The roadmap to Industry 4.0 in India: how foreign technology licensing influences the process innovation activities among Indian manufacturing companies

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Author: Julia Lefferts – 543380
Supervisor: dr. S.J.A. Hessels
Co-reader: S. Ramezani
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ERASMUS UNIVERSITEIT ROTTERDAM
ERASMUS SCHOOL OF ECONOMICS

Abstract

Outdated technology has been a massive problem among Indian manufacturing companies. Even though process innovation is accountable for a large proportion of industrial progress and increased productivity among manufacturing companies, the determinants of process innovation at the firm level have been less addressed than those of product innovation. This study aims to contribute to existing literature by focusing on how foreign technology licensing affects the probability of being a process innovator. In addition, the role of R&D investment, patenting, and the influence of certain firm and industry characteristics are considered. The empirical analysis of 1594 Indian manufacturing companies in the period 2010-2013 confirms most of the expectations. The findings reveal that the probability of being a process innovator is higher for firms that license foreign technology. Evidence is also provided that this relation is influenced by their R&D investment and training efforts, although in a different direction than expected. Additionally, there exists heterogeneity in the relation among firms in the supplier-dominated industry and science-based industry. This research supports managers and policy makers in their decision to favor this type of technology acquisition, as it might be of great importance for Indian companies to decrease the gap in critical technologies, leading to more efficient production processes. This could help the Indian manufacturing sector to move more towards industry 4.0.

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1. Introduction

Process innovation plays a central role in the principal theories of economic development and innovation. Nonetheless, despite its widely acknowledged importance, this type of innovation generally receives less attention in the literature on the determinants and sources of technological progress than product innovation (Reichstein & Salter, 2006). One important incentive for firms to engage in process innovation is the increase in output, which increases their product market competitiveness (Overvest & Veldman, 2008). The technological profile is one of the key determinants for firms' innovation performance according to the international business literature (Wang et al., 2013). In this literature, however, the new industrial stage in which information and communication technologies (ICT) and manufacturing systems for operations become more integrated seems to be relatively unexplored. This concept is referred to as Industry 4.0: the fourth industrial revolution. It describes a blend of traditional manufacturing and sophisticated technology, which allows companies to have real-time visibility in their whole value chain (Alicke et al., 2016). In the operations of manufacturing companies, digital technologies have resulted in a higher efficiency of production processes due to lower costs. (Brettel et al., 2014; Jeschke et al., 2017). Many countries have already set up programs in order to stimulate the adoption and development of Industry 4.0 technology (Iyer, 2018). Nonetheless, it is recognized that several emerging countries are less able to profit from these new developments. India is well-known for its large manufacturing industry and has been ranked as the fastest-growing economy for many years (World Bank, 2014). However, the country suffers from some serious technology gaps and therefore it is estimated to be at the technology level of Industry 2.0, which describes more traditional manufacturing (Iyer, 2018). The focus is shifting and the Indian government is stimulating the technological development, but the largest challenge for the manufacturing industry will be to decrease the gap in critical technologies. The "Make in India" campaign aims to increase manufacturing capability and technology upgradation (Anand et al., 2015) and the way in which firms acquire their technologies could have an impact on the degree to which they are able to transform technology upgradation into their innovative performance.

In the past, most of the manufacturing firms relied on their own technologies for innovation. Nowadays, technological resources from external origins are important for innovating since they provide companies with strategic assets that could not be obtained internally (Reichstein & Salter, 2006; Vega-Jurado et al., 2009). One important solution for firms in this globally integrated market is therefore to license technology from a foreign-owned company. Inward technology licensing is defined as a contractual agreement in which one firm has the right to use the technology, usually in the form of trademarks, patents, or technical knowledge, from another company or organization (Atuahene-Gima, 1993). Multiple studies focus on the importance of foreign technology licensing for industrialization. According to Lall (2000), the most crucial first input into technological development in developing countries is provided by imported technologies. Firms that conduct all their Research and Development

(R&D) activities internally need a large amount of resources, which will increase uncertainties and risks. (McNally et al., 2011).

In India, the manufacturing industry is already confronted with Industry 4.0, as the competitive pressure from developing countries increases. For example, Germany and Japan are already on their way to adopt and implement both digital technologies and sustainable manufacturing processes. Consequently, managers and policy makers cannot rely on old methods in this new challenging environment. Therefore, the country needs to focus on critical technologies to sustain their growth (Iyer, 2018). Many prior studies have either focused on the determinants of the decision to license foreign technology, the effect of licensing technology on sales- or export performance, or on product innovation. According to Tsai & Wang (2008), the main incentive for a company to acquire technology externally is to improve their added value when performing product or process innovation. Nonetheless, no studies yet considered the influence of foreign technology licensing on process innovation activities. Therefore, this report will contribute to existing literature by focusing on how foreign technology licensing affects the probability of being a process innovator among Indian manufacturing companies. A large share of the existing literature has provided evidence for the high importance of technology licensing as a suitable alternative to internal development with R&D (Lambe & Spekman, 1997; Hagedoorn & Duysters, 2002). However, research has also overwhelmingly indicated that licensing and R&D investment are complementary strategies. Next to this, patenting has been used widely in the literature as an indicator of innovation. Therefore, the role of R&D investment and patent applications will be considered in this study; in particular to assess whether a complementary relation exists with foreign technology licensing. The role of firm size, export orientation and training efforts is also analyzed to see whether the above-mentioned expected relation is different for these characteristics. This report also contributes to existing literature by making a distinction between two sectoral categories: science-based and supplier-dominated firms. Industry differences are widely known to be of importance in examining firm performance, as different characteristics can influence innovation behavior at the firm level. Therefore, it is of interest to see whether the relation between foreign technology licensing and process innovation differs between these industries. Bearing in mind all the determinants that are expected to be of relevance, the research question is stated as follows:

What is the effect of foreign technology licensing on the introduction of process innovation activities among Indian manufacturing companies, and how is this effect influenced by their innovation inputs, firm- and industry characteristics?

This work is based on two surveys collected from the World Bank Microdata Library on a sample of 1594 Indian manufacturing companies. It takes an empirical approach to address the role of foreign technology licensing on the process innovation strategy at the firm level. Lastly, a large part of the existing literature has linked foreign technology acquisition and product innovation. Therefore, an additional analysis on the effect of foreign licensing on product innovation is also conducted in order to test whether the findings in the literature also hold for Indian manufacturing companies.

The results confirm the expectations that the probability of being a process innovator is higher for firms that license foreign technology. What is not in line with the expectations is that the positive relation between foreign technology licensing and process innovation is weaker for firms that invest in R&D, which suggests a substitutive relation. Additionally, when firms are operating in the science-based industry, this negatively influences the relation between foreign technology licensing and process innovation, compared to supplier-dominated firms. Supplier-dominated firms are thus better able to transform foreign licensed technology into process innovation activities, which is in line with the expectations. Moreover, if firms provide training to their employees, this weakens the positive relation between foreign technology licensing and process innovation compared to firms that do not provide training regarding innovation. This is a striking finding, since it was expected that training effort strengthens the above-mentioned relation. The results also reveal that product and process innovation have different determinants, but are both influenced by whether the firm licenses foreign technology. These findings provide both managers and policymakers with a greater insight in the role of internal versus external technology acquisition and the influence of different firm and industry characteristics, on both process and product innovation. Managers in Indian manufacturing companies may have to regard R&D investment and licensing as alternatives and could decide to license foreign technology in order to increase product and process innovation activities. This research might also support policy makers in their decision to favor foreign technology licensing by initiating policies toward higher efficiency of inward technology flows, especially in supplier-dominated industries. It can be of great importance for Indian companies to license foreign technology in order to increase production processes and decrease the gap in critical technologies, which could help them to move towards industry 4.0.

This report is structured as follows: In the next section the theoretical framework and hypotheses are presented, followed by the data and methodology. Next, the expected empirical results and robustness checks are highlighted and discussed. Lastly, the conclusions and limitations of this research will be explained, followed by the policy implications and suggestions for future research.

2. Theoretical Framework

2.1 The definition and sources of product and process innovation

Technological progress of firms involves both product and process innovations. While product innovation refers to creating new markets by introducing or improving new products, process innovations are introduced to reduce production costs or to increase efficiency of production processes. Process innovation is thus defined as the introduction of new concepts into the company’s production process or service operations, in order to achieve lower costs and/or a higher quality of products.

(Freeman & Soete, 1997; Utterback, 1994). Process innovation is a central element in the main theories of economic development and innovation. Nonetheless, it has received less attention in the literature than product innovation, which is perceived as the more popular form of innovation (Reichstein & Salter, 2006). What is interesting is that according to Bergfors & Larssen (2009), process and product innovation are intertwined and that further research should focus more on this intertwinement. Rouvinen (2002) explores a wide range of firm and industry levels in Finland and finds that the determinants of product and process innovation highly differ. Process innovation is more likely to be performed in industries with high capital intensity and low appropriability, while product innovations are more appropriable and easier to protect with patenting. Also, there exists a negative relation between the age of employees and process innovation, while this is not the case for product innovation. Lastly, they find that the investment in Research & Development (R&D) is only correlated with product innovation, not process innovation. The use of external sources of knowledge were correlated with both product and process innovation. Also, Goedhuys & Veugelers (2012) find that there are no innovation strategies of significant effect on process innovation performance for firms that are only engaged in process innovation. The authors provide evidence for a positive link between the decision to buy technology and innovative performance. Nonetheless, this holds for firms that are engaged in only product innovation or in both types of innovation. Vega-Jurado et al., (2009) examine the influence of the external sourcing of knowledge on the development of both product and process innovation for Spanish manufacturing firms and find that process innovation is for a large part driven by the external acquisition of knowledge processed in equipment and machinery, while product innovation is built on the firm's internal capabilities. However, they mention that this effect depends on the type of sourcing strategy, the knowledge source and firm- and sector characteristics. Milgrom & Roberts (1990) point out that product and process innovations are complements as they mutually support each other. According to Reichstein & Salter (2006), the variables that measure the ability of a firm to achieve product innovation also relate to sources of process innovation, and introducing them simultaneously leads to a higher firm performance. In sum, while product and process innovation are related, they are for a large part driven by different aspects.

There exist fewer studies that empirically investigate the incentives for firms to engage in process innovation activities than for product innovation. Therefore, this research will mainly focus on the determinants of process innovation. From an operational perspective, digital technologies increase the efficiency of set-up times, labor and material costs and processing times, resulting in higher productivity of production processes (Jeschke et al., 2017; Brettel et al., 2014). One important incentive for firms to engage in process innovation is the increase in output, which increases their product market competitiveness (Overvest & Veldman, 2008). The authors of Baldwin et al. (2002) investigate the determinants of process innovation for Canadian manufacturing companies and find that, among others, firm size, R&D activity, and the competition intensity in an industry are important influencers for why a firm is a process innovator. The authors use three categories of competition, namely 0-5, 6-20 and more than 20 competitors and find that the probability of process innovating first increases and then declines. Also, Weiss (2003) examines the influence of the competition intensity on firms' decision to innovate and finds that if competition is less severe in the industry they operate in, firms are more likely to be engaged in process innovation. Cabagnols & Le Bas (2002) analyze a sample of French manufacturing firms in order to understand the different determinants of why firms perform product and process innovation. The authors find that in highly concentrated industries, firms are more likely to be engaged in process innovation than in product innovation. These findings related to the competitiveness in the market could be explained by the fact that when there is a low level of competition, products are more heterogeneous. This leads to the result that introducing new products does not increase profits to a large extend anymore. In this case, process innovation is preferred over product innovation in order to reduce production costs. Goel & Nelson (2018) examine the determinants of process innovation in developing countries and find that certain firm characteristics, such as being a sole proprietor and a R&D investor, positively influences the introduction of process innovations. It might be expected that large firms have a higher probability of introducing process innovations, as they have more resources. However, they also are more lethargic and have a lower flexibility than sole proprietors. Even though the determinants of process innovation have received some attention in the existing literature, the effect of external sources of knowledge and technologies on the innovative activities of processes is less clear and needs further attention.

