TFP and other variables for this industry.

Table 5.11: Estimation results for the Mining Industry.

Mining	Constant	ageyr	ln_sales	d_f	royalties1	rnd1	X1	mraw1	mkg1	for_eq
	-9.051** (3.924)	0.086** (0.043)	1.485*** (0.493)	-5.990*** (1.764)	-0.054 (0.163)	-8.416* (5.371)	0.133* (0.102)	-0.051 (0.368)	-2.392 (2.952)	0.051*** (3.924)

Higher proportion of foreign equity is likely to have caused higher TFP in our period of analysis. However, if the firm is privately owned by a foreign entity, it is likely to have lost TFP gains as compared to the Indian firms.

It is evident that older firms had gained over the cost of newer firms in the three-decade period of our study. Also, bigger firms are more likely to register higher TFP levels in this industry.

Greater export orientation of firms is more likely to have encouraged TFP improvement in our analysis. Investment in R and D though, has led to decline in the productivity of the firms. other modes of technology transfer such as expenditure on royalties, import of raw materials and capital goods have led to decline in TFP values for firms. This result is however, statistically insignificant.

5.3.11 Electricity Industry

This industry was analysed by using Equation (5.2) in our study.

Table 5.12: Estimation results for the Electricity Industry.

Electricity	Constant	ageyr	ln_sales	d_f	royalties1	rnd1	X1	mraw1	mkg1	for_eq
	3.247*** (0.596)	-0.013** (0.007)	-0.183*** (0.076)	0 (omitted)	0.229 (3.904)	0 (omitted)	0.053** (0.023)	0.068 (0.173)	-0.824 (0.956)	-0.007 (0.391)

Results show that firms with high export orientation are more likely to have greater TFP levels. This also seems to be the only statistically significant mode of technology transfer in our analysis.

Other channels of technology transfer such as expenditure on royalties and know-how and import of raw materials are expected to drive up the TFP. But these results are insignificant in this analysis. Similarly, import of capital goods is found to cause a negative influence on TFP of the firms. This result is also statistically insignificant.

Firms with high foreign equity are likely to have low TFP in this industry in India. Even though this result too is insignificant, this still guides us to indicate that government is better placed to continue its investments in this industry.

Variables related to R and D and ownership of firms were omitted because of collinearity. This was also because of very few firms in this sample of analysis.

Firm specific variables indicate that younger and smaller firms are more likely to gain higher TFP levels as compared to older and bigger firms in this industry. Both these results are statistically significant in this study.

5.3.12 Construction and Real Estate Industry

Regression results for this industry were produced by using Equation (5.2).

Table 5.13: Estimation results for the Construction and Real Estate Industry.

Construction and Real Estate	Constant	ageyr	ln_sales	d_f	royalties1	rnd1	X1	mraw1	mkg1	for_eq
	-47.541*** (8.838)	0.483*** (0.132)	3.343*** (0.660)	0 (omitted)	0.848* (0.535)	0.305 (2.122)	0.042* (0.033)	-0.057* (0.049)	-0.001 (0.026)	0.085** (0.042)

Estimation shows that older firms are more likely to statistically register higher TFP values as compared to newer firms in this industry. Also, bigger firms will tend to have higher TFP than smaller ones.

Firms with higher foreign equity are more likely to succeed with high TFP levels statistically and thus foreign players may be encouraged to invest in this industry.

Among the channels of technology transfer, expenditure on royalties and high export orientation are expected to increase the TFP levels significantly. While both import of raw materials as well that of capital goods is likely to decrease the TFP of firms, only the former variable is set to do so statistically significantly.

Firm's expenditure on research and development is expected to increase the TFP by a marginal amount, though the result is insignificant.

The variable indicating foreign ownership was omitted while estimating the model because of collinearity.

5.3.13 Miscellaneous Manufacturing Industry

We looked at this industry for our analysis by using Equation (5.2).

Table 5.14: Estimation results for the Miscellaneous Manufacturing Industry.

	Constant	ageyr	ln_sales	d_f	royalties1	rnd1	X1	mraw1	mkg1	for_eq
Miscellaneous Manufacturing	5.170*** (0.857)	-0.034*** (0.010)	- 0.176** (0.095)	-0.886 (1.724)	0.075** (0.041)	-0.436 (0.667)	-0.007* (0.004)	-0.006 (0.009)	-0.009 (0.011)	0.001 (0.005

It was observed that the firm specific variables- age, size and export orientation, were found to be statistically significant and caused a negative influence on the TFP of the firm in this industry. Thus, younger firms tend to have more TFP as compared to the older firms. Also, here, smaller firms are more likely to skirt away the inefficiencies caused by managerial bottlenecks perhaps. Firms that are privately owned by foreign entities are less likely to register high TFP levels here. But this result is insignificant. Also, presence of foreign equity in a firm in this industry is likely to register higher TFP but again, this result too is statistically insignificant.

Expenditure on royalties seems to be the only channel of technology transfer that leads to positive significant influence on TFP of the firm in this industry. R and D investment; import of raw materials as well as that of capital goods are likely to reduce the TFP levels of the firms. But these results aren't statistically significant as per our study.

5.4 APPENDIX FOR CHAPTER 5

Table 5.15: Estimation results for Total Factor Productivity of firms in different sub-samples of data, as a function of various factors related to the technology regime of the firms where the independent variables have been taken in intensity form as described in Equation (5.1).

Sl. No.	Industry	Constant	ageyr	ln_sales	d_f	royalties_i	rnd_i	X_i	m_raw_i	m_k_i	for_eq
1	Manufacturing	2.489*** (1.050)	-0.030*** (0.011)	0.069 (0.116)	0.783* (0.625)	10.440*** (1.590)	11.440 (18.494)	0.531 (0.549)	-1.071* (0.875)	0.652 (1.807)	-0.020*** (0.005)
2	Food and Agro Based Products	-2.675 (9.529)	0.003 (0.126)	0.181 (0.839)	-3.993 (12.102)	21.997 (29.900)	366.312 (444.246)	3.953 (26.603)	10.813 (15.100)	-42.995 (60.680)	0.021 (0.057)
3	Chemicals and Chemical Products	3.324* (2.372)	0.206*** (0.042)	-2.081*** (0.347)	-5.630** (3.13)	16.250 (27.151)	-32.199 (65.176)	19.419*** (5.756)	-11.201* (8.601)	-12.543* (10.718)	0.289*** (0.062)
4	Machinery	4.460*** (1.595)	0.023* (0.017)	-0.170* (0.144)	0.037 (1.097)	5.183** (2.795)	-140.270*** (43.259)	-0.711 (1.838)	-3.799** (1.999)	-31.376 (31.024)	-0.032** (0.017)
5	Transport Equipment	0.901*** (0.294)	0.011*** (0.002)	-0.052** (0.028)	-1.399*** (0.143)	8.956*** (0.943)	-9.396* (5.533)	3.216*** (0.656)	-1.369*** (0.483)	-0.935*** (0.379)	0.016*** (0.002)
6	All Industries (Complete Sample)	2.389*** (1.007)	-0.029*** (0.011)	0.070 (0.113)	0.828* (0.596)	10.501*** (1.546)	12.396 (17.346)	0.539* (0.535)	-1.052* (0.842)	0.625 (1.761)	-0.021*** (0.005)

Table 5.16: Estimation results for regression Equation (5.2) with dependent variable Total Factor Productivity of firms in different sub- samples of data, as a function of various factors related to the technology regime of the firms expressed in percentage share form.

Sl. No.	Industry	Constant	ageyr	ln_sales	d_f	royalties1	rnd1	X1	mraw1	mkg1	for_eq
1	Textiles	5.590*** (1.616)	-0.0251* (0.021)	-0.295* (0.188)	11.383*** (4.546)	0.155 (0.228)	-0.051 (0.112)	-0.011 (0.012)	-0.028* (0.026)	-0.001 (0.059)	-0.172*** (0.049)
2	Consumer Goods	1.734*** (0.388)	-0.015** (0.007)	-0.003 (0.043)	0.852** (0.389)	0.042*** (0.017)	0.006 (0.130)	0.002 (0.003)	-0.005** (0.003)	0.021 (0.031)	-0.001 (0.003)
3	Construction Materials	3.294*** (1.016)	-0.007** (0.004)	-0.234** (0.111)	1.779*** (0.342)	26.801*** (1.822)	-48.657 (43.649)	-0.318 (0.463)	-0.889 (1.048)	-6.499 (6.411)	-0.021*** (0.003)
4	Metals and Metal Products	-25.536*** (8.368)	-0.168 (0.171)	5.259*** (1.010)	0 (omitted)	0.223 (0.819)	0.305 (2.166)	0.0003 (0.005)	-0.087 (0.092)	-0.067 (0.430)	-0.168** (0.085)
5	Mining	-9.051** (3.924)	0.086** (0.043)	1.485*** (0.493)	-5.990*** (1.764)	-0.054 (0.163)	-8.416* (5.371)	0.133* (0.102)	-0.051 (0.368)	-2.392 (2.952)	0.051*** (3.924)
6	Electricity	3.247*** (0.596)	-0.013** (0.007)	-0.183*** (0.076)	0 (omitted)	0.229 (3.904)	0 (omitted)	0.053** (0.023)	0.068 (0.173)	-0.824 (0.956)	-0.007 (0.391)
7	Construction and Real Estate	-47.541*** (8.838)	0.483*** (0.132)	3.343*** (0.660)	0 (omitted)	0.848* (0.535)	0.305 (2.122)	0.042* (0.033)	-0.057* (0.049)	-0.001 (0.026)	0.085** (0.042)
8	Miscellaneous Manufacturing	5.170*** (0.857)	-0.034*** (0.010)	-0.176** (0.095)	-0.886 (1.724)	0.075** (0.041)	-0.436 (0.667)	-0.007* (0.004)	-0.006 (0.009)	-0.009 (0.011)	0.001 (0.005

Chapter 6 R&D And Technology Transfer: Complements or Substitutes?