2.2 Technology licensing as a determinant for firm innovation performance

Innovators often rely on several different external sources of knowledge and technology. In developing economies, productivity growth depends largely on whether the adoption and adaptation of foreign technology is successful (Gentile, 2020). Many theories suggest that individual firms are rarely capable of innovating on their own and that a firm's technological capabilities are not sufficient to deal with the challenging global market, especially in developing countries (Vega-Jurado et al., 2009). Existing literature in the field of international business and economics paid a lot of attention to the concept of external or foreign technology acquisition (Wang et al., 2013; Wang & Li-Ying, 2014; Tsai et al., 2011;). There exist several external technology acquisition strategies. Nonetheless, foreign technology licensing is the most direct way to gain profits from another firm's intellectual assets, such as an idea or a process (Fosfuri, 2006). Licensing may be defined as a contractual agreement in which an organization sells the right to use its technology in the form of, processes, patents and technical know-how to another company. It means that the licensee firm agrees on purchasing technology that is already developed by another organization, which could be both related to product or process technologies (Atuahene-Gima & Patterson, 1993). Foreign technology licensing could benefit the licensee to a large extent, but there are also costs and risks attached to it. To start with, the licensee could partly lose control over some strategic aspects such as production quantity and control of quality, which could limit its ability to make profits (Sen and Rubenstein, 1989). Secondly, it could take a lot of time to adapt the new technology to the operations and markets of the licensee. Thirdly, the licensed technology may not be up to date anymore because licensors are often reluctant to license-out their newest innovations due to fear of competition (McDonald and Leahey, 1985). Nonetheless, a large share of the existing literature has provided evidence for the high importance of foreign technology licensing as a suitable alternative to internal development (Lambe & Spekman, 1997; Hagedoorn & Duysters, 2002). According to Tsai & Wang (2007), firms can gain several benefits, such as lowering their development time and development risks, and expanding their technological knowledge by learning from the acquired technology in order to improve their competitive position.

Many of the existing studies focused on analyzing the effect of foreign technology licensing on firm performance, which is measured by sales or innovation performance, or by the competitive position of firms. However, the results are somewhat contradictory. For example, Tsai & Wang (2008) find that for the electronics-manufacturing industry in Taiwan, there is no evidence for a direct effect of external technology acquisition on firm performance. Firm performance is measured as sales from output less the cost of material input. They investigate both the effect of inward technology licensing and purchasing patents, which together forms the concept of external technology acquisition. However, when including internal R&D in the analysis, the authors do find a positive relationship of these two variables on firm performance as the level of R&D increases. These results indicate that acquiring technology externally does not influence their firm performance, unless R&D is also performed. This means that there exists a complementary relationship between technology acquisition and internal R&D investment. On the other hand, Jones et al. (2001) analyze the impact of external technology acquisition on product-, market-, and financial performance and find that for U.S.- based multinational subsidiaries, there exists a negative relationship between technology acquisition and these three performance indicators. According to the authors, the fact that acquiring external technology detracts from firm performance can be explained by the differentiation of firms and industries. In addition to this, some studies focus on the effect of external technology acquisition on the competitive position of firms, which is measured in terms of export performance or market share. Wang et al. (2013) examine the effect of inward technology licensing on the export performance of Chinese manufacturing firms and provide evidence for a positive relationship. This relationship is stronger for the exporting firms that acquired technology from foreign countries than for those that relied on a domestically designed technology. Narayanan (1998) finds that for the Indian automotive industry, asymmetry among firms in external technology acquisition explains a large part of the differences in their competitiveness, which is measured by their market share. Companies that imported foreign technology were able to acquire a larger domestic market share.

Even though the way of acquiring knowledge seems an important determinant for process innovation, studies have mainly focused on other innovation performance indicators. Mixed results related to the effect of acquiring external technological knowledge on innovation performance have been found (Kessler et al., 2000; Caloghirou et al., 2004). Kessler et al., (2000) focus on the effect of external technology sourcing, such as licensing agreements, on the speed of innovation. What is striking is that U.S. based companies that have a higher external technology sourcing instead of internal sourcing in the later stage of development, also have a lower innovation speed. The more a new product development project depended on external sourcing, the longer it took to complete the innovation project. According to the authors, this could be explained by the fact that workers have a stronger association with the project and thus a higher commitment if internal technologies or ideas are used, which increases the probability of successful completion. Caloghirou et al., (2004) analyze the effect of both internal capabilities and external sources of knowledge on their innovation performance. Seven European countries were considered, namely Italy, Greece, Denmark, UK, France, the Netherlands and Germany for several manufacturing and service industries. Innovativeness is measured as the percentage of firms' sales related to products or services that were new or significantly improved in the previous three years. The authors provide evidence that both internal and external knowledge acquisition are crucial for upgrading innovation performance.

Some other studies analyze the effects of external technology licensing on a firm's product innovation activities (Tsai et al., 2011; Wang & Li-Ying, 2014). There are not many firms that can sustain their competitive advantage by relying only on their technologies and R&D developed internally (Wang & Li-Ying, 2014). The authors focus on analyzing product innovation performance and find that inward technology licensing from foreign origins has a positive impact on the high-tech Chinese licensee firm's subsequent New Product Development (NPD) performance. This is measured as the average share of new product sales over total sales. Also, Johnson (2002) highlights that the NPD of Brazilian firms benefits from 'learning-by-licensing', where NPD is measured similarly as by Wang & Li-Ying (2014). Torvinen et al. (2014) analyze the acquisition of external technology among Russian firms and find that companies that source, acquire and implement foreign technologies have been better able to enhance New Product Development, to decrease their costs of conducting R&D and thus, improve their performance. Additionally, they find evidence for the fact that external technology acquisition supports companies to focus on their core competencies and positively influences their competitiveness and market position. Ahula & Katila (2001) use a sample of firms in the global chemicals industry and find that the absolute size of the acquired knowledge base improves innovation performance, which is measured by the patenting frequency. According to the authors, it is of high importance for companies to introduce innovations at a fast pace, in order to outperform competitors and capture new opportunities in the rapidly changing innovation landscape. Leone and Reichstein (2012) show that for U.S. based companies, licensing-in technologies makes it possible for the licensee to introduce new inventions more rapidly than their non-licensee counterparts, which supports the argument that foreign technology licensing positively influences the product innovation performance of firms. Even though the effect of foreign technology licensing on product innovation performance is proven to be overwhelmingly positive, the results of this type of foreign acquisition and its effect on competitiveness or sales performance are somewhat contradicting.

2.3 The literature gap for foreign technology licensing in India

The existing literature has acknowledged that the effect of foreign technology licensing on firm performance, in terms of innovation or competitiveness, may differ per type of country considering the development level. Differences in productivity are an enormous source of cross-country income variations and technological progress is an important driver of the growth in productivity (Fu et al., 2011). Their article focuses on the role of foreign innovation efforts for technological progress and suggests that these two methods are complementary. The authors state that the benefits of worldwide technology diffusion can only be accomplished together with parallel indigenous innovation efforts. Even though many articles are focused on licensing in the Chinese manufacturing industry (Wang & Li-Ying, 2014; Li, 2011; Wang et al., 2015), not many articles can be found using Indian companies. Lewis (2007) investigates the technology acquisition in the Chinese and Indian manufacturing utility-scale wind turbines industry, focusing on specific companies and their way of acquiring technology. This study highlights the fact that licensing of technology from overseas companies is one of the easiest methods to quickly obtain advanced technology. Nonetheless, there exists a disincentive for the licensors to license to firms that could become a competitor, which may be particularly true for developing countries with less expensive inputs and labor. This could result in identical products, but a cheaper production process. Furthermore, Chakrabarti & Bhaumik (2010) study the internationalization of technology development in India by looking into the role of R&D and patenting, but do not consider the influence of technology licensing.

Outdated technology is an enormous problem affecting especially small and medium enterprises (SME) in developing countries like India. In order to solve this issue, Indian Policy Makers have increased their support to SME's for external technology acquisition in order to achieve technology upgradation (Subrahmanya et al., 2014). In 2014, the 'Make in India' campaign was constructed to increase growth in the manufacturing sector (Iyer, 2018). According to the World Economic Forum's competitiveness ranking (2016), India scores extremely low in their technological readiness, even lower than the average of other developing Asian economies. Therefore, the campaign has been set up in order to invite Foreign Direct Investment (FDI) and stimulate the business environment for manufacturing. Iyer (2018) states that the largest challenge for the Indian industry to move up in the value chain of manufacturing is to decrease the gap in critical technologies. Developed economies such as Japan and Germany are already on their way to use digital technologies and sustainable processes for manufacturing combined. Therefore, new alliances with foreign partners are critical for India in order to move from the stage of industry 2.0 to industry 4.0. Shortly, this study fills the gap in the literature by analyzing whether foreign technology licensing could be beneficial for Indian manufacturing companies in terms of technological process innovation.

2.4 The importance of foreign technology licensing for process innovation

As mentioned before, process innovation alters the production process, but often leaves the end-product unchanged, therefore lowering production costs (Goel & Nelson, 2018). Additionally, process innovations could be introduced as a result of product innovations, which can make corresponding adaptation of the production process necessary (Martínes-Ros & Labeaga, 2009). Process innovation could clearly help to improve the competitive position of a firm, but the capacity to sustain a competitive advantage depends on the form in which a firm generates and accumulates knowledge externally (Martínes-Ros & Labeaga, 2009). Vega-Jurado et al., (2009) presents evidence of the influence of external knowledge-sourcing strategies on the development of both product and process innovation among Spanish manufacturing firms. They find that the acquisition of external knowledge embodied in the equipment and machinery significantly and positively impacts process innovation activities. Chudnovsky et al., (2006) examine Argentinean manufacturing companies and provide evidence that technology acquisition expenditures positively influence the probability of obtaining process innovations. The authors point out that the key form of technology acquisition in the 1990s was embodied technology, which is the main source of process innovation in the Argentinian manufacturing industry. However, technology licensing is only a small component of their variable for external technology licensing, as this is measured together with patent rights and trademarks.

Tsjai & Wang (2008) mention that in order to offer a more comprehensive picture of a firm's technological innovation, further research should consider investigating the effect of external technology sourcing on a firm's process innovation performance. Furthermore, as mentioned, Lewis (2007) states that licensing technology from overseas companies is one of the easiest methods to quickly obtain advanced technology, especially for developing countries. This technology, in turn, increases the efficiency of production processes. The largest part of the existing literature finds positive effects of external technology licensing on competitiveness and product innovation performance. It has been recognized that product and process innovation are significantly correlated (Martínez-Ros, 2000; Reichstein and Salter, 2006). When firms are more dedicated to engaging in product innovation activities, it may be necessary to also engage in process innovation activities, generating complementarities in these two types of innovations. This could be explained by the fact that implementing a product innovation can make corresponding process innovation necessary (Martínes-Ros & Labeaga, 2009). For these reasons, it is expected that foreign technology licensing will also positively influence the introduction of innovative process activities. For Indian manufacturing firms, it is of interest to see if foreign technology licensing could help to increase their technological readiness and thus, their process innovation activities. As mentioned, digital technologies decrease set-up times, labor and material costs and processing times, resulting in a higher efficiency of production processes (Jeschke et al., 2017; Brettel et al., 2014). If the expectations are confirmed and foreign technology licensing has a positive influence on process innovation activities, the 'Make in India' Campaign could focus more on stimulating this type of technology acquisition. Furthermore, as mentioned, product and process innovation are related, but they are largely driven by different determinants. As the literature suggests that foreign technology licensing positively impacts product innovation performance, it is of interest to examine whether this also holds for Indian manufacturing companies. Therefore, the first two hypotheses are stated as follows:

H1a: Foreign technology licensing positively relates to the introduction of process innovation activities among Indian manufacturing companies.

H1b: Foreign technology licensing positively relates to the introduction of new or significantly improved products or services among Indian manufacturing companies.

2.5 The association between different types of innovation strategies

This report will from now on elaborate on process innovation by focusing on how the relationship between foreign technology licensing and this type of innovation is influenced by several aspects. To start with, one important area of investigation is the relation between internal technology generation and process innovation of firms, which is mainly measured by the investment in Research & Development (R&D). In the case of process innovation, R&D reflects to what extend firms need to search for new technologies other than their internal ones. R&D is useful for the development of manufacturing processes and favors the flexibility of firms to adapt to market changes. Therefore, R&D positively affects both product and process innovation within a firm (Raymond & St. Pierre, 2010). Goel & Nelson (2018) investigate manufacturing firms across 118 countries and found that firms performing their own R&D were more likely to introduce process innovations. Baldwin et al., (2002) provide evidence for correlation between R&D investment and process innovation. Furthermore, Mairesse & Mohnen (2002) study high- and low-tech industries in France and find that there is a strong relation between R&D and process innovation. On the other hand, Rouvinen (2002) does not find a relationship between R&D and process innovation. Reichstein et al., (2008) analyze U.K. construction firms and find that R&D expenditures do not play a role in explaining the probability of achieving process innovation. Also, Freel (2003) finds that internal R&D expenditure by supplier-dominated and science-based firms was not associated with process innovation. However, Reichstein & Salter (2006) provide evidence for a positive and significant relation between these variables. Thus, considering the theory available, a positive association between the two variables is expected.

The nature of the relationship between foreign technology licensing and internal R&D efforts has been a subject of debate. Even though most of the literature has emphasized the positive association between foreign technology acquisition and process innovation performance, some researchers have warned about overestimating the role of external technology acquisition and pointed out that external technology acquisition and internal technological effort are complementary (Lall, 2000). Existing literature provides evidence that companies that conduct inhouse R&D are better able to absorb external information and knowledge (Mowery, 1983). According to Walter (2012), a firm's R&D intensity determines the absorptive capacity of a firm and generates innovative technologies and products. Absorptive capacity depends on whether a firm can recognize and use valuable external knowledge. Cohen & Levinthal (1990) focus on the absorptive capacity of firms and state that this largely depends on the extent to which a firm's existing knowledge base is relatable to the external knowledge or technology. Additionally, R&D both generates innovation and facilitates learning, because the knowledge itself may include several learning skills and companies can learn from one another. This means that if knowledge is transferred, the prior knowledge helps the learning of new related knowledge and causes progressive improvement. Li (2011) examines the effect of internal R&D investment, purchasing domestic technology and importing foreign technology on the innovation capabilities of companies. The author finds that for Chinese state-owned high-tech enterprises, only importing foreign technology does not positively impact innovation unless internal R&D is also performed. This means that a complementary relationship exists. Furthermore, Tsai et al., (2011) show that R&D investment increases the positive effect of acquiring external technology on product innovation activities. Investing in R&D does not only increase the ability of a firm to exploit the existing knowledge from external sources, but also helps to develop new knowledge and inventions. On the other hand, it might also be expected that R&D and foreign technology are substitutes. Several articles provide evidence for a substitutive relation between internal and external R&D. Berchicci (2013) finds that internal and external R&D investment activities have a complementary relation, up to a point of R&D investment after which they become substitutes. Firms that invest more in building a higher internal R&D capacity, can substitute external knowledge more easily. This can be explained by the fact that firms with a higher R&D capacity are better able to exploit external knowledge in terms of innovation output, so they have to invest relatively less in acquiring this external knowledge. In the increased competitive world and rapid technological development, firms are looking to access external technologies to substitute expensive internal R&D efforts (Caloghirou et al., 2004). Basant & Fikkert (1996) analyze Indian manufacturing firms and find that R&D and technology purchase expenditures are substitutes in the production of knowledge, in the sense that each variable decreases the marginal productivity of the other. This is in line with the findings of Basant & Fikkert (1993). Laursen & Salter (2006) analyze the innovation behavior among U.K. manufacturing firms and find a substitutive relationship between performing internal R&D activities and the use of external sources and. Even though it could be that firms with more R&D investment might have to rely less on external sources for technologies, the evidence overwhelmingly points at the complementary relation between these two variables. Thus, firms that license foreign technology are expected to also benefit from investing in R&D. Tsai & Wang (2007) indicate that firms can better use international technology licensing as a complement rather than a substitute of internal R&D for their performance. Therefore, it is expected that a company's investment in Research and Development (R&D) moderates the expected positive relationship between external technology licensing and the introduction of process innovation activities. The second hypothesis is formulated as follows:

H2: The positive relationship between foreign technology licensing and the introduction of process innovation activities is stronger for firms that invested in Research and Development compared to those that did not.

Patent applications have been used widely in the literature as an indicator of innovation. However, it does not directly reflect the innovative output as it takes a while before a patent application is actually transmitted into a new product or process. Brouwer & Kleinknecht (1999) analyze Dutch firms and provide evidence that smaller innovators have a lower probability of applying for a patent than larger innovators. The authors use patent applications as an indicator for innovation output, but mention that this can be problematic as the relation highly depends on firm and sector characteristics. Arundel & Kabla (1998) analyze large European industrial firms and also find that the propensity to patent highly depends on industry and firm size. Abraham & Moitra (2001) study patent data in India and highlight that patent applications provide firms and researchers with more insight into the intentions regarding innovation and technological progress. However, the authors mention that a quick granting of a patent is necessary in order for firms to benefit from them. Additionally, they find that in India, there is large delay in granting the patents and that it can be assumed that technology is already well-known by the company when the patent is accepted. Furthermore, not all innovations are patented. This means that whether a firm applied for a patent does not have much extra value as a source of information regarding innovations. However, in order to make production processes more efficient, patenting could still be relevant, because it reflects the internal effort for the development of an idea or technology. Mansfield (1985) shows that new technologies inevitably leak out quickly to competitors once these are introduced on the market. This might make it more important for firms to focus on other ways to gain an advantage. A competitive advantage could be achieved by combining internal technologies with foreign technologies, which suggests a complementary relation. In sum, it is of interest to see whether patent applications are of importance in this model regarding process innovation. As mentioned earlier, internal and external R&D might be both substitutive as complementary. Patent applications also reflect internal knowledge generation, while foreign technology licensing reflects external acquisition of knowledge. Consequently, it can be argued that the relationship between patent applications and licensing is similar to the relationship between R&D and licensing. Therefore, following the arguments of the previous hypothesis, it can be expected that if a firm applied for a patent application concerning a process innovation, the effect of foreign technology innovation on process innovation is stronger. Therefore, the following is hypothesized:

H3: The positive relationship between foreign technology licensing and the introduction of process innovation activities is stronger for firms that have applied for a patent concerning a process innovation compared to those that did not.

2.6 Firm specific characteristics

There exists a considerable body of research that debates whether large or small firms have a higher process innovation performance. Some research indicates that process innovation is more important for larger firms (Cohen & Klepper, 1996; de Mel et al., 2009). Fritsch & Meschede (2001) investigate German manufacturing firms and highlight that large firms profit more from process innovation, because they have a higher output level which increases efficiency. Also, Cohen & Klepper (1996) argue that large firms can spread their innovation costs over larger volumes of output, which increases their advantage in process innovation. In a process innovation strategy, greater production flexibility is more important for small firms, while large firms may invest more in new machinery and equipment, and the search for new and larger markets (Vaona & Pianta, 2008). Furthermore, Reichstein et al., (2008) examine a U.K. sample of construction firms and find that large firms have a higher probability of achieving process innovations than small firms, but this does not hold for product innovation. However, even though large firms benefit more from process innovation, small firms might be able to profit more from foreign technology licensing in terms of process innovation. As mentioned earlier, there are some risks attached to inward technology licensing. The licensee does not control the technology and it may not fully comprehend the knowledge that supports the technology (Walter, 2012). Over time, the licensee may gain valuable insights from the experience with the licensed technology, but this depends on characteristics of the licensee. In addition to the factors described in the previous hypotheses, Atuahene-Gime (1993) finds evidence for specific firm characteristics that influence the ability of firms to adopt foreign technologies. Specifically, the largest factors influencing the firm's propensity to successfully adopt foreign licensing is previous licensing experience, the perceived advantages and disadvantages of licensing, the awareness of opportunities, and the new product development and R&D capabilities of the firm. These aspects highly differ per type of company in terms of size, age, industry and export orientation. Therefore, is of great importance to consider specific firm characteristics when analyzing the effect foreign technology licensing on process innovation performance.

Large firms have economies of scale in R&D, more resources and networks, and knowledge accumulation, which could benefit their ability to profit from external knowledge and technologies (Van Wijk et al., 2008). In contrast, a large part of the existing literature provides evidence that foreign licensing has a larger impact on the innovative performance of smaller firms compared to larger firms (Avarmaete et al., 2004; Tether, 2002; Rogers, 2004). According to Avarmaete et al., (2004), small firms seldom innovate on their own, but are largely depending on external sources of knowledge and other inputs. According to Rogers (2004), small and medium firms may rely more on external networks as an input to innovation than do larger firms. In general, small and medium firms have more resource constraints and do not have the advantage of technological accumulation. Therefore, the ability to obtain knowledge and other inputs externally is a key determinant of innovation within smaller firms (Tether, 2002). Tsai & Wang (2007) mention that acquiring external technology by licensing could be of greater importance for smaller firms in industries that are characterized by rapidly developing technology than for larger firms. Additionally, Tsai et al., (2011) mention that large firms often have a more complex administrative structure than smaller firms which makes absorbing new information more difficult. They also cope with bureaucracy, disincentives to innovate and a loss of managerial control, which will affect the diffusion of knowledge within the firms (Cohen & Levin, 1989). This excessive bureaucratic control within large firms leads to a lower development of new products with significant innovations. Tsai et al., (2011) do find evidence for the fact that firm size negatively influences the contribution of external technology acquisition on product innovation. In sum, it is clear that process innovation is more important for large firms. Nonetheless, when adding the acquisition of foreign technology into the equation, it becomes interesting to see whether small firms are also better able to profit from this in terms of process innovation. Considering the large part of the literature on the ability of small firms to better deal with external technology, the following hypothesis is stated as follows:

H4: The positive relationship between foreign technology licensing and the introduction of process innovation activities is stronger for small and medium firms compared to large firms.