This chapter analyses the relationship between technology transfer (various modes of it that we have discussed in the previous chapter) and a firm's own expenditure on research and development of new products and techniques of production. The analysis in this chapter is done by using Heckman Two Step Procedure, as described in Chapter 2 earlier. Estimation results for both the steps in the analysis for Heckit estimation are described and discussed in this chapter at length.

6.1 Relationship Between R&D and Technology Transfer

After having looked at the first research objective, we now turn to the second objective of our study. We now attempt to look at the nature of relationship between a firm's own R and D and the process of technology transfer undertaken by it. In order to examine this, we have employed the Heckman Two Step Procedure. This procedure involves two steps in our analysis. The first step looks at the factors that might influence the decision made in order to undertake investment in R and D.

To estimate this, the variable DRD is taken as the independent variable. This is a dummy variable that takes on value 1 for firms that undertake R and D, and 0 for firms that do not invest in R and D. this dependent variable is specified for the full sample as well as different industries as per the requirement of the sample that we are regressing. For this step, the following regression equation was estimated:

$$DRD_{i,t} = b_0 + b_1\, ageyr_{i,t} + b_2\, ln\_sales_{i,t} + b_3\, d\_f_{i,t} + b_4\, royalties\_i_{i,t} + b_5\, X\_i_{i,t} + b_6\, m\_raw\_i_{i,t} + b_7\, m\_k\_i_{i,t} + b_8\, for\_eq_{i,t} + e_{i,t} \qquad (6.1)$$

All the variables in the above equation have the same meaning as described earlier in Section. It is also to be noted that the independent variables in Equation (6.1) are in intensity form. For few industry samples, these variables were transformed into percentage share form in order to get estimation results in STATA, because Equation (6.1) omitted most of the variables in regression model. Thus, after transformation, the regression model becomes as following:

$$DRD_{i,t} = a_0 + a_1\, ageyr_{i,t} + a_2\, ln\_sales_{i,t} + a_3\, d\_f_{i,t} + a_4\, royalties1_{i,t} + a_5\, X1_{i,t} + a_6\, mraw1_{i,t} + a_7\, mkg1_{i,t} + a_8\, for\_eq_{i,t} + u_{i,t} \qquad (6.2)$$

Both equations (6.1) and (6.2) help us find out the factors that influence the decision of the firms to undertake investment in R and D. This is an important step in our analysis, as this will guide us in predicting as to which firms are more likely to invest in R and D. Since R and D is a crucial method of technology acquisition, it is pertinent to look at the factors that might encourage or discourage a firm in this direction. This is the selection model, wherein decision to select which firms decide to invest in R and D takes place.

Estimation results for various samples for equation (6.1) and (6.2) have been summarised in Tables 6.1, 6.2, 6.3 and 6.4, at the end of this chapter. The discussion of these results will take place together with the estimation of the second step of Heckman Two Step Procedure.

After the first step, we then turn to look at the relationship between R and D investment and the various channels of technology transfer for those firms that actually invest in R and D. This is the outcome model, implying that it tells us about the nature of relationship between R and D and other channels of technology transfer for the firms in our sample that actually decided to undertake R and D investment. This is estimated using the regression equation as given below:

$$rnd\_i_{i,t} = c_0 + c_1\, ageyr_{i,t} + c_2\, ln\_sales_{i,t} + c_3\, d\_f_{i,t} + c_4\, royalties\_i_{i,t} + c_5\, X\_i_{i,t} + c_6\, m\_raw\_i_{i,t} + c_7\, m\_k\_i_{i,t} + c_8\, for\_eq_{i,t} + \Omega_{i,t} \quad (6.3)$$

all variables in the above regression equation have been taken as described in the earlier section. The independent variables in this equation that relate to the technology regime of the firm, have been taken in the form of intensity of the sales turnover. This has also been described in the same section earlier. This has been named as Equation (6.3).

In the process, few regression equations for some of industry samples yielded omitted variables in the estimation results. This happened because of the problem of collinearity. To get rid of the problem, the independent variables were transformed into percentage shares of sales turnover of the firms. This transformed regression equation can be stated as Equation (6.4), as below:

$$rnd1_{i,t} = d_0 + d_1\, ageyr_{i,t} + d_2\, ln\_sales_{i,t} + d_3\, d\_f_{i,t} + d_4\, royalties1_{i,t} + d_5\, X1_{i,t} + d_6\, mraw1_{i,t} + d_7\, mkg1_{i,t} + d_8\, for\_eq_{i,t} + \pi_{i,t} \quad (6.4)$$

the variables have also been described in an earlier section as stated. This transformation is just similar to the regressions done in our analysis earlier. This entire process is done and repeated for the full sample as well as the 13 industries in our analysis. The details of the estimated results for both steps of the Heckman Two Step Procedure have been discussed together for the respective samples in the sections that follow. Also, the summary of estimation results for Equations (6.1), (6.2), (6.3) and (6.4) has been summarised in Tables 6.1, 6.2, 6.3 and 6.4.

6.1.1 Full Sample

In order to solve the second objective of our analysis, the Equation (6.1) and (6.3) were regressed for the complete sample of firms from all industries for the complete period of 1991-2018. The selection model in our full sample is regressed with decision to undertake R and D for all the firms as the dependent variable, with all other technology transfer related variables and firm specific variables being taken as the independent variables. This was done using Equation (6.1). Next step was to look at the factors affecting the R and D intensity of firms that actually undertook R and D investment was done using Equation (6.3).

Table 6.1: Heckit Estimation Results for All Industries (Complete Sample)

All Industries (Complete Sample)	Constant	ageyr	ln_sales	d_f	royalties_i	X_i	m_raw_i	m_k_i	for_eq
Step 1	0.691** (0.270)	-0.005** (0.002)	0.008 (0.029)	0.366*** (0.137)	0.571* (0.437)	-0.285* (0.165)	0.492* (0.313)	0.118 (0.513)	-0.005*** (0.002)
Step 2	0.010** (0.005)	0.0001*** (0.000)	-0.001** (0.001)	-0.004* (0.003)	-0.00002 (0.007)	-0.002 (0.003)	-0.009** (0.004)	0.018*** (0.007)	3.82e-06 (0.00002)

It was found that the private foreign ownership of a firm has a significant positive impact on the decision to undertake R and D investment. That means that foreign business entities tend to undertake R and D for better performance, as compared to the Indian firms. However, once the decision to spend on R and D is taken up, firms that are owned privately by foreign companies tend to have lesser intensity of R and D to their sales. Thus, the foreign private firms that decided in favour of spending on own R and D, had lesser extent of R and D expenditure as compared to that of the Indian firms.

Also, presence of foreign equity on the other hand, seems to negatively influence the decision to take up R and D investment. And once the decision is taken up, it was found that foreign equity participation has no significant effect on the final R and D investment undertaken by the firm.

We find that firms that spend on royalties and import raw materials from abroad are more likely to undertake R and D. In the outcome model however, it was observed that firms that finally took up R and D, seemed to rely less on import of raw materials from abroad as a means of technology transfer. This implies that firms which import raw materials from abroad, have lesser intensity of R and D in the production process. This means that the import of raw materials from abroad sort of substitutes the firm's own research. This might be so, because the raw materials would be either directly employed in the production or, very less research would be required to mould these imported raw materials to the firm's own local conditions. Hence, import of raw materials might be said to be substitute for firms own R and D investment. At the same time, the variable with respect to expenditure on royalties seemed to have no effect on the R and D expenditure of the firm.

Surprisingly, export orientation seems to negatively influence the decision to take up spending on R and D for the firms in this sample. Same result was observed for the outcome model too. Thus, export orientation tends to have no influence on the decision of the firm to take up R and D as well as the final R and D intensity of the firms that actually invest in their own research and development.