One other area in which a considerable body of theory focuses on the incentive to engage in process innovation is the export orientation of a firm. Damijan et al., (2010) state that exporting firms are superior in terms of productivity, compared to non-exporters. The authors use Slovenian data and find evidence that exporting increases the probability of being a process innovator. Also, Golovko & Valentini (2014) use a sample of Spanish firms and show that large firms are more engaged in process innovation once they entered the export market. This could be explained by the fact that participating in trade may benefit the firm efficiency by stimulating process innovations, which suggests that the 'Learning by Exporting' hypothesis is true. This hypothesis refers to the mechanism that firms have a better productivity after entering export markets (De Loecker, 2013). However, this hypothesis is not always confirmed (Keller, 2004; Wagner, 2007). This can be explained by self-selection of more productive firms going into exporting markets (Andersson & Lööf, 2009). Also, Aghion et al., (2018) analyze French manufacturing firms and find that as more firms enter the export market, it reduces innovation activities and profitability, particularly for firms with a lower productivity. In sum, the results on the relation between exporting and process innovation are inconclusive.

When considering the question whether exporting firms can better translate foreign technology licensing into process innovation activities, mixed results have been found. According to Wang et al., (2013), the technology profile is one of the key determinants for a firm's export performance. Analyzing a sample of Chinese manufacturing companies, they find that inward technology licensing and export performance of these companies are positively associated and that this effect is stronger for foreign technology licensing, compared to domestic. When companies participate in international trade, stronger competition from abroad forces exporting companies to invest in R&D in order to improve its competitive position. By being exposed to foreign knowledge and technology, the innovation performance and productivity of exporting firms is boosted (Ganotakis & Love, 2011). Filatotchex et al., (2009) examine small and medium enterprises in an emerging economy and find that companies that are export-oriented have more mobile human capital, which means that their performance depends more on technology transfers. On the other hand, Evenson & Joseph (1999) find that even though technology licensing enhances firms' profitability, it has a negative effect on the export earnings.

In sum, there is still relatively little known about whether exporting firms that license foreign technology have a higher probability of being engaged in process innovation than non-exporting firms that also license. It could be expected that when firms are both engaged in foreign technology licensing and exporting, there is a higher need to conduct process innovation as firms need to live up to the international competitive environment. In this case, they need to remain competitive and thus decrease their production costs. Also, exporting firms have stronger international connections and are better in using foreign knowledge to their advantage. Aw et al., (2007), study the electronics industry in Taiwan and find that the participation in the export market is more than just the self-selection of more productive companies into the export market. They find that the 'Learning-By-Exporting' hypothesis holds and that firms that are participating in the export market have a higher growth in productivity than the ones that do not participate. Exporting firms profit from technology that is transferred from customers abroad, because they profit more from exposure to the export market. Baldwin & Gu (2004) analyze Canadian manufacturing plants and find that exporters have a higher probability of investing in more complex technology to improve their absorptive capacity. For these reasons, it is expected that companies that are internationally active and license foreign technology have a higher probability of introducing process innovations. Therefore, the following is hypothesized:

H5: The relationship between foreign technology licensing and the introduction of process innovation activities is stronger for exporting firms compared to those that do not export.

Another important determinant for both product and process innovation is whether firms train their employees. Training increases the flow of existing knowledge and stimulates the generation of new knowledge (Caloghirou et al., 2018). Many studies provide evidence of a positive effect of firm training on innovation performance. Gallié & Legros (2012) measure the influence of human capital on innovation for French industrial firms and find that training has a positive effect on technological innovation. Aw & Batra (1998) use firm-level cross-section data from Taiwan and show that worker training activities are positively related to firm efficiency. Additionally, Piening & Salge (2015) examine German manufacturing and service firms and show that employee training is related to the improved process innovation. This means that if firms train their employees, the likelihood of achieving successful process innovation is higher. Training can help to motivate employees to use an innovation in the right manner. This in turn increases the firm's ability to accumulate its experience with the innovation and help to decide how to best use the technology (Edmondson et al., 2001). It can be expected that when firms license foreign technology, it could especially benefit from training since external technologies might be more difficult to work with. Katz & Allen (1982) describe the 'not-invented-here syndrome' which is defined as the resistance among employees against innovative ideas from external sources. Providing information to the employees about how to use process innovations helps them to overcome this syndrome and set operational routines. However, some studies do not find significant relations. Arvanitis et al., (2016) examine Swiss firms and do not find a significant training effect on the innovative propensity, which reflects whether the firm has introduced process or product innovations. Gonzáles et al., (2016) find a significant effect of employee training on product innovation, but only for large firms. They investigate Spanish manufacturing firms and their findings do not hold for small and medium firms. Especially for developing countries like India, it is interesting to see whether firms that both license foreign technology and provide formal training for their employees have a higher probability of being a process innovator. It could for example be that firms are not effective or correct in providing training, which is a waste of time and then it might decrease their innovation performance. Also, it could be argued that firms in need of training have a performance deficiency. In that case, increasing an employee's knowledge and skills does not directly solve the problem, which is a waste of time and resources (Cekada, 2010). Nonetheless, following the literature that overwhelmingly indicates a positive relation, the sixth hypothesis is stated as follows:

H6: The relationship between foreign technology licensing and the introduction of process innovation activities is stronger for firms that provided formal training to its employees compared to those that did not.

2.7 Industry specific characteristics

According to Reichstein & Salter (2006), future research on the determinants of process innovation could link the sources of process innovation with industry-specific characteristics. Some evidence in the literature highlights industry-level differences in licensing, due to the differences in concentration ratios, product complexity, growth rates and patenting (Kim, 2004). In high-tech sectors such as biotechnology, software, chemicals, computers and machinery, licensing accounts for 20% to 33% of all the alliances between firms (Kim, 2005). However, according to Li (2011), technology is often more difficult to transfer in an industry with higher complexity of learning and innovation. This could possibly lead to a lower effect of foreign technology licensing on process innovation performance. Existing empirical research that analyses the role of technical development and innovation performance most often focuses on high-tech industries (Deeds, 2001; Liu & Buck, 2007). Linder (2006) highlights that innovations are a crucial factor for firms that want to achieve a competitive advantage in a high technology industry. Therefore, it would seem logical to assume that the incentive to innovate in these industries is higher. Some of the literature that focuses on analyzing determinants of process innovation has used Pavitt's (1984) taxonomy of patterns of technological change, which classifies firms as supplier-dominated, scale intensive, science-based and specialized supplier. Even though it can be seen as a simple classification, this method has been used in some studies. (Arundel et al., 1995; Vega-Jurado et al., 2009). The authors of Vega-Jurado et al., (2009) mention that for supplier-dominated firms, technological knowledge is for a large part embodied in the machinery, equipment and capital assets produced in other industries. On the other hand, in science-based firms, the most important sources of information are the internal R&D activities of firms and scientific research performed by public research institutions and universities. According to this article, R&D outsourcing is generally associated with product innovation, especially for science-based firms. On the other hand, technological knowledge embodied in equipment and machinery is related to process innovation, especially for supplier-dominated firms (Von Hippel, 1988). Also, Souitaris (2002) tests the applicability of Pavitt's taxonomy and finds that science-based firms have a higher rate of innovation than supplier-dominated industries. However, the main source of technology is internal R&D for science-based firms, because they produce a high proportion of their own process technology. This industry is also characterized by the highest number of patent applications. In contrast, the determinants of innovation for supplier-dominated firms were related to the acquisition of external information. Therefore, the following is hypothesized:

H7: The relationship between foreign technology licensing and the introduction of process innovation activities is stronger for supplier-dominated firms than for firms in the science-based industry.

The existing literature has mainly focused on the effect of foreign technology licensing on different indicators measuring firm performance and product innovation. Additionally, the effect of the general concept of external knowledge acquisition on product and process innovation has received some attention. This study extends previous research in many ways. Firstly, it is analyzed whether the positive effect of foreign technology licensing on product innovation discovered in the literature also holds for Indian manufacturing companies. After, the report specifically focuses on the effect of licensing foreign technology on the extent to which firms introduce process innovation activities. It also contributes to existing literature by considering the effect of complementary innovation input strategies. R&D investment and patent applications for processes are analyzed to see whether this complementary effect holds for Indian manufacturing companies that use a foreign licensing strategy. In addition, firm specific- and industry characteristics are examined. This research is especially of interest to Indian managers and policy makers, since the technology gap is a significant problem, and foreign technology licensing is expected to be the most direct way to capture profits from external technology acquisition.

3 Data and methodology

3.1 Data

The hypotheses outlined in section 2 will be tested using two datasets collected from the World Bank Microdata Library. The first dataset includes the Enterprise Survey on 9281 Indian manufacturing companies from 23 regions and 23 industries. The sample was selected using stratified random sampling to obtain unbiased estimates for the whole population. It includes general information about the company characteristics, such as size, age and export orientation, but also data on innovation activities, licensing behavior, competition intensity and employment. This general dataset is collected in order to capture data covering measures of firm performance and the business environment in general. In order to obtain more detailed information on the innovation behavior of the firms, the general dataset was merged with data from the Innovation Follow-up Survey covering 3,492 manufacturing companies. This sample size is obtained by randomly selecting a subset of respondents from the Enterprise Survey. In terms of firm- and industry characteristics, there are thus no differences in the sample division that need further attention. This dataset includes more detailed information on innovation and innovation-related activities across a large number of manufacturing firms, in order to provide evidence on the role, nature and determinants of innovation. Both datasets are from 2014 and contain information from during the period 2010-2013. The two datasets are merged into one final dataset that contains only the 3492 matched companies and will be used for the analysis conducted in this article. The service industries were deleted from the sample, because this article focuses on only the manufacturing industry. After also deleting observations with missing values, the sample consists of 2456 firms. Three levels of stratification were used in India: establishment size, industry and region. Industry stratification was designed in the way that the division was made into 11 manufacturing industries. An overview of the industry classification can be found in appendix B. The classification follows Pavitt's taxonomy (1984), that distinguishes between supplier-dominated, scale intensive, specialized supplier, and science-based industries. In this research, the focus is only on supplier-dominated and science-based firms, which will be explained in the following section. After this categorization, we are left with 1594 firms. The division of firms within each category in terms of size, innovation input and output behavior and licensing behavior is shown in the tables below.

Table 1 Tabulation of Firm Size and Licensed Technology

Firm Size	Licensed Foreign Technology			
	Not Licensed	Licensed	%	Total
Small & Medium Firms <100	1070	92	7.91	1162
Large Firms >=100	354	78	18.06	432
Total	1424	170	10.66	1594

Table 1 shows the sample distribution in terms of size and licensing activity. Firms are classified as small or medium when the number of employees is less than 100 and large when it is equal or larger than 100. 72.9% of the sample consists of small and medium firms. 7.91 % of these firms licensed foreign technology at the time of the interview. 27.10 % of the sample consists of large firms, of which 18.06% licensed foreign technology. In total, 10.66% of the sample licensed foreign technology.

Table 2 Tabulation of Process Innovation and Licensed Technology

Process Innovator	Licensed Foreign Technology			
	Not Licensed	Licensed	%	Total
No Process Innovator	610	32	4.98	642
Process Innovator	814	138	14.50	952
Total	1424	170	10.66	1594

Table 3 Tabulation of Innovation Activities

Invested in Research and Development	Applied for a patent for process innovation			
	No Patent	Patent	%	Total
R&D Investor	656	95	12.63	751
No R&D Investor	749	94	11.15	843
Total	1405	189	10.66	1594

Table 2 shows the sample distribution in terms of licensing activities and process innovation, which are the main variables in this report. 50.63% of the sample engaged in process innovation in the period 2010-2013. Within this group, 14,5% licensed foreign technology. The distribution in terms of intermediate innovation activities are shown in table 3. 11.85% of the sample applied for a patent for process innovation in the period 2010-2013. 47.15% of the total sample invested in R&D in this same period. A descriptive overview of all the variables is provided in Appendix A.

3.2 Sectoral classification

According to Malerba (2005), internal and external knowledge sources of innovation are largely determined by industrial dynamics. To control for this variation and test Hypothesis 7, Pavitt's (1984) taxonomy of patterns of technological change is often used in the literature (Arundel et al., 1995; Vega-Jurado et al., 2009). This classification distinguishes between supplier-dominated, scale intensive, specialized supplier, and science-based industries. Vega-Jurado et al., (2009) use this method and focus only on supplier-dominated and science-based firms for several reasons. To start with, these two categories include the companies for which industrial and scientific sources are more easy to distinguish. Pavitt (1984) suggests that for supplier-dominated firms, technological knowledge is for a large part embodied in the equipment, capital assets and machinery that are produced by other industries. On the other hand, for science-based firms, internal R&D investment and research performed by universities and public institutes is the main source of knowledge. Moreover, according to Cassiman & Veugelers (2006), a firm's dependence on more basic types of knowledge influences complementarity level between innovation strategies. Lastly, the categories are different concerning the technological opportunity which could affect the use of external technology acquisition. Therefore, it is expected that there exists heterogeneity among the extent to which firms are engaged in foreign technology licensing in these two different industries. Thus, this classification method of Vega-Jurado et al., (2009) will also be used in this article. The innovation performance of science-based firms is expected to be more influenced by foreign technology licensing than supplier-dominated firms. Bogliacino & Pianta (2016) revised the Pavitt Taxonomy classification and came up with slightly alternative industry groupings, which will be used in this article since it is more recent.

Table 4 Distribution of sample by Sectoral Classification

Pavitt's category	Economic activity	Sample	Sample%
Supplier-dominated			
	Food	189	11.85
	Tobacco	32	2.01
	Textiles	155	9.72
	Garments	97	6.08
	Leather	38	2.38
	Wood	51	3.20
	Paper	54	3.39
	Fabricated metal products	219	13.73
	Furniture	28	1.76
	Recycling	13	0.82
	Wholesale	1	0.06
	Total	*876*	*54.96%*
Science-based	Chemicals	223	13.98
	Machinery and equipment	268	16.80
	Electronics	202	12.66
	Precision instruments	25	1.57
	Total	*718*	*45.04%*
Total		*1594*	*100%*

The distribution of the final sample is shown in Table 4. It shows the number of firms per category and the percentage in the total sample of the respective sectoral category. After deleting the Specialized Supplier and Scale & Information Intensive categories, the sample consists of 1594 firms, with 876 supplier-dominated firms, which is 54.96% and 718 science-based firms, 45.04%.

3.3 Measurements

3.3.1. Dependent variable

Even though there exist some studies that consider the determinants of process innovation, the literature on technology acquisition strategies has traditionally focused on studying product innovations, and thus partly neglects process innovations (Reichstein & Salter, 2006). In this analysis, the dependent variable was derived from one question in the survey about whether the firm engaged in an introduction of innovative supporting activity for processes between 2010 and 2013. This variable in the survey can take three different values. The firm might have answered (i) don't know, (ii) yes, and (iii) no. By only selecting the companies that chose either answer (ii) or (iii), the distinction between these two groups of companies can be made. In the statistical analysis, this will therefore be used as the dependent dummy variable *Processinnov*. It takes the value 1 if the company introduced new innovative activities for processes from fiscal year 2010/2011 thru 2012/2013 and 0 if not. This dummy, also used by other literature, is a good indicator of process innovation. It is important to gain insight into whether a firm has undertaken process innovation activities or not, because it shows its willingness and commitment to innovate and remain competitive in the market. (Evangelista et al., 1998; Baldwin et al., 2002; Avermaete et al., 2004). Furthermore, it is useful to measure whether firms that license foreign technology have a higher probability of becoming a process innovator compared to those that do not, which can only be assessed with a dummy variable.

3.3.2. Explanatory variables

The main independent variable of the first model *LicensedTech* is derived from the question whether the firm uses licensed technology from a foreign owned company at the time of the survey. The variable in the survey can take three different values: (i) don't know, (ii) yes and (iii) no. The companies that answer (i) don't know are deleted so that a dummy variable could be created which takes the value 1 if companies licensed foreign technology and 0 if not. Furthermore, *RDinvestment* is included, which takes the value 1 when the firm invested in internal R&D activities in the fiscal years 2010/2011 thru 2012/2013, and 0 if not. R&D reflects to what extend firms need to search for new technologies other than their internal ones. R&D is useful for the development of manufacturing processes and favors the flexibility of firms to adapt to market changes. Since existing articles have found evidence for an effect of R&D on product innovation activities, it is interesting to examine whether this positively affects process innovation. Additionally, patent applications have been used widely in the literature as an indicator of innovation. However, it does not directly reflect the innovative output as it takes a while before a patent application is actually transmitted into a new product or process. Therefore, a dummy variable that indicates whether a firm applied for a patent regarding process innovation will be included to analyze whether this affects the probability of being engaged in process innovation. Furthermore, firm size is relevant as the literature has established that larger firms conduct more process innovation. In order to measure firm size, the variable *Largefirm* is created, which takes the value 0 for small and medium firms and the value 1 for large firms. Firms are classified as small or medium when the number of employees is less than 100 and large when it is equal or larger than 100. As mentioned in the literature framework, exporting firms are expected to be more engaged in process innovation than firms who do not. Therefore, the dummy variable *Export* is considered to test whether the firm is exporting in 2013 or if it considers exporting in the next year.

Innovation is highly idiosyncratic and firms have heterogeneous characteristics (Baldwin et al., 2002). Several variables that are commonly used as controls in the literature on innovation are analyzed in this study. To start with, the increasing literature on innovative performance of firms use firm characteristics as firm age, ownership, patent applications, competition intensity and product innovation as control variables (Wang & Li-Ying, 2015; Wang et al., 2013; Yi, Wang, & Kafouros, 2013). Firm age is expected to negatively influence process innovation, according to a large part of the literature. As the firm grows older, the willingness to adapt to changes decreases, lowering the probability of engaging in process innovation. *Firmage* is measured as the number of years between the year when a company was founded and the year in which the survey was conducted. The ownership structure is captured via sole proprietorship. Therefore, *Ownership* is included as a dummy variable that shows whether firms are owned by a sole proprietor. Being owned by a sole proprietor addresses agility to move to changing demands of the marketplace and increases the probability of being a process innovator (Goel & Nelson, 2018). The *Processpatent* variable indicates whether the firm applied for a patent concerning a process innovation in the period 2010-2013. According to Acs and Audretsch, (1989), patents are a reliable indicator for innovative outputs. Even though it does not indicate the output of an innovation process, it represents the degree to which firms engage in technical improvements (Ahuja & Katila, 2001). Also, *Competition* is included, which is a categorical variable that measures the number of competitors. Baldwin et al., (2002) investigate the determinants of process innovation for Canadian manufacturing companies and find that the number of competitors in an industry is an important determinant for why a firm is a process innovator. Also, they show that the probability of process innovation first increases and then decreases as the number of competitors increase. They use three categories for competition, namely 0-5, 6-20 and more than 20 competitors. In this study, the categories are slightly changed, with 0-5, 6-20, 20-100 and >100 competitors, based on the division of competitors in the sample. As mentioned, Narayanan (1998) states that the absence of competitive forces in the Indian automotive market led to a disincentive for firms to technologically innovate. Therefore, the number of competitors in the market is important to consider as a control variable.

Furthermore, the literature suggests that it is necessary to control for industry effects, because companies in different industries have different strategic orientation and incentives to innovate (Cohen et al., 2002). As mentioned in the theoretical framework, the process innovation performance of science-based firms is expected to be more influenced by foreign technology licensing than supplier-dominated firms. Therefore, the industry categories are considered with the dummy *Sciencebased* which takes the value 1 if firms operate in these industries and 0 if not. Lastly, region fixed effects are added to control for secular trends in the outcome that are common across the 23 different regions (Bhaskarabhatla et al., 2017). In appendix C, an overview of all the regions is shown.

3.4 Methods

The engagement in process innovation activities among the manufacturing companies in the sample can be measured with the dependent variable can take the discrete values 0 and 1. Therefore, a binary logit model is used to measure the effect on the decision of two alternatives (King, 2008). In the analysis, the base model examines all available observations and considers the independent variable *LicensedTech* to indicate whether or not the firm purchased foreign technology in the years 2010/2011 thru 2012/2013. The probabilities of each firm becoming a process innovator (*Processinnov*) are calculated by regressing the exogeneous variables available for all observations. In every model, strict probability weights from the full dataset are included to control for the possibility that observations had a different probability of being sampled (Dupraz, 2013). The binary logistic regression is analyzed with the following formula:

$$(Base\ Model) \qquad Log\left(P\frac{(Processinnov = 1)}{(Processinnov = 0)}\right) = \beta_0 + \beta_1 LicensedTech + \beta_2 RDinvestment + \beta_3 Processpatent + \beta_4 LargeFirm + \beta_5 Export + \beta_6 Training + \beta_7 Sciencebased + \beta_8 Firmage + \beta_9 Ownership + \beta_{10} Productinnov + \beta_{11} Competition$$

In base models 1a and 1b, the effect of foreign technology licensing on a firm's process and product innovation activities is analyzed. Therefore, it should be noted that the formula for testing hypothesis 1b about product innovation has a similar set-up, except for the fact that the dependent variable differs. In order to examine whether there exist complementary or a substitutive relationships between our main explanatory variables, several interaction terms are added to the models. In the second model, an interaction term of *RDinvestment* and *Licensedtech* is generated to test the second hypothesis: *RD_License*. It is expected that having internal R&D activities increases the probability of engaging in process innovation. For the third model, an interaction term of the variables *LicensedTech* and *Patentprocess* is generated to test the third hypothesis: *Patent_License*. Since firms that apply for patents regarding process innovation are more likely to have a higher absorptive capacity, this relation is expected to be complementary.