Import of capital goods didn't influence the decision to undertake R and D. That means that probability of spending on R and D isn't affected by the intensity of import of capital goods by the firm. However, the firms that import capital goods and also invested in research are more likely to have higher extent of R and D intensity. This is indicative of the fact that the sample has a complementary relationship between R and D expenditure and import of capital goods mode of technology transfer. For the rest of the channels of technology transfer, no concrete comments on the relationship aspect between the two variables can be made. Thus, it might be so that the firms that import capital goods from outside, complement it with their own research in order to produce new and innovative products.

From the results it is observed that younger firms are more likely to decide in favour for R and D expenditure as compared to older firms. This can be so because younger firms may have to learn and adapt with the change in technology in time. But in the outcome model, it was observed that older firms tend to have greater intensity of R and D than younger firms. This is indicative of the fact that older firms might learn with time and once they decide to invest in R and D, they tend to have more resources set up for own research.

Size of the firms doesn't seem to influence the decision to spend on R and D in case of full sample analysis. However, the outcome model specifications show that smaller firms are more likely to have greater extent of R and D as compared to larger firms.

6.2 Relationship between R and D and Technology Transfer for Different Industries

The following section discusses the estimation results of the second objective of our study. This section focusses on the results of the 13 industries in our analysis. These results are based on estimation of Equations (6.1), (6.2), (6.3) and (6.4) as per the demands of the sample in consideration. Both steps of the Heckman specification estimation model have been discussed for the respective industries.

6.2.1 Manufacturing Industry

The first step of the Heckman Two Step procedure for this industry was estimated using Equation (6.1) in our model with decision to decide in favour or against investing in R and D as the dependent variable in our analysis. The next step to look at relationship between R and D intensity and various forms of technology transfer was done by using Equation (6.3) as specified earlier.

Table 6.2: Heckit Estimation Results for Manufacturing Industry.

Manufacturing Industry	Constant	ageyr	ln_sales	d_f	royalties_i	X_i	m_raw_i	m_k_i	for_eq
Step 1	0.793*** (0.284)	-0.005** (0.002)	0.007 (0.031)	0.481*** (0.146)	0.462* (0.442)	- 0.554*** (0.209)	0.411* (0.329)	-0.046 (0.546)	- 0.007*** (0.002)
Step 2	0.011*** (0.005)	0.0001** (0.0001)	-0.001** (0.001)	-0.005* (0.003)	-0.0003 (0.007)	-0.002 (0.003)	- 0.010*** (0.004)	0.018*** (0.008)	0.0001 (0.0001)

Greater foreign equity participation as well as export orientation seems to discourage decision to undertake R and D investment for these firms. However, once the decision to undertake R and D is taken up by the firm in this industry, both these variables are found to be statistically insignificant in our analysis.

It is highly likely that firms which are privately owned by foreign business entities would decide in favour of R and D investment. But, in our outcome model we observed that the research and development intensity for such firms that are foreign private, is found to be lesser than that of the Indian firms. This is evident because these firms are relying on other modes of technology transfer, mainly by importing capital goods, such that they substitute research and development of products by such import of technology.

A firm that is spending on royalties and know- how would also decide in favour of investing in research for development of new products. However, there is no great difference in the research expenditure intensity of firms that spend on royalties and those that do not do so.

It is also observed that younger firms are more likely to make a decision of investment in R and D. However, the outcome model shows that older firms are likely to have greater extent of R and D spending than the younger firms.

Size doesn't seem to affect the selection model for this industry. But it seems that smaller firms are more likely to have a trend of greater intensity of research and development as compared to the bigger firms.

Import of capital goods turned out to be a statistically insignificant factor in encouraging a firm to invest in research and development in case of manufacturing industry. But it is a positive significant variable in our outcome model thereby implying that firms that import capital goods from abroad are going to have more R and D intensity than firms that do not do so. Thus, these firms are complementing their technology transfer process through import of capital goods with high intensity of research and development expenditure.

Import of raw materials seems to encourage the decision made in favour of research and development investment. In our outcome model, we see that this factor however tends to substitute the R and D expenditure of firms in this industry, in case the firm decides to opt for R and D investment.

6.2.2 Food and Agro Based Products

Our selection model for this industry was estimated by using Equation (6.1) with dependent variable DRD that takes value 1 if the firm invests in R and D and 0 otherwise. The next step, to estimate the outcome model for this industry was done by using Equation (6.3) with R and D intensity for the firm as the dependent variable. For both equations, the independent variables have been taken in intensity form as share of sales turnover.

Table 6.3: Heckit Estimation Results for Food Industry.

Food and Agro Based Products	Constant	ageyr	ln_sales	d_f	royalties_i	X_i	m_raw_i	m_k_i	for_eq
Step 1	2.692*** (0.584)	-0.009** (0.005)	-0.172*** (0.061)	-0.018 (0.163)	3.743*** (1.383)	-0.203 (0.719)	-2.170* (1.281)	20.699*** (6.885)	0.001 (0.003)
Step 2	0.018*** (0.005)	0.0001** (0.0001)	-0.002*** (0.0003)	0.005*** (0.002)	-0.034* (0.019)	-0.045*** (0.007)	0.014** (0.007)	0.087** (0.045)	-0.0001*** (0.00001)

Export orientation seems to be irrelevant in influencing the decision to undertake R and D investment for these firms. however, the outcome model shows that the firms that are export oriented are less likely to invest in R and D. The R and D intensity of such firms is lesser than the firms are not export oriented.

Also, firms' ownership as foreign private or Indian doesn't affect its decision about R and D investment. But it is observed that firms that the R and D intensity of the privately owned foreign firms is more than that of the Indian firms.

Spending on royalties and know- how is a highly significant variable in terms of encouraging the decision in favour of investing in research for development of new products in this industry. But in the outcome model, it seems that R and D intensity of the firms that spend on royalties and know-how is lesser than the firms that do not spend on royalties or opt for this mode of technology transfer. Thus, we conclude that R and D and expenditure on royalties are substitutes for food industry.

It is also observed that younger firms are more likely to opt for R and D investment. However, it is found that the older firms had greater extent of R and D investment as compared to the younger firms.

Firm's size seems to be a significant variable in decision making with regards to the selection model for this industry. It is observed that smaller firms are more likely to decide on investing in research and development as compared to bigger firms. in the outcome model also, small firms dominate in terms of higher R and D intensity than that of the bigger firms.

Import of capital goods is a highly significant variable that encourages investment in R and D in this sample. This variable complements the investment in R and D as firms that actually undertake R and D also have higher import of capital goods. Hence, the relationship between the two modes of technology acquisition is found to be one of complements.

Import of raw materials turned out to be statistically significant factor, but it discourages a firm from investing in research and development in case of this industry. However, for firms that decided to undertake R and D, had greater imports of raw materials. This relationship is also found to be complementary for the sample of data in consideration here.

Foreign equity participation seems to be irrelevant from the perspective of decision making in favour of investment in research and development in case of this sample. However, in the outcome model, it was observed that firms with higher foreign equity tend to have lower R and D intensity. Thus, foreign presence within the firm seems to discourage R and D investment in firms in India.

6.2.3 Textiles Industry

The selection model for firms in this industry has been estimated by using Equation (6.2) with DRD as the dependent variable and independent variables in intensity form. For the outcome mode, Equation (6.4) was estimated with R and D intensity in percentage form of sales of the firm, as the dependent variable. The technology regime related independent variables have also been specified in the form of percentage shares of sales of the firm.

Table 6.4: Heckit Estimation Results for Textiles Industry.

Textiles	Constant	ageyr	ln_sales	d_f	royalties1	X1	mraw1	mkg1	for_eq
Step 1	-0.021 (0.103)	0.001 (0.002)	0.019** (0.009)	-0.565*** (0.254)	-0.006* (0.006)	-0.0003 (0.001)	0.002* (0.001)	-0.002 (0.003)	0.007*** (0.002)
Step 2	0.932* (0.832)	-0.004 (0.013)	-0.043 (0.089)	-0.043 (1.983)	-0.023 (0.066)	-0.012* (0.007)	0.001 (0.014)	0.015 (0.031)	-0.005 (0.021)

The probability of deciding in favour of R and D investment by a firm in this industry happens to be positively influenced by its bigger size in market. This implies that larger firms will decide in favour of investing in R and D in this industry. In the outcome model however, size of the firms appears to be an insignificant variable in our sample in determining the R and D intensity of the firm.

It is also observed that if the firm is importing raw materials from abroad, then it is highly likely to invest in own research and development of new products. But this variable turned out to be insignificant in the outcome model in this sample.

If the firm is spending on royalties and know- how, then it is less likely that it will decide for investing in R and D. This channel of technology transfer however, was found to be irrelevant in determining the R and D intensity of the firm in our sample.

Foreign private ownership discourages a firm's decision in favour of research and development of new products. Ownership seemed to be a statistically insignificant variable in the outcome model in our analysis.

Export orientation as well as import of capital goods do not affect the decision of taking up R and D in our selection model. Latter variable was also found to be insignificant in the outcome model of our analysis. Export orientation on the other hand, seems to discourage R and D intensity in the firms. That means, that in textiles industry, more export producing firms are going to have lesser R and intensity than those firms that do not participate in export production.

Participation in foreign equity seems to be highly significant variable that encourages decision in favour of R and D investment for firms in this industry. The variable however, turned out to be statistically insignificant in the outcome model in our analysis.

6.2.4 Chemicals and Chemical Products

The first step of the Heckman Two Step procedure for this industry was estimated using Equation (6.1) in our model with decision to decide in favour or against investing in R and D as the dependent variable in our analysis. The next step to look at relationship between R and D intensity and various forms of technology transfer was done by using Equation (6.3) as specified earlier.

Table 6.5: Heckit Estimation Results for Chemicals Industry.

Chemicals and Chemical Products	Constant	ageyr	ln_sales	d_f	royalties_i	X_i	m_raw_i	m_k_i	for_eq
Step 1	1.485* (0.969)	-0.034*** (0.014)	0.132* (0.086)	0.881* (0.743)	14.023*** (3.910)	-0.496 (0.865)	-7.674** (3.659)	0.317 (4.115)	-0.022* (0.015)
Step 2	0.039** (0.017)	0.001*** (0.0001)	-0.009*** (0.002)	0.019* (0.012)	-0.017 (0.069)	0.039* (0.025)	0.137** (0.060)	0.079** (0.042)	-0.001* (0.0002)

If the firm is spending on royalties and know- how, then it is highly likely that it will decide in favour of investing in R and D in case of this sample. Spending on royalties however turned out to be irrelevant in case of determining the R and D intensity of the firm in this industry.

The probability of deciding in favour of R and D investment by a firm in this industry will be positively influenced by lesser age and bigger size in market. Thus, larger and younger firms are more likely to undertake investment in R and D. In the outcome model, it is observed that older firms tend to have greater extent of R and D intensity as compared to the younger firms. Also, R and D expenditure was found to be more for smaller firms than that of the bigger firms in case of this industry.

It is also observed that if the firm is importing raw materials from abroad, then it is less likely to invest in own research and development of new products. However, R and D intensity was found to be more for firms importing raw materials from abroad. The relationship between technology transfer through import of raw materials and R and D seems to be complementary with each other in this sample.

Foreign private ownership encourages firms to invest in R and D for this sample. It is also observed that privately owned firms by any foreign business entity tend to have more R and D intensity than the Indian firms.

Exports orientation as well as import of capital goods do not affect the decision of taking up R and D in our selection model. In the outcome model however, it was observed that more export-oriented firms tended to invest heavily in R and D.

Firms that imported capital goods also tend to have higher proportion of R and D than the firms that do not acquire technology through import of capital goods. Both variables seem to have a complementary relationship in this sample of data.

Foreign equity participation seems to discourage the investment in R and D. Even in the outcome model, it was observed that firms with more foreign equity participation tended to have lesser extent of R and D intensity than those that had lesser foreign equity presence.

6.2.5 Consumer Goods Industry

For this industry, the selection model employs Equation (6.2) whereas the outcome model was estimated by using Equation (6.4) as specified earlier in the chapter.

It is observed that in this sample older firms are more likely to opt for R and D investment as compared to older firms. Older firms were also found to have greater extend of R and D intensity as compared to younger firms.

Table 6.6: Heckit Estimation Results for Consumer Goods Industry.

Consumer Goods	Constant	ageyr	ln_sales	d_f	royalties1	X1	mraw1	mkg1	for_eq
Step 1	-0.486*** (0.133)	0.002 (0.002)	0.104*** (0.011)	0.058 (0.148)	0.001 (0.001)	-0.0001 (0.001)	-0.001 (0.001)	0.0004 (0.015)	-0.0002 (0.001)
Step 2	-0.249* (0.247)	0.007* (0.004)	0.021* (0.015)	-0.149 (0.299)	-0.0001 (0.001)	-.0001 (0.002)	-0.001 (0.002)	-0.018 (0.019)	0.001 (0.002)

Firm's size seems to be a very significant variable in decision making with regards to the selection model for this industry. It is observed that bigger firms are more likely to decide in favour of investing in research and development as compared to smaller firms. Bigger firms also appear to garner greater amounts of resources on R and D than the smaller firms in this industry.

Export orientation; firms' ownership as foreign private or Indian; spending on royalties and know- how; import of capital goods and raw materials; and foreign equity participation- all these variables seem to be irrelevant in influencing the decision to undertake R and D investment for these firms.

All these variables were also statistically insignificant in the outcome model for this industry sample in our analysis.

6.2.6 Construction Materials Industry

Our selection model for this industry was estimated by using Equation (6.1) with dependent variable DRD that takes value 1 if the firm invests in R and D and 0 otherwise. The next step, to estimate the outcome model for this industry was done by using Equation (6.3) with R and D intensity for the firm as the dependent variable. For both equations, the independent variables have been taken in intensity form as share of sales turnover.

Table 6.7: Heckit Estimation Results for Construction Materials Industry.

Construction Materials	Constant	ageyr	ln_sales	d_f	royalties_i	X_i	m_raw_i	m_k_i	for_eq
Step 1	0.127 (0.662)	0.001 (0.004)	0.051 (0.066)	0.165 (0.290)	-0.251 (1.327)	0.357* (0.326)	-0.016 (0.649)	1.041 (1.503)	-0.004* (0.004)
Step 2	0.017*** (0.003)	- 0.0004*** (0.00002)	-0.001*** (0.0003)	0.0001 (0.001)	-0.011* (0.006)	-0.002 (0.003)	-0.005 (0.005)	0.007 (0.012)	0.00003* (0.00002)

Foreign equity participation seems to discourage decision against investment in research and development in case of this sample. In the outcome model however, it was concluded that firms with greater foreign equity presence also had greater extent of R and D intensity.

On the other hand, export orientation seems to encourage decision to undertake R and D investment for these firms. This variable however turned out to be insignificant in our analysis of outcome model for this industry.

Ownership of the firms seems to be irrelevant from the perspective of decision making about R and D investment as well as in determining the R and D intensity of the firms the firms that actually undertook investment in research and development.

Spending on royalties and know- how didn’t turn out to be a significant variable influencing the decision about investment in research for development of new products. The variable however discouraged the intensity of R and D undertaken by the firms. Thus, it can be said that the relationship between this channel of technology transfer and a firm’s own R and D turns out to be that of substitutes for this sample of data in our analysis.

It is also observed that age of the firm isn’t a statistically insignificant factor in influencing the firm’s decision about investment in R and D. In the outcome model however, it was specified that younger firms tend to have more R and D intensity as compared to the older firms.

Firm's size seems to be an insignificant variable in decision making with regards to the selection model for this industry. Smaller firms tend to have more R and D intensity than the bigger firms for this industry in the outcome model.

Import of capital goods as well as import of raw materials turned out to be statistically insignificant factors in encouraging a firm to invest in research and development in case of this industry. Both variables again turned out to be statistically insignificant in the outcome model also.

6.2.7 Metals and Metal Products Industry

The selection model for firms in this industry has been estimated by using Equation (6.2) with DRD as the dependent variable and independent variables in intensity form. For the outcome mode, Equation (6.4) was estimated with R and D intensity in percentage form of sales of the firm, as the dependent variable. The technology regime related independent variables have also been specified in the form of percentage shares of sales of the firm.

Table 6.8: Heckit Estimation Results for Metals and Metal Products Industry.

Metals and Metal Products	Constant	ageyr	ln_sales	d_f	royalties1	X1	mraw1	mkg1	for_eq
Step 1	0.099 (0.107)	-0.003* (0.002)	0.023*** (0.009)	-0.117 (0.254)	-0.0001 (0.001)	0.0001 (0.0002)	-0.003* (0.002)	0.017* (0.014)	-0.0001 (0.002)
Step 2	0.018 (0.034)	0.001** (0.001)	-0.005** (0.003)	0 (omitted)	0.008* (0.005)	-0.0001 (0.0003)	0.001* (0.001)	-0.001* (0.001)	-0.005 (0.007)

Foreign equity participation as well as export orientation seems to be irrelevant in decision undertaken for R and D investment for these firms. Same variables were also found to be statistically insignificant in our outcome model as well.

Firm's ownership is also insignificant in influencing the decision of a firm to undertake R and D investment. This variable was omitted in our analysis (even in the model with transformation of variables) due to collinearity.

Firms that import capital goods are likely to decide in favour of investing in research for development of new products. In the outcome model it was observed that firms that import capital goods tend to have lesser R and D intensity, indicating that they are substituting the latter by the former. In case of this industry thus, technology transfer through import of capital goods and R and intensity of the firms are substitutes for each other.

It is also observed that younger firms are more likely to make a decision in favour of investment in R and D. However, such firms show a trend of lesser R and D intensity as compared to the older firms in the outcome model.

Bigger size of the firm seems to positively affect the selection model for this industry. But it was observed that smaller firms show a tendency of having greater extent of R and D intensity than the bigger firms.

Expenditure on royalties and know-how etc turned out to be a statistically insignificant factor in encouraging a firm to invest in research and development in case of manufacturing industry. However, it was observed in the outcome model that firms with more spending on royalties tend to complement it with greater R and D investment also.