Since firm specific characteristics are considered to be of influence in the relation between foreign technology licensing and process innovation activities, an interaction term of *LicensedTech* and the dummy variable *Largefirm* is created in model 4: *Large_License*. It is acknowledged that large firms are more engaged in process innovation. Also, according to the literature, larger firms are expected to be better able to transform foreign licensing technology into process innovations than smaller firms. Additionally, to test whether technology licensing has a larger influence on process innovation for exporting firms, an interaction variable between *Export* and *LicensedTech* is created for model 5: *Export_License.* These firm characteristics are analyzed in order to determine to what extend these characteristics influence the process innovation outcome and see if and what their moderating impact is on the influence of foreign technology licensing. For model 5, an interaction term *Training_License* is generated in order to examine whether firms that train their employees and license foreign technology have a lower probability of being a process innovator than firms that do not train their employees but do license. Lastly, the comparison is made between science-based and supplier-dominated firms to examine whether these industry effects influence the relation between foreign technology licensing and process innovation. Therefore, the interaction term *Sciencebased_License* is added to the 7th model. The 8th model includes all the interaction terms to examine whether they have a combined effect on process innovation.

4. Results

4.1 Correlation analysis

The Spearman correlation matrix that is shown in table 5 reveals some interesting insights. Overall, there are no strong correlations among the main variables of this research, which means that there is a low chance of multicollinearity in the models. As expected, there exists a positive significant association between the key variables process innovation and foreign technology licensing. Additionally, the moderately strong association between process innovation and R&D investment is positive, which is in line with the literature that also find a positive correlation between these two variables (Baldwin et al., 2002; Raymond & St. Pierre, 2010). Product innovation and process innovation are also positively correlated. Only the control variables *Training*, *Ownership* and *Competition* are not significantly correlated with process innovation, which is not in line with the expectations. It seems that for Indian manufacturing firms, process innovation is independent of whether the firm trains its employees, the competition intensity of the industry and whether the company is a sole proprietor or not.

4.2 Regression analyses

In the first column of table 6, model 1a reports the baseline model for process innovation including all the explanatory variables without interaction terms. The results suggest that the probability of introducing a process innovation is 8,5 percentage points (PP) higher for firms that license foreign technology. In a binary model, this probability is evaluated against the predicted probability in the sample of being a process innovator. On average, the probability of being a process innovator is 59.7% and when companies license foreign technology, the probability of being a process innovator increases from 59.7% to 68.2%. Therefore, hypothesis 1a, stating that the parameter foreign licensing is equal to zero, can be rejected at a significance level of 10%. Additionally, the outcomes suggest that the probability of introducing a process innovation is 27,2 PP higher for firms that that invested in R&D, so the predicted probability of being a process innovator increases from 59.7% to 86.9%. Furthermore, the probability of introducing a process innovation is 10,1 PP higher for firms that applied for a patent compared to firms that did not, which means that the predicted probability of being a process innovator increases from 59.7% to 69.8%. The positive relations are in line with the expectations and the largest part of the analyzed literature. Lastly, the probability of being a process innovator is 4.9 PP higher for larger firms than for small and medium firms. This is also in line with the large part of the analyzed literature. Firms that introduced product innovation activities have a lower probability of 5,3 PP of being a process innovator, significant at a 5% significance level. As mentioned before, it is of interest whether the evidence provided in the existing literature on product innovation also holds for this sample of Indian manufacturing companies, and if it is associated with the same determinants as process innovation. What can be seen in the second column of Table 6 is that the probability of being a product innovator is 9.7 Percentage Points (PP) higher for firms that license foreign technology than for firms that do not, significant at a 5% significance level. This is in line with the existing literature and thus it provides evidence that the licensing effect on product innovation holds. Also, the probability of being a product innovator is 8.6 PP higher for firms that invest in R&D, compared to firms that do not. The predicted probability of being a product innovator thus increases from 61.6% to 70.2% when firms invest in R&D. Furthermore, the probability of being a product innovator is influenced by the competition intensity. As the number of competitors in the market increases, compared to having only 0-5 competitors, this decreases the probability of being engaged in product innovation. Next to this, exporting companies, companies that provide training to its employees, and firms that are owned by a sole proprietor have a higher probability of being a product innovator than those that are not. Another finding is that product innovation and process innovation are negatively and significantly associated, which is not in line with the positive correlation detected in Table 5. After running the regression with each variable separately, the reason for this remarkable finding was found. After adding the region fixed effects to the model, the sign of *Processinnov* changed. This means that product innovation and process innovation are regionally concentrated. In India, there exist major differences in terms of development among regions. The inequality in India could weaken or even change the sign of the relation between product and process innovation. In the appendix C, an overview of product and process innovators across different regions is provided.

Table 5: Spearman Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Processinnov	1											
LicensedTech	0.151***	1										
RDinvestment	0.369***	0.0440	1									
Processpatent	0.127***	0.125***	0.0227	1								
Largefirm	0.158***	0.146***	0.227***	0.0383	1							
Export	0.0838***	0.0642*	0.191***	0.00846	0.328***	1						
Training	0.0367	0.00417	0.188***	-0.0204	0.142***	0.0714**	1					
Sciencebased	0.0519*	-0.0187	0.117***	0.0307	0.0125	0.0159	0.0468	1				
Firmage	-0.103***	-0.0866***	-0.0253	-0.0270	0.101***	0.0711**	0.0514*	0.00658	1			
Ownership	-0.0389	0.0364	-0.175***	0.0354	-0.202***	-0.215***	-0.169***	-0.0830***	-0.122***	1		
Productinnov	0.0791**	0.114***	0.160***	0.0963***	0.0952***	0.0850***	0.0686**	0.0362	-0.0514*	0.00353	1	
Competition	0.0394	0.0622*	-0.0447	0.0573*	-0.00354	0.0686**	-0.131***	-0.0640*	-0.0608*	0.108***	0.0180	1

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6 Determinants of Process- and Product Innovation, Binary logistic Regression

Independent variables	Base Model (1a) Processinnov	Base model (1b) Productinnov
LicensedTech	0.085*	0.097**
	(0.049)	(0.044)
RDinvestment	0.270***	0.086***
	(0.024)	(0.029)
Processpatent	0.101**	0.043
	(0.041)	(0.042)
Largefirm	0.049*	0.016
	(0.027)	(0.029)
Export	0.017	0.055*
	(0.028)	(0.029)
Training	0.019	0.049**
	(0.023)	(0.024)
Sciencebased	-0.019	0.015
	(0.023)	(0.029)
Firmage	-0.0003	-0.001
	(0.0007)	(0.001)
Ownership	-0.010	0.051**
	(0.024)	(0.023)
Processinnov		-0.050**
		(0.025)
Productinnov	-0.055**	
	(0.024)	
Competition_5-20	-0.040	-0.098***
	(0.036)	(0.035)
Competition_21-100	0.017	-0.112***
	(0.045)	(0.044)
Competition_>100	-0.005	-0.073**
	(0.032)	(0.030)
Region dummies	Included	Included
Pseudo R2	0.249	0.129
Observations	1,594	1,594

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
In this regression, marginal effects are displayed with standard errors between parentheses.
Intercepts and coefficients of regions are not displayed but are available upon request.

When comparing the determinants of product and process innovation, it can be seen that the effect of foreign technology licensing is slightly larger for product innovation than for process innovation (9,7 > 8,5 PP). The predicted probability of being a product innovator is 61.6%, but this increases to 71.3% for firms that license. Moreover, product innovation is less influenced by the investment in R&D than process innovation (8.6 < 27.1 PP). However, the positive significant effect of R&D investment exists for both types of innovation. Furthermore, as process innovation is influenced by whether the firm applies for a patent and whether a firm is large compared to being small or medium, product innovation is not. Nonetheless, the probability of being a product innovator is influenced by whether the firm exports, provides training, and whether it is owned by a sole proprietor. Also, competition intensity influences the decision to engage in product innovation. All these characteristics do not influence process innovation. Lastly, it is clear from both regressions that product and process innovation are negatively related to each other. This effect is significant at the 5% significance level. In sum, most results are in line with the existing literature. Most importantly, even though product and process innovation are influenced by different determinants, licensing foreign technology positively influences the probability of being engaged in both types of innovation for Indian manufacturing companies.

Table 7 shows the regression results for all the models, including the interaction terms. However, there are some differences between these models as the inclusion of the interaction variables change the effects of the other variables. In order to test hypothesis 2, on whether a complementary relation exists between R&D investment and foreign licensing, an interaction term of these two variables is added to the analysis. This second model shows some interesting insights. The sign of *RD_License* is negative and significant, indicating that the relation between foreign technology licensing and process innovation is weaker for firms that invested in R&D, compared to those that did not. This means that hypothesis 2, stating that these two variables have a complementary relationship, is not supported. The substitutive relationship is significant at a 1% significance level, which is in line with some of the literature discussed earlier (Basant & Fikkert 1996; Lauren & Salter, 2006).

The econometric analysis does not support hypothesis 3 that the positive relation between foreign technology licensing and whether firms are engaged in process innovation is stronger for firms that have applied for a patent concerning process innovation, compared to those that did not. The interaction term is not significant which indicates that there is no evidence for this hypothesis.

To test hypothesis 4, 5 and 6, on the differential importance of foreign technology licensing for process innovation considering several firm characteristics, one interaction term is added to each model. These three models test whether the effect of foreign licensing on the probability of being a process innovator is stronger for firms with the different firm characteristics: firm size, export orientation and training effort, respectively. The two interaction terms for firm size and export orientation are not significant, which indicates that being a large firm or an exporting firm does not seem to affect the relation between foreign technology licensing and process innovation to a different degree than for smaller firms and firms that do not export. The interaction term in model 6 *Training_License* on the other hand, is negative and highly significant at the 1% significance level. This is a striking finding, since it was expected that firms that provide training to their employees are better able to profit from foreign technology licensing in terms of translating this into their process innovation performance. However, this effect seems to be the other way around, so hypothesis 6 is not supported. If firms provide training to their employees, this negatively influences, thus weakens, the positive relation between foreign technology licensing and process innovation compared to firms that do not provide training regarding innovation.