6.2.8 Machinery Industry

The first step of the Heckman Two Step procedure for this industry was estimated using Equation (6.1) in our model with decision to decide in favour or against investing in R and D as the dependent variable in our analysis. The next step to look at relationship between R and D intensity and various forms of technology transfer was done by using Equation (6.3) as specified earlier.

Table 6.9: Heckit Estimation Results for Machinery Industry.

Machinery	Constant	ageyr	ln_sales	d_f	royalties_i	X_i	m_raw_i	m_k_i	for_eq
Step 1	1.237* (1.076)	-0.016*** (0.007)	0.014 (0.109)	0.844** (0.433)	-0.009 (1.591)	-0.515 (0.671)	1.449** (0.759)	-3.354* (3.686)	-0.016*** (0.005)
Step 2	0.016** (0.007)	-0.0001* (0.00005)	-0.0002 (0.001)	-0.007* (0.006)	-0.011 (0.019)	0.001 (0.008)	-0.025*** (0.008)	0.031 (0.129)	0.0001 (0.0001)

Foreign equity participation seems to be discouraging firms from making decision in favour of investment in research and development in case of this sample. This variable however, turned out to be insignificant in our outcome model in the analysis.

On the other hand, export orientation seems to be irrelevant on decision to undertake R and D investment for these firms. Similar insignificance was observed in the outcome model as well for the variable about export orientation of firms.

It is highly likely that firms which are privately owned by foreign business entities would decide in favour of R and D investment. But it was observed that Indian firms tend to be more R and D intensive than foreign private firms in our analysis.

Spending on royalties and know- how didn't turn out to be a significant variable influencing the decision about investment in research for development of new products. Same result was observed in the outcome model as well.

It is also observed that age of the firm is a statistically significant factor in influencing the firm's decision about investment in R and D. Younger firms are more likely to decide in favour of investing in R and D. Younger firms also tend to be more R and D intensive than the older firms.

Firm's size seems to be an insignificant variable in decision making with regards to the selection model and in determining R and D intensity in the outcome model as well, for this industry.

Import of capital goods as well as import of raw materials turned out to be statistically significant factors in influencing a firm's decision to invest in research and development. The former discourages it, whereas the latter encourages the decision to invest in R and D. In the outcome model however, import of capital goods didn't seem to be determining the R and D intensity of the firms. Import of raw materials however, was found to be substituting for research and development within this industry.

6.2.9 Transport Equipment Industry

The selection model for firms in this industry has been estimated by using Equation (6.2) with DRD as the dependent variable and independent variables in intensity form. For the outcome mode, Equation (6.4) was estimated with R and D intensity in percentage form of sales of the firm, as the dependent variable. The technology regime related independent variables have also been specified in the form of percentage shares of sales of the firm.

Table 6.10: Heckit Estimation Results for Transport Equipment Industry.

Transport Equipment	Constant	ageyr	ln_sales	d_f	royalties1	X1	mraw1	mkg1	for_eq
Step 1	-0.033 (0.145)	-0.001 (0.003)	0.053*** (0.014)	0.359* (0.218)	-.001 (0.002)	0.002* (0.001)	0.001 (0.002)	0.001 (0.001)	-0.001 (0.002)
Step 2	0.007 (0.336)	0.007* (0.006)	-0.006 (0.029)	1.652*** (0.627)	-0.002 (0.004)	-0.001 (0.002)	0.001 (0.004)	0.001 (0.003)	-0.003 (0.004)

Foreign equity participation seems to be irrelevant from the perspective of decision making in favour of investment in research and development in case of this sample. Similar result was observed for this variable in the outcome model as well.

Export orientation seems to encourage decision to undertake R and D investment for these firms. This variable however was irrelevant in determining the R and D intensity of the firms in this industry.

It is highly likely that firms which are privately owned by foreign business entities would decide in favour of R and D investment. In the outcome model as well, R and D intensity of the foreign private firms was found to be more than that of the Indian firms in our sample.

Spending on royalties and know- how didn't turn out to be a significant variable influencing the decision about investment in research for development of new products. Similar insignificance was shown in determining R and D intensity of the firms as well.

It is also observed that age of the firm isn't a statistically significant factor in influencing the firm's decision about investment in R and D. However, it was observed that older firms tend to have greater extent of R and D intensity in our sample.

Firm's size seems to be a significant variable in decision making with regards to the selection model for this industry. It is observed that bigger firms are more likely to decide on investing in research and development. This variable was found to be irrelevant in determining the R and D intensity of the firms.

Import of capital goods as well as import of raw materials turned out to be statistically insignificant factors in encouraging a firm to invest in research and development in case of manufacturing industry. Same statistical insignificance was seen in the outcome model too.

6.2.10 Mining Industry

Estimation results for this industry have been summarised in Tables 6.2 and 6.4. The selection model employs Equation (6.2) whereas the outcome model was estimated by using Equation (6.4) as specified earlier in the chapter.

Table 6.11: Heckit Estimation Results for Mining Industry.

Mining	Constant	ageyr	ln_sales	d_f	royalties1	X1	mraw1	mkg1	for_eq
Step 1	-0.241 (0.318)	-0.002 (0.004)	0.041* (0.024)	0.345*** (0.140)	0.038*** (0.009)	-0.019*** (0.006)	-0.034* (0.031)	-0.087 (0.327)	0.004* (0.004)
Step 2	-0.069 (0.093)	-0.001* (0.001)	0.014** (0.007)	0.021 (0.041)	0.017*** (0.003)	-0.006*** (0.002)	-0.010* (0.009)	-0.099* (0.095)	0.001* (0.001)

Greater foreign equity participation encourages decision on R and D investment in mining industry. It also ensures higher R and D intensity of firms in our outcome model too.

Export orientation seems to discourage decision to undertake R and D investment for these firms. More export-oriented firms were also found to have lesser R and D intensity.
It is highly likely that firms which are privately owned by foreign business entities would decide in favour of R and D investment. Ownership was found to be an irrelevant variable in our outcome model.
A firm that is spending on royalties and know- how would also decide in favour of investing in research for development of new products. Such firm is also likely to have more R and D intensity than the firms that do not spend on royalties. Thus, for this industry technology transfer through spending on royalties seems to substitute for the R and D expenditure of the firm.
Age of the firms doesn't seem like a factor that would alter the decision of investment in R and D. Younger firms though seem to be more R and D intensive than the older firms in our outcome model.
Bigger size of the firms seems to encourage the decision in favour of R and D investment in the selection model as well as the R and D intensity in the outcome model for this industry.
Import of capital goods turned out to be a statistically insignificant factor in encouraging a firm to invest in research and development in case of mining industry. However, firms that import capital goods from abroad tend to have lesser extent of R and D intensity. This is indicative of the fact that technology transfer for these firms happens through import of capital goods which substitutes the R and D undertaken by them.

6.2.11 Electricity Industry

Results could not be produced for this industry even with transformation of variables. This was so because of very low number of observations in the sample for this industry.

6.2.12 Construction and Real Estate Industry

The selection model for firms in this industry has been estimated by using Equation (6.2) with DRD as the dependent variable and independent variables in intensity form. For the outcome mode, Equation (6.4) was estimated with R and D intensity in percentage form of sales of the firm, as the dependent variable. The technology regime related independent variables have also been specified in the form of percentage shares of sales of the firm.

Table 6.12: Heckit Estimation Results for Construction and Real Estate Industry.

Construction and Real Estate	Constant	ageyr	ln_sales	d_f	royalties1	X1	mraw1	mkg1	for_eq
Step 1	-0.471*** (0.134)	0.002 (0.002)	0.075*** (0.013)	-0.272 (0.360)	0.005 (0.006)	- 0.006*** (0.001)	0.009*** (0.002)	0.0003 (0.001)	0.007*** (0.001)
Step 2	-0.087 (0.148)	0.001 (0.002)	0.016* (0.013)	-0.019 (0.435)	0.006 (0.007)	-0.002* (0.001)	0.003* (0.002)	0.0001 (0.001)	0.001 (0.001)

Spending on royalties and know- how appears as an insignificant factor in influencing the decision to undertake research and development as well as the R and D intensity of the firms that actually invested in research.

Age of the firm is irrelevant from the perspective of deciding as well as in determining the intensity of spending on research and development.

Bigger size of the firm seems to affect the selection model for this industry in positive significant manner. That means, bigger firms are more likely to decide in favour of research investment as compared to smaller firms. Bigger firms also tend to have higher extent of R and D intensity than the smaller firms.

Greater foreign equity participation is likely to encourage research and development in a firm for this industry. Foreign equity participation however, turned out to be irrelevant in determining the extent of R and D intensity of the firms in the outcome model.

Export orientation on the other hand seems to discourage the firm to decide to undertake R and D investment. More export-oriented firms were also found to be less intensive in R and D expenditure.

Also, import of raw materials turns out to positively significant variable in influencing the decision of the firms in this industry to undertake investment in R and D. Import of raw materials is also found to be complementary with the R and D expenditure of the firms. Thus, technology transfer process for this firm through import of raw materials complements the firm’s own R and D.

The probability of investment in R and D is not affected by the ownership of the firm in this industry, implying that it doesn’t matter whether the firm is owned by foreign private entity or if it is an Indian firm, the ownership is irrelevant from the perspective of investment in research by the firm. Same result is obtained in our outcome model as well for this sample.

Import of capital goods turned out to be a statistically insignificant factor in encouraging a firm to decide as well as invest in research and development in case of this industry.

6.2.13 Miscellaneous Manufacturing Industry

The selection model for this industry was estimated by using Equation (6.2) with dependent variable DRD that takes value 1 if the firm invests in R and D and 0 otherwise. The next step, to estimate the outcome model for this industry was done by using Equation (6.4) with R and D intensity for the firm as the dependent variable. For both equations, the independent variables have been taken in intensity form as share of sales turnover.

Table 6.13: Heckit Estimation Results for Miscellaneous Manufacturing Industry.

Miscellaneous Manufacturing	Constant	ageyr	ln_sales	d_f	royalties1	X1	mraw1	mkg1	for_eq
Step 1	-0.226* (0.147)	0.005*** (0.002)	0.029* (0.017)	0.228 (0.237)	-0.003* (0.002)	-0.001 (0.001)	-0.015*** (0.003)	-0.001 (0.003)	-0.001 (0.002)
Step 2	-0.015** (0.007)	0.0001*** (0.00005)	0.0001 (0.001)	0 (omitted)	-0.008*** (0.002)	-0.0001* (0.0001)	0.00004* (0.00004)	0.0005** (0.002)	0.00004** (0.00002)

The probability of deciding in favour of R and D investment by a firm in this industry happens to be positively influenced by old age and bigger size in market. In the outcome model however, size of the firm is found to be irrelevant in determining its R and D intensity. Older firms however appear to have greater intensity of R and D as compared to newer firms.

It is also observed that if the firm is importing raw materials from abroad, then it is less likely to invest in own research and development of new products. In the outcome model however, this mode of technology transfer through import of raw materials is complementary with firm's own expenditure on R and D.

If the firm is spending on royalties and know- how, then also it is less likely that it will decide for investing in R and D. Royalties are also observed to substitute for the research and development of the firm in this industry, as stated in the outcome model of our analysis for this sample.

Foreign private ownership, exports orientation, foreign equity participation as well as import of capital goods do not affect the decision of taking up R and D in our selection model.

The variable on ownership of the firm was omitted because of collinearity (even in the transformed variable model). More export-oriented firms were found to be less R and D intensive in our outcome model.

Firms that have greater foreign equity also tend to be more intensive in R and D. Technology transfer through import of capital goods was found to be complementary to the R and D expenditure of the firm for this sample of our analysis.

6.3 APPENDIX FOR CHAPTER 6

Table 6.14: Estimation results for Step 1 of Heckit Specification Procedure as per Equation (6.1).

Sl. No.	Industry	Constant	ageyr	ln_sales	d_f	royalties_i	X_i	m_raw_i	m_k_i	for_eq
1	Manufacturing	0.793*** (0.284)	-0.005** (0.002)	0.007 (0.031)	0.481*** (0.146)	0.462* (0.442)	-0.554*** (0.209)	0.411* (0.329)	-0.046 (0.546)	-0.007*** (0.002)
2	Food and Agro Based Products	2.692*** (0.584)	-0.009** (0.005)	-0.172*** (0.061)	-0.018 (0.163)	3.743*** (1.383)	-0.203 (0.719)	-2.170* (1.281)	20.699*** (6.885)	0.001 (0.003)
3	Chemicals and Chemical Products	1.485* (0.969)	-0.034*** (0.014)	0.132* (0.086)	0.881* (0.743)	14.023*** (3.910)	-0.496 (0.865)	-7.674** (3.659)	0.317 (4.115)	-0.022* (0.015)
4	Construction Materials	0.127 (0.662)	0.001 (0.004)	0.051 (0.066)	0.165 (0.290)	-0.251 (1.327)	0.357* (0.326)	-0.016 (0.649)	1.041 (1.503)	-0.004* (0.004)
5	Machinery	1.237* (1.076)	-0.016*** (0.007)	0.014 (0.109)	0.844** (0.433)	-0.009 (1.591)	-0.515 (0.671)	1.449** (0.759)	-3.354* (3.686)	-0.016*** (0.005)
6	Electricity	Regression not possible due to very few number of observations								
7	All Industries (Complete Sample)	0.691** (0.270)	-0.005** (0.002)	0.008 (0.029)	0.366*** (0.137)	0.571* (0.437)	-0.285* (0.165)	0.492* (0.313)	0.118 (0.513)	-0.005*** (0.002)

Table 6.15: Estimation results for Step 1 of Heckit Specification Procedure as per Equation (6.2).

Sl. No.	Industry	Constant	ageyr	ln_sales	d_f	royalties1	X1	mraw1	mkg1	for_eq
1	Textiles	-0.021 (0.103)	0.001 (0.002)	0.019** (0.009)	- 0.565*** (0.254)	-0.006* (0.006)	-0.0003 (0.001)	0.002* (0.001)	-0.002 (0.003)	0.007*** (0.002)
2	Consumer Goods	-0.486*** (0.133)	0.002 (0.002)	0.104*** (0.011)	0.058 (0.148)	0.001 (0.001)	-0.0001 (0.001)	-0.001 (0.001)	0.0004 (0.015)	-0.0002 (0.001)
3	Metals and Metal Products	0.099 (0.107)	-0.003* (0.002)	0.023*** (0.009)	-0.117 (0.254)	-0.0001 (0.001)	0.0001 (0.0002)	-0.003* (0.002)	0.017* (0.014)	-0.0001 (0.002)
4	Transport Equipment	-0.033 (0.145)	-0.001 (0.003)	0.053*** (0.014)	0.359* (0.218)	-.001 (0.002)	0.002* (0.001)	0.001 (0.002)	0.001 (0.001)	-0.001 (0.002)
5	Mining	-0.241 (0.318)	-0.002 (0.004)	0.041* (0.024)	0.345*** (0.140)	0.038*** (0.009)	- 0.019*** (0.006)	-0.034* (0.031)	-0.087 (0.327)	0.004* (0.004)
6	Construction and Real Estate	-0.471*** (0.134)	0.002 (0.002)	0.075*** (0.013)	-0.272 (0.360)	0.005 (0.006)	- 0.006*** (0.001)	0.009*** (0.002)	0.0003 (0.001)	0.007*** (0.001)
7	Miscellaneous Manufacturing	-0.226* (0.147)	0.005*** (0.002)	0.029* (0.017)	0.228 (0.237)	-0.003* (0.002)	-0.001 (0.001)	- 0.015*** (0.003)	-0.001 (0.003)	-0.001 (0.002)

Table 6.16: Estimation results for Step 2 of Heckit Specification Procedure as per Equation (6.3).

Sl. No.	Industry	Constant	ageyr	ln_sales	d_f	royalties_i	X_i	m_raw_i	m_k_i	for_eq
1	Manufacturing	0.011*** (0.005)	0.0001** (0.0001)	-0.001** (0.001)	-0.005* (0.003)	-0.0003 (0.007)	-0.002 (0.003)	-0.010*** (0.004)	0.018*** (0.008)	0.0001 (0.0001)
2	Food and Agro Based Products	0.018*** (0.005)	0.0001** (0.0001)	-0.002*** (0.0003)	0.005*** (0.002)	-0.034* (0.019)	-0.045*** (0.007)	0.014** (0.007)	0.087** (0.045)	-0.0001*** (0.00001)
3	Chemicals and Chemical Products	0.039** (0.017)	0.001*** (0.0001)	-0.009*** (0.002)	0.019* (0.012)	-0.017 (0.069)	0.039* (0.025)	0.137** (0.060)	0.079** (0.042)	-0.001* (0.0002)
4	Construction Materials	0.017*** (0.003)	-0.0004*** (0.00002)	-0.001*** (0.0003)	0.0001 (0.001)	-0.011* (0.006)	-0.002 (0.003)	-0.005 (0.005)	0.007 (0.012)	0.00003* (0.00002)
5	Machinery	0.016** (0.007)	-0.0001* (0.00005)	-0.0002 (0.001)	-0.007* (0.006)	-0.011 (0.019)	0.001 (0.008)	-0.025*** (0.008)	0.031 (0.129)	0.0001 (0.0001)
6	Electricity	Regression not possible due to very few number of observations								
7	All Industries (Complete Sample)	0.010** (0.005)	0.0001*** (0.000)	-0.001** (0.001)	-0.004* (0.003)	-0.00002 (0.007)	-0.002 (0.003)	-0.009** (0.004)	0.018*** (0.007)	3.82e-06 (0.00002)

Table 6.17: Estimation results for Step 2 of Heckit Specification Procedure as per Equation (6.4).