Table 7 Determinants of Process Innovation with interactions, Binary Logistic Regression

Independent Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
LicensedTech	0.505* (0.293)	1.277*** (0.402)	0.361 (0.299)	0.373 (0.354)	0.547 (0.385)	1.617*** (0.466)	1.427*** (0.418)	2.275*** (0.610)
RDinvestment	1.598*** (0.163)	1.715*** (0.167)	1.600*** (0.163)	1.602*** (0.163)	1.598*** (0.163)	1.631*** (0.162)	1.608*** (0.163)	1.716*** (0.169)
RD_License		-1.463*** (0.487)						-0.863 (0.563)
Processpatent	0.602** (0.243)	0.599** (0.243)	0.458* (0.261)	0.606** (0.244)	0.601** (0.243)	0.610** (0.242)	0.655*** (0.246)	0.464* (0.259)
License_Patent			1.283 (0.801)					1.665* (0.940)
Largefirm	0.292* (0.160)	0.286* (0.161)	0.298* (0.161)	0.259 (0.167)	0.293* (0.160)	0.328** (0.161)	0.280* (0.161)	0.235 (0.171)
Large_License				0.293 (0.482)				0.857 (0.558)
Export	0.099 (0.168)	0.118 (0.168)	0.104 (0.168)	0.097 (0.168)	0.108 (0.171)	0.104 (0.167)	0.101 (0.168)	0.106 (0.174)
Export_License					-0.106 (0.580)			0.0759 (0.630)
Training	0.112 (0.137)	0.115 (0.138)	0.104 (0.137)	0.109 (0.137)	0.112 (0.137)	0.239* (0.142)	0.127 (0.137)	0.230 (0.143)
Training_License						-1.830*** (0.515)		-1.783*** (0.552)
Sciencebased	-0.071 (0.132)	-0.084 (0.133)	-0.075 (0.133)	-0.071 (0.133)	-0.070 (0.133)	-0.052 (0.133)	0.0631 (0.137)	0.049 (0.138)
Sciencebased_Licence							-1.758*** (0.492)	-1.605*** (0.523)
Firmage	-0.002 (0.005)	-0.003 (0.005)	-0.002 (0.005)	-0.002 (0.005)	-0.002 (0.005)	-0.002 (0.005)	-0.002 (0.005)	-0.002 (0.005)

Table 7 Continued								
Ownership	-0.0572	-0.0663	-0.0622	-0.0579	-0.0575	-0.0475	-0.0538	-0.0624
	(0.145)	(0.145)	(0.144)	(0.145)	(0.145)	(0.145)	(0.146)	(0.144)
Productinnov	-0.327**	-0.328**	-0.329**	-0.331**	-0.327**	-0.308**	-0.337**	-0.328**
	(0.140)	(0.142)	(0.140)	(0.140)	(0.140)	(0.141)	(0.142)	(0.144)
Competition_5_20	-0.234	-0.226	-0.241	-0.237	-0.233	-0.229	-0.254	-0.273
	(0.212)	(0.212)	(0.212)	(0.213)	(0.212)	(0.211)	(0.212)	(0.212)
Competition_21_100	0.103	0.0978	0.0907	0.103	0.103	0.101	0.123	0.0894
	(0.271)	(0.270)	(0.269)	(0.270)	(0.271)	(0.272)	(0.271)	(0.271)
Competition>100	-0.0313	-0.0603	-0.0517	-0.0334	-0.0309	-0.0556	-0.0506	-0.129
	(0.190)	(0.190)	(0.189)	(0.190)	(0.189)	(0.189)	(0.190)	(0.192)
Region dummies	Included	Included	Included	Included	Included	Included	Included	Included
Pseudo R2	0.2489	0.2534	0.2503	0.2491	0.2489	0.2556	0.2556	0.2660
Observations	1,594	1,594	1,594	1,594	1,594	1,594	1,594	1,594

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Regression coefficients are displayed with standard errors between parentheses.
Intercepts and coefficients of regions are not displayed but are available upon request.

What is also interesting is that there is no significant effect throughout all the models for being a science-based firm compared to being a supplier-dominated firm on the probability of being a process innovator. Nonetheless, the interaction term between the science-based industry and foreign licensing shows a strong negative significant effect on process innovation. This indicates that when firms are operating in the science-based industry, this negatively influences, or weakens, the relation between foreign technology licensing and process innovation, compared to supplier-dominated firms. Supplier-dominated firms are thus better able to transform foreign licensed technology into process innovation activities. Souitaris (2002) finds that science-based firms have a higher innovation performance than supplier-based firms. However, the main source of technology for science-based firms is internal R&D, because they produce a high proportion of their own process technology. On the other hand, the determinants of innovation for supplier-dominated firms were related to the acquisition of external information and technology. In sum, hypothesis 7 is supported, which is in line with the results obtained in the literature.

The impact of the control variables is consistent for all the models presented. *Firmage* is not significant which means that this firm characteristic is not associated with a higher or lower probability of being engaged in process innovator. The ownership structure, whether a firm is a sole proprietor or not, is never significant and thus also does not seem to affect the probability of a firm being a process innovator. Goel & Nelson (2018) find that being a sole proprietor increase the likelihood of process innovation. However, they find differences across industries and this positive coefficient was notably larger for service industries. As this sample only consists of manufacturing firms, it is not remarkable that no significant effect could be detected. Also, there is no significant effect for any of the competition intensity categories. Having more competitors, compared to having 0-5 competitors, does not influence the probability of being a process innovator. These results are not in line with Baldwin et al., (2002) who use three categories of competition, namely 0-5, 6-20 and more than 20 competitors. They find that the probability of being a process innovator is higher for the lowest and highest categories, compared to the middle one. The different results obtained in table 7 could be explained by the different competitiveness classifications that also include a separate category of competitors above 100. Lastly, as mentioned before, what is striking is that firms that conducted product innovation have a lower likelihood of being engaged in process innovation activities, compared to firms that did not. This effect is significant throughout all models at a 5% significance level. This could be explained by the heterogeneous characteristics among regions, or it means that these two innovation strategies are substitutive. The findings are in line with Li et al., (2007), that find that process innovation and product innovation might be considered alternatives to each other.

In order to check whether there exists a problem of multicollinearity in the models, the variance inflation factors (VIF) are tested. Throughout all the models 1-7, the VIFs are all below 3. Only in model 8, the VIF of *LicensedTech* is 5.46, which is still no cause for concern that the problem of multicollinearity exists.

4.3 Robustness Analyses

4.3.1 Alternative measure for process innovation

In order to see whether the results are consistent and unaffected by different methods for process innovation and industries, two robustness checks are conducted. In the first analysis, a different dependent variable is used that is similar to the one used in the main analysis. Pilav-Velic & Marjanovic (2016) measure process innovation with several variables. Firstly, they use innovations in supporting processes. This variable is the same one used in the main analysis in this research. Nonetheless, they also use process innovation within production methods such as manufacturing, and/or service providing. According to the authors, a linear relationship exists between these variables and the average process innovation level. The variable *Processinnov_R* is derived from one question in the survey about whether the firm introduced any new or significantly improves methods of manufacturing products or services. This variable in the survey can take three different values. The firm might have answered (i) don't know, (ii) yes, and (iii) no. By only selecting the companies that chose either answer (ii) or (iii), the distinction between these two groups of companies can be made. It takes the value 1 if the company answered yes for the fiscal year 2010/2011 thru 2012/2013 and 0 if not. This variable similarly measures whether firms engaged in process innovation in an alternative way and therefore it is a good way of testing whether the results are robust. Table 8 shows the results for all the models. The results are somewhat similar to the results obtained previously in terms of sign and significance, but not all of them. To start with, foreign technology licensing still has a positive significant effect on process innovation. This means that our findings stating that the probability of being a process innovator is higher for firms that license foreign technology than for firms that do not are consistent for Indian manufacturing companies. Secondly, the results show that firms investing in R&D have a higher probability of introducing a process innovation than those that do not invest in R&D are also robust. Nonetheless, firms that apply for a patent related to process innovations have a lower probability of being engaged in process innovation throughout all models compared to firms that do not. This is not in line with the expectations. Also, while no significant result was found for the ownership variable in the main analysis, the robustness analysis indicates a negative significant sign. This shows that firms that are owned by a sole proprietor have a lower probability of being a process innovator compared to those that are not. For some of the interaction terms, different results are also obtained which means that they are not robust. Firstly, for *RD_License,* a significant effect still exists but the sign is now positive, which is remarkable. According to this regression, the relation between foreign technology licensing and process innovation is stronger for firms that invested in R&D compared to those that did not. This suggests a complementary relation between R&D investment and foreign technology licensing, significant at a 1% significance level. Also, while in the previous results no significant result could be found for *Export_License*, this analysis indicates a weakly significant but positive effect. It means that the relation between foreign technology licensing and process innovation is stronger for exporting firms, compared to firms that do not export. Lastly, while the main analysis indicates a significant positive effect for the interaction term *Sciencebased_License*, no evidence was provided for a significant effect in the robustness check.

In sum, the main finding on our independent variable foreign technology licensing is robust. However, not all the interaction terms are robust and associations that were not significant in the main analysis are found to be of importance in this robustness check. This might be explained by the slightly different definitions and perceptions of both process innovation variables, which causes firms to provide different answers in the interview. Even though the two measures for process innovation are perceived as similar by the literature, it could be that firms view these as two separate aspects. The interpretations of 1) introducing new or improved supporting activities for processes on the one hand, and 2) introducing improved methods of manufacturing products or offering services could cause the different results. R&D investment weakens the relation between foreign technology licensing and the first-mentioned concept of process innovation, but strengthens the relation between licensing and the second-mentioned concept. This means that both external and internal generation of technology is suitable for developing improved methods of manufacturing, but only either R&D or foreign licensing should be conducted for introducing new supporting activities for processes.

4.3.2 Different industry division

The second check which includes data on all the four industries of Pavitt's Taxonomy (1984) is performed to see whether the results are robust for a larger sample, instead of using only the two categories supplier-dominated and science-based. The sample size now includes 2,456 firms from four different industry categories: science-based, information-intensive, specialized-supplier, and the base category supplier-dominated. The results in table 9 are qualitatively similar to those presented in table 6 and 7. Both the signs and significance stay the same, which means that the results are robust among the larger sample size with a different categorization of industries. One different result that can be detected in table 9, while comparing it to the results in table 7 is that *License_Patent* is now significant. This could be explained by the fact that patenting might have a more important role in the industries that are now included in the sample size. The association between foreign technology licensing and process innovation is thus stronger for firms that also applied for a patent regarding process innovation. Secondly, *Competition_21-100* becomes significant and positive in every model. This means that the relation between technology licensing and process innovation is stronger for firms that operate in an industry with 21-100 competitors, compared to firms that are active in an industry with less than 5 competitors. The different finding could be caused by the fact that in this larger sample size with the different industry classification, competition intensity becomes more relevant and thus is of influence for how foreign technology licensing affects process innovation activities among Indian manufacturing firms.