Sl. No.	Industry	Constant	ageyr	ln_sales	d_f	royalties1	X1	mraw1	mkg1	for_eq
1	Textiles	0.932* (0.832)	-0.004 (0.013)	-0.043 (0.089)	-0.043 (1.983)	-0.023 (0.066)	-0.012* (0.007)	0.001 (0.014)	0.015 (0.031)	-0.005 (0.021)
2	Consumer Goods	-0.249* (0.247)	0.007* (0.004)	0.021* (0.015)	-0.149 (0.299)	-0.0001 (0.001)	-.0001 (0.002)	-0.001 (0.002)	-0.018 (0.019)	0.001 (0.002)
3	Metals and Metal Products	0.018 (0.034)	0.001** (0.001)	- 0.005** (0.003)	0 (omitted)	0.008* (0.005)	-0.0001 (0.0003)	0.001* (0.001)	-0.001* (0.001)	-0.005 (0.007)
4	Transport Equipment	0.007 (0.336)	0.007* (0.006)	-0.006 (0.029)	1.652*** (0.627)	-0.002 (0.004)	-0.001 (0.002)	0.001 (0.004)	0.001 (0.003)	-0.003 (0.004)
5	Mining	-0.069 (0.093)	-0.001* (0.001)	0.014** (0.007)	0.021 (0.041)	0.017*** (0.003)	- 0.006*** (0.002)	-0.010* (0.009)	-0.099* (0.095)	0.001* (0.001)
6	Construction and Real Estate	-0.087 (0.148)	0.001 (0.002)	0.016* (0.013)	-0.019 (0.435)	0.006 (0.007)	-0.002* (0.001)	0.003* (0.002)	0.0001 (0.001)	0.001 (0.001)
7	Miscellaneous Manufacturing	-0.015** (0.007)	0.0001*** (0.00005)	0.0001 (0.001)	0 (omitted)	-0.008*** (0.002)	-0.0001* (0.0001)	0.00004* (0.00004)	0.0005** (0.002)	0.00004** (0.00002)

Chapter 7 Conclusion and Policy Suggestions

This chapter discusses the conclusions, policy suggestions and limitations of the study and finally formulates points directing further research on this topic that might act as an extension of this study.

The main purpose of this study was to investigate the trends in TFP, the factors that affect the TFP of the Indian industrial firms and the nature of relationship between the technology transfer process and its expenditure on own R and D.

The main emphasis was laid on the attempt to figure out the relationship between various modes of technology transfer being adopted by the firms and the effect of such channels on their TFP in the period after liberalisation of Indian economy in 1991.

The study uses secondary data to analyse the above questions that were also mentioned at the beginning of the study. The study analyses the trends in productivity of the firms in the industrial sector. We also looked at the trends in TFP of firms in different industries. Thereafter we looked at the factors that might relate the technology regime of the firms to their TFP performances and we tried to find out which factors turned out to influence the performance of the firms in the respective samples of our analyses. This was done for the complete period of 28 years from 1991- 2018.

Subsequently, we were successful in finding out the nature of relationship between the various modes of technology transfer available for different industries and their efforts towards maintaining their own research and development in production of new and innovative goods.

7.1 Major Findings of Study

The study began with a detailed review of the literature on the process of technology transfer, its various means and effects on the overall productivity of the firms. We also discussed the various factors that are expected to be instrumental in influencing the productivity of the firms and that also develops a link between the technology regime of the business entity. This has been our bedrock and the constant check on our study that we kept revisiting to draw a research gap that would make this study more meaningful.

The three methods to calculate TFP: the Ratio method, the Cobb Douglas Production function approach and the Levinsohn and Petrin method- all showed different stories of TFP trend in the period 1991- 2018. Among the three methods, the LP method sort of appeared to be a balance between the two other methods. The Ratio method, though the simplest of the three, seems to suffer from overestimation of TFP for the firms (this problem was highlighted in the literature on total factor productivity). The Cobb Douglas production function approach, even the most widely used and popular in the literature in economics research, also fails to completely account for the unobservable productivity shocks because it only looks at the residuals estimated in the process of estimation of the production function. Thus, we resort to the most recent development in research in estimation of TFP for firms- the LP method. This approach, though quite recent, has instantly caught up with the researchers in this field, mainly because of its assumptions that provide it more credibility in terms of efficiency in estimation of the unobservable productivity shocks. This advantage available with this method of TFP estimation, thus encouraged us to adopt the LP measures of TFP for the examination of further two objectives of our research study.

The LP method pegs the TFP level of the entire industrial sector for the period 1991-2018 at 3.37. the Electricity; Construction and Real Estate; Mining and Consumer Goods industries fall in the category of high TFP as compared to the rest of the industries that are very close to each other in terms of TFP levels. On the other hand, the Construction materials industry lags behind as the industry with least TFP in our sample.

We used the TFP measures calculated by the LP method as the dependent variable for the second objective in our study where we looked at the effect caused by various firm specific factors and its technology regime related variables on its overall productivity. This exercise was done for the entire sample of all 2,661 firms as well as for the sample of each of the 13 industries (sub-groups) for the entire period of 1991-2018.

Age of the firm is a great indicator of the accumulated knowledge of the firms as well as the ability of the firm to adjust its operations with the change in unobservable shocks in productivity. The expectation is that older firms may be better equipped to handle and adjust with the changes in operations. However, cases of swift adjustment by newer firms were also found to be relatively more in case of Indian industries. In our sample, younger firms seemed to be more equipped to deal with productivity shocks in case of full sample (entire industrial sector), manufacturing industry, textiles industry, consumer goods industry, construction materials industry, electricity industry and miscellaneous manufacturing industry.

Thus, for the majority of the industrials firms young age of the firm is likely to improve their TFP levels. For Construction and real estate industry, mining industry, transport industry and machinery industry, opposite results were obtained. For these set of samples, older firms seemed to have better measures of TFP.

Food and agro based products industry and Metals and Metal products industry's TFP seemed to be unaffected by the age of the firm.

Younger age of the firm also seemed to influence the decision made in favour of undertaking R&D in case of manufacturing sector, food and agro based industry, chemicals and chemical products industry, machinery industry, metals and metal products industry, and the complete sample of all firms. The result was opposite only in case of miscellaneous manufacturing industry.

It was also observed that once the decision to undertake R& D was taken, it was found that such investment was greater in case of larger firms of the manufacturing, food, chemicals, consumer goods, metals, transport, miscellaneous manufacturing as well as the complete sample of firms in our study. For, construction materials, machinery and mining industries, the younger firms seemed to be putting in more resources in R&D.

Size of the firms is a very important variable in terms of determining its overall TFP. Literature favours bigger size as a crucial factor that immensely helps in achieving higher productivity for the firms. While this hypothesis was found to be true for the Construction and real estate industry, mining industry and metals and metal products industry; the opposite case of smaller firms displaying higher levels of TFP was observed in firms belonging to Miscellaneous manufacturing firms, electricity industry, construction materials industry, textiles industry, transport equipment industry, machinery industry and chemicals and chemical products industry. It was surprising to see that size doesn't matter in determining TFP levels of firms in the manufacturing industry in our sample.

Bigger firms were likely to decide in favour of R and D investment in cases of chemical and chemical products industry, textiles industry, consumer goods industry, metals and metal products industry, transport industry, mining industry, construction and real estate industry and miscellaneous industry. This factor was surprisingly statistically insignificant in case of manufacturing and the complete sample in our study. But it can be concluded on the whole, that bigger size leaves firms with ample of resources to be invested on research and development.

Once the decision about R&D investment was taken up, it was observed that such investment was actually found to be more for smaller firms in case of manufacturing, food, chemicals, construction materials, metals, and all firms sample in our study. Larger firms seemed to be putting in more resources aside for R&D in case of consumer goods, mining and construction and real estate industries.

Exports orientation is found to be an important factor in improving the overall health and performance of the firm. This was observed only in case of chemicals and chemical products industry, transport equipment industry, mining industry, electricity industry and construction and real estate industry. It is noticeable to see that that for all the firms in our sample, exports orientation seems to favour higher productivity. Only Miscellaneous manufacturing firms seemed to display an inverse relationship between the two variables in our sample. For rest of the industries, exports intensity didn't seem to matter in determining their TFP levels.

This variable was supposed to encourage firms to decide in favour of undertaking R and D in case of construction materials industry and transport industry. For the manufacturing industry, mining industry, construction and real estate industry as well as the complete sample, it was observed that the export orientation of firms in turn discouraged them from deciding in favour of R and D investment.

Exports orientation seemed to favour more R&D intensity in case of chemicals industry only. For miscellaneous manufacturing, construction and real estate, mining, textiles and food industries, it was however found that more exports orientation led to fewer resources being left for R&D investment.

Competitive imports are supposed to be an important indicator of better health of the economy. Such imports if done in favour of technology improvement and adoption are expected to have far reaching benefits for the industrial sector as this will give an edge to the firms and make them more competitive because of swift adoption, acquisition and transfer of technology which is conducive to the local environments. In our sample, import of capital goods, which is a form of embodied technology transfer was found to be unfavourable in case of transport industry and chemicals and chemical products industry only. This is a noticeable result on the ground that not a single industry in our sample seems to be gaining from import of capital goods from abroad. This is a huge inference from the point of view of policy framework. Productivity of rest of the industries isn't affected by the import of capital goods. Thus, the conclusion based on the results may be that import of capital goods may not be encouraged for any of the industries as it doesn't lead to any improvement in the TFP of these firms.

Import of capital goods seemed to influence firms to decide in favour of undertaking R&D investment in case of food and metals industries only. For machinery industry, it seemed to influence the decision in a negative way. This variable was insignificant in decision making with regards to R&D investment in case of the rest of the industries.

The relationship between R&D and import of goods was found to be complementary in case of manufacturing, food, chemicals, miscellaneous manufacturing and the complete sample of firms in our study. It was a form of substitute for R&D in case of metals and mining industries. Import of raw materials, which is a disembodied form of technology transfer, isn't found to be a beneficial factor to the TFP of the firm in any of the industries. This is a big result because such means of technology transfer isn't leading to any positive growth in the TFP of Indian firms. Rather, this factor is discouraging TFP improvements in manufacturing industry, chemicals and chemical goods industry, machinery industry, transport industry, textiles industry, consumer goods industry, construction and real estate industry as well as the combine sample in our analysis. Thus, this means of technology transfer may be strictly discouraged across all firms in the Indian industrial sector.

This variable seemed to favourably influence the decision to undertake R&D investment in case of manufacturing, machinery, textiles, construction and real estate and the complete sample of all firms. The relation was negative however, in case of food, chemicals, metals, mining, and miscellaneous manufacturing industry.

The relationship between R and D and import of raw materials was found to be that of substitutes in case of mining, machinery, manufacturing and all firms sample in our study. The relationship is complementary in case of food, chemicals, metals, construction and real estate and miscellaneous manufacturing industries.

Expenditure on royalties and know- how is also a form of disembodied technology transfer. This variable was found to be encouraging TFP levels in case of manufacturing industry, machinery industry, transport equipment industry, consumer goods industry, construction materials industry, construction and real estate industry, miscellaneous manufacturing industry and the overall full sample of our analysis. Thus, for majority of the firms, this form of technology transfer seems to favour their TFP levels. For rest of the firms, this variable was found to be statistically insignificant. Hence, it can be concluded that expenditure on royalties doesn't discourage the TFP levels of the firms in our sample.

These variable favours decision on investment in R&D in case of manufacturing, food, chemicals, mining and the complete sample in our study. The decision is influence in a negative manner in case of textiles and miscellaneous manufacturing industries.

Relationship between expenditure on R and D and that on royalties is of complementary nature in case of metals and mining industries only. These two variables are substitutes in case of miscellaneous manufacturing, construction materials and food and agro based industry.

Greater participation in foreign equity is also expected to help boost the process of technology transfer and thereby improve the performance of the industries. Spill over effects from such equity is observed in case of Indian industries in various earlier studies. In our sample, greater proportion of foreign equity as share of total equity was found to be beneficial in case of transport equipment industry, mining industry, construction and real estate industry and chemicals and chemical products industry. The effect was opposite in case of manufacturing industry, machinery industry, textiles industry, construction materials industry, metals and metal products industry, and the overall industrial sample in our analysis. Thus, nothing concrete can be said about this variable in general and policy prescriptions regarding presence of foreign equity in the firms may be based on the analysis of individual industries.

Greater share of foreign equity in the firms favoured the decision to undertake R&D in case of textiles, mining and construction and real estate industries only. Rather, it discouraged the decision in R& D in case of manufacturing, chemicals, construction materials, machinery and the complete sample of all industries in our sample. Thus, for most of the industry samples in our study, foreign equity participation actually discouraged firms from investing in R&D.

After the decision about R&D investment was taken, it was observed that the extent of R&D was far more in cases of construction materials, mining and miscellaneous manufacturing industries. This is indicative of the complementary relationship between foreign equity participation and R&D in case of these industries.

On the other hand, the relationship was of substitutes in cases of food and agro based and chemicals and chemical products industries. For the rest of the industries, this variable didn't seem to have any effect om the R&D expenditure of the firms. Thus, foreign equity participation may be encouraged on a case-by-case basis as per the results obtained from the various industry samples in our study.

We also looked at the ownership of firms as foreign private and Indian firms (private and public). It was observed that foreign private firms were found to have more TFP than their Indian counterparts in case of manufacturing industry, textiles industry, consumer goods industry, construction materials industry and the complete sample of all firms. This represents the majority of firms in the sample. Indian firms performed better in terms of TFP in case of chemicals and chemical products industry, transport industry and mining industry. For rest of the industries in our sample, the effect was found to be ambiguous.

Privately owned foreign firms seemed to decide in favour of R&D in case of manufacturing, chemicals, machinery, transport, mining and all industry samples in our study. For textiles industry however, Indian firms seemed to be more inclined towards deciding in favour of R&D investment.

After the decision on investment in R&D, the extent of such investment was actually found to be more for food, chemicals and transport industries. Thus, for this set of industries foreign ownership of firms seems to complement their R and D efforts.

The relationship was found to be that of substitutes in case of manufacturing, machinery industries and the complete sample of all firms in the study.

R&D expenditure in our analysis yielded insignificant results for most of the industries. This might be because of the very low level of the variable. As was also pointed out in the literature, the relationship between R & D and TFP might be insignificant because of the very low level of R and D expenditure in case of Indian economy. This has been cited as a prime blunder that is causing low overall growth of the industrial sector and is thereby causing a lag to the economic growth of the economy as a whole. In our analysis, R&D seemed to negatively influence the TFP levels of firms in case of machinery industry, transport industry and mining industry. It is also worth noting that R&D expenditure wasn't found to be positively influencing the overall TFP of the firm in any of the samples. This is a very remarkable result that shows that Indian firms still largely rely on other means of adoption of technology.

7.2 Policy Implications and Suggestions

The findings of this study have significant policy implications for the entire industrial sector as well as the 13 different industries in our analysis. The policy implications can hence be derived from the respective industry's estimation and results discussion in the previous chapters.

We need to ensure more positive spill overs between foreign and domestic firms so that a smoother process of technology transfer can be observed on a more equivalent level across all firms irrespective of their ownership.

Younger firms may be encouraged to enter the market and the barriers to entry for the industrial firms may be slashed in order to give rise to better performing firms that are endowed with capability of adjusting to the unobservable productivity shocks.

Bigger size also seems to favour higher total factor productivity; thus, it may be noted that firms are properly incentivised and encouraged to increase their size in the market. Lessons, however may be learnt from the experiences of the different industries and such policy suggestions may be adhered to, on a case-by-case basis.

Both import of capital goods and import of raw materials aren't serving as majorly helpful means of technology transfer in case in Indian industrial firms on a broad basis. Thus, it may be noted that these two methods of technology transfer may not be specially encouraged by the firms.

Expenditure on royalties and know- how is still a better form of technology transfer from abroad because it largely yields better TFP levels in our sample of study.

Participation in foreign equity and ownership in terms of foreign private firms are two variables that give mixed results. The industry specific results may hence be taken into account for policy making specific to the various industry samples that we have analysed.

Other policy suggestions are mainly derived from the lessons learnt in the empirical literature as discussed in Chapter 1 of this study.

A technology development fund and consultancy services are a great idea to go ahead and encourage firms to invest in research and development to increase innovation in products and services. This may also reduce the dependence on the foreign technology imports that are anyway harmful for the Indian firms' productivity as was evident in our analysis in this study.

Greater allowance to FDI can be another motivator for the industries to invite more and varied investment and take benefits offered by the technology as well as managerial capacity offered by such investment because of the presence of foreign firms.

We need to address the problem of 'missing middle' and encourage small firms to increase their size and become more competitive with higher levels of TFP.

Integrated industrial clusters as the ones present in East Asian economies are also a way forward to replicating higher growth of industrial sector in India also.

Needless to say that we need to put up better policy initiatives for greater R and D investment by the firms themselves. This is essential in order to reduce dependence on foreign firms and also, make the imported technology suitable as per the local demands in a more efficient manner. Focus has to be put in order to make capital more efficient. Indian firms suffer from very low investment in R and D on an overall basis and this problem needs to be solved in order to give fillip to the TFP levels of the industrial firms in our economy.

For technology upgradation, need based financing may be made available at lower costs so that all firms, irrespective of their size and ownership have access to these benefits. Use of advanced information and communication technology (ICT) are a must to become more competitive at the global platform. Industrial policies may be directed to make this happen and incentivise the firms for adoption of technology in production operations. It is pertinent to become more productive and efficient in the global economy which is more interconnected, open and competitive.

Well formulated and though out policies thus are a prime requirement for increased productivity, technology development and upgradation in the Indian industrial sector.

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