Table 8 Robustness 1) Determinants of Process Innovation with interactions, Binary Logistic Regression

Independent Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
LicensedTech	0.640**	-0.0485	0.685**	0.790**	0.262	0.230	0.738**	-0.309
	(0.294)	(0.418)	(0.326)	(0.374)	(0.331)	(0.339)	(0.330)	(0.572)
RDinvestment	1.383***	1.234***	1.382***	1.375***	1.394***	1.371***	1.383***	1.236***
	(0.176)	(0.181)	(0.177)	(0.177)	(0.177)	(0.177)	(0.176)	(0.181)
RD_License		1.887***						1.837**
		(0.663)						(0.761)
Processpatent	-0.554**	-0.544**	-0.516*	-0.552**	-0.557**	-0.559**	-0.547**	-0.506*
	(0.239)	(0.246)	(0.277)	(0.239)	(0.241)	(0.242)	(0.241)	(0.273)
License_Patent			-0.210					-0.328
			(0.469)					(0.640)
Largefirm	0.243	0.289	0.243	0.285	0.241	0.234	0.242	0.343*
	(0.174)	(0.177)	(0.174)	(0.189)	(0.174)	(0.174)	(0.174)	(0.186)
Large_License				-0.352				-0.850
				(0.423)				(0.584)
Export	0.244	0.241	0.242	0.243	0.159	0.243	0.244	0.153
	(0.181)	(0.181)	(0.181)	(0.181)	(0.183)	(0.180)	(0.181)	(0.182)
Export_License					1.127*			1.430*
					(0.663)			(0.746)
Training	0.151	0.136	0.153	0.153	0.147	0.0817	0.153	0.0882
	(0.144)	(0.144)	(0.144)	(0.144)	(0.144)	(0.150)	(0.144)	(0.147)
Training_License						0.856*		1.011
						(0.450)		(0.663)
Sciencebased	0.0470	0.0608	0.0483	0.0492	0.0440	0.0377	0.0643	0.0887
	(0.141)	(0.141)	(0.141)	(0.141)	(0.141)	(0.141)	(0.147)	(0.144)
Sciencebased_License							-0.212	-0.711
							(0.437)	(0.704

Table 8 Continued

Firmage	0.00499	0.00488	0.00498	0.00496	0.00487	0.00484	0.00500	0.00470
	(0.00458)	(0.00459)	(0.00458)	(0.00458)	(0.00463)	(0.00460)	(0.00458)	(0.00462)
Ownership	-0.293**	-0.269*	-0.291**	-0.291**	-0.289**	-0.295**	-0.293**	-0.263*
	(0.145)	(0.146)	(0.145)	(0.145)	(0.144)	(0.145)	(0.145)	(0.145)
Productinnov	-0.137	-0.135	-0.136	-0.134	-0.134	-0.146	-0.137	-0.135
	(0.155)	(0.154)	(0.155)	(0.155)	(0.155)	(0.155)	(0.155)	(0.154)
Competition_5-20	-0.286	-0.321	-0.284	-0.283	-0.295	-0.296	-0.285	-0.329
	(0.229)	(0.229)	(0.229)	(0.229)	(0.230)	(0.229)	(0.229)	(0.228)
Competition_21-100	-0.0980	-0.126	-0.0973	-0.102	-0.0979	-0.121	-0.0930	-0.142
	(0.285)	(0.285)	(0.285)	(0.285)	(0.284)	(0.282)	(0.286)	(0.283)
Competition_>100	-0.322	-0.297	-0.317	-0.318	-0.329	-0.311	-0.321	-0.289
	(0.200)	(0.201)	(0.200)	(0.200)	(0.201)	(0.200)	(0.200)	(0.200)
Region dummies	Included	Included	Included	Included	Included	Included	Included	Included
Pseudo R2	0.3025	0.3076	0.3026	0.3028	0.3042	0.3040	0.3026	0.3114
Observations	1,594	1,594	1,594	1,594	1,594	1,594	1,594	1,594

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Regression coefficients are displayed with standard errors between parentheses.
Intercepts and coefficients of regions are not displayed but are available upon request.

Table 9 Robustness 2) Determinants of Process innovation with interactions, Binary Logistic Regression

Independent Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
LicensedTech	0.562***	1.501***	0.391*	0.489*	0.607**	1.742***	0.880***	2.133***
	(0.218)	(0.311)	(0.229)	(0.274)	(0.272)	(0.390)	(0.256)	(0.463)
RDinvestment	1.524***	1.670***	1.531***	1.526***	1.524***	1.555***	1.523***	1.667***
	(0.128)	(0.130)	(0.128)	(0.128)	(0.128)	(0.127)	(0.128)	(0.131)
RD_License		-1.803***						-1.320***
		(0.380)						(0.446)
Processpatent	0.531***	0.499***	0.405**	0.532***	0.529***	0.577***	0.539***	0.444**
	(0.185)	(0.186)	(0.199)	(0.186)	(0.185)	(0.187)	(0.185)	(0.201)
License_Patent			0.900*					0.714
			(0.481)					(0.556)
Largefirm	0.305**	0.303**	0.306**	0.285**	0.307**	0.334***	0.306**	0.266**
	(0.123)	(0.123)	(0.123)	(0.130)	(0.123)	(0.124)	(0.123)	(0.132)
Large_License				0.163				0.598
				(0.371)				(0.402)
Export	0.0835	0.107	0.0933	0.0829	0.0970	0.0954	0.0871	0.0848
	(0.134)	(0.135)	(0.134)	(0.134)	(0.138)	(0.134)	(0.134)	(0.141)
Export_License					-0.136			0.281
					(0.438)			(0.472)
Training	0.150	0.161	0.142	0.149	0.150	0.281**	0.153	0.275**
	(0.107)	(0.109)	(0.108)	(0.107)	(0.107)	(0.112)	(0.107)	(0.113)
Training_License						-1.820***		-1.698***
						(0.420)		(0.432)
Sciencebased								0.0658
								(0.134)
Sciencebased_License							-0.990***	-0.897**
							(0.376)	(0.373)

Table 9 Continued								
Firmage	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Ownership	-0.177	-0.192*	-0.180	-0.177	-0.177	-0.172	-0.174	-0.183
	(0.116)	(0.116)	(0.115)	(0.116)	(0.116)	(0.116)	(0.116)	(0.116)
Productinnov	-0.324***	-0.331***	-0.326***	-0.325***	-0.323***	-0.313***	-0.325***	-0.329***
	(0.114)	(0.114)	(0.113)	(0.113)	(0.114)	(0.114)	(0.114)	(0.115)
*Industrygroups**								-
Science-based	-0.016	-0.028	-0.021	-0.016	-0.015	-0.003	0.075	0.067
	(0.127)	(0.129)	(0.127)	(0.127)	(0.127)	(0.128)	(0.132)	(0.134)
Information-intensive	-0.207	-0.226	-0.208	-0.202	-0.209	-0.231	-0.223	-0.236
	(0.206)	(0.206)	(0.207)	(0.206)	(0.206)	(0.205)	(0.206)	(0.207)
Specialized-supplier	-0.147	-0.140	-0.158	-0.148	-0.146	-0.105	-0.141	-0.111
	(0.128)	(0.129)	(0.128)	(0.128)	(0.128)	(0.129)	(0.129)	(0.130)
Competition_5-20	0.0808	0.0729	0.0689	0.0804	0.0814	0.0704	0.0845	0.0530
	(0.167)	(0.167)	(0.167)	(0.167)	(0.168)	(0.166)	(0.168)	(0.167)
Competition_21-100	0.471**	0.448**	0.457**	0.472**	0.471**	0.457**	0.488**	0.445**
	(0.216)	(0.216)	(0.215)	(0.216)	(0.216)	(0.216)	(0.216)	(0.216)
Competition_>100	0.120	0.0806	0.100	0.119	0.120	0.0885	0.116	0.0387
	(0.151)	(0.152)	(0.152)	(0.151)	(0.151)	(0.150)	(0.152)	(0.153)
Region dummies	Included	Included	Included	Included	Included	Included	Included	Included
Pseudo R2	0.233	0.241	0.235	0.233	0.233	0.240	0.235	0.248
Observations	2,456	2,456	2,456	2,456	2,456	2,456	2,456	2,456

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Regression coefficients are displayed with standard errors between parentheses.
Intercepts and coefficients of regions are not displayed but are available upon request.
*The base category for Industrygroups = Supplier-dominated

5. Conclusion and discussion

Both product and process innovations are important determinants for the technological progress of firms. In developing countries, the most important initial input into technological development is provided by imported technologies. Foreign licensing is the most direct way of acquiring technologies for firms to capture profits, leading to more efficient processes. In India, outdated technology is a massive problem and the 'Make in India' campaign was set up in 2014 in order to drive growth in the manufacturing sector. The most important challenge for the country to increase the performance of manufacturing firms is to decrease the gap in critical technologies. Therefore, it is important to raise the understanding of the determinants of technological progress and innovation. However, the literature on this topic is scarce and has provided inconclusive results. Even though process innovation is responsible for a large proportion of increased productivity and industrial progress, the determinants of process innovation at the firm level have been less researched than those of product innovation. Additionally, even though the influence of external technology acquisition on product innovation performance is proven to be overwhelmingly positive, the results of its effect on firm performance and process innovation are somewhat unclear (Reichstein & Salter, 2006; Wang & Li-Ying, 2014; Wang et al., 2013; Tsai et al., 2011;).

This research contributes to the existing literature in several ways. To start with, the results provide insight into the importance of acquiring technology externally for both product and process innovations. Several studies analyze the determinants of becoming a process- and/or product innovator (Baldwin et al., 2002; Cabagnols & Le Bas, 2002). Some articles provide evidence for a positive effect of external technology acquisition on innovation performance (Chudnovsky et al., 2006; Vega-Jurado et al., 2009). However, literature also indicates a negative or no direct effect on firm performance, explained by the risks attached to using external technologies (Jones et al., 2001; Tsai & Wang, 2008). This report focuses on inward foreign licensing specifically, since it is seen as the most direct way of acquiring technology in order to obtain profits, compared to other methods. The results suggest that Indian manufacturing companies that license foreign technology have a higher probability of being a process innovator. Also, it is shown that foreign technology licensing positively influences the decision to engage in product innovation activities, which is in line with the analyzed literature. This study thus concludes that even though product and process innovation are influenced by different determinants, the probability of being a product- and/or process innovator is higher for the firms that license foreign technology compared to those that do not. It could be argued that these results contribute to solving technological challenges in India by showing that technology licensing helps manufacturing companies to engage in both process and product innovation activities. The literature has indicated risks that are attached to using external technologies, such as the loss of control or quality (Sen and Rubenstein, 1989; McDonald and Leahey, 1985). However, these articles only focus on the broad definition of external technology acquisition including different methods. This research shows that specifically foreign technology licensing seems to be a suitable strategy for increasing innovation performance, which means that the risks are not significantly important enough to negatively influence the decision to license for Indian manufacturing companies. This is an important finding because it helps firms to distinguish between different strategies related to the acquisition of technology. When comparing the results to the articles that find a negative effect of technology acquisition on process innovation, it suggests that there exist differences between countries, which could be caused by the level of development or the policy environment (Jones et al., 2001; Tsai & Wang, 2008). It may be argued that developing countries benefit from foreign licensing to a larger extend, as the quality of internal generated technologies might be lower. This research therefore contributes to the potential development of the manufacturing sector in India.

One other important contribution of this research, compared to prior studies is that nature of the relationship between foreign technology licensing and process innovation is analyzed for firms with different internal innovation efforts. Prior studies suggest that investing in R&D not only increases the ability of a firm to exploit existing knowledge from external sources, but also develops new knowledge and inventions (Li, 2011; Tjai et al., 2011). However, unlike most findings from other studies, the striking results in this research indicate a substitutive relation between R&D investment and foreign licensing. This relation could be explained by the fact that when firms have more internal knowledge, they invest relatively less in acquiring external technologies. Also, firms with a higher R&D capacity can more efficiently exploit external knowledge in terms of innovation output, and thus need relatively less investment in foreign technology. Therefore, putting effort in one strategy goes at the expense of putting effort in the other strategy. Basant & Fikkert (1996) find that R&D costs and technology purchase expenditures are substitutes in the production of knowledge, in the sense that each variable decreases the marginal productivity of the other. The results thus do not support the argument of absorptive capacity that firms conducting R&D are better able to identify and acquire external knowledge and transform this into process innovation. Nonetheless, heterogeneity among firms in their level of investment in R&D and licensing foreign technology exists. This heterogeneity could further determine the nature of the relationship between foreign technology licensing and process innovation, which might be interesting to consider in future research. For firms that for example invest in both types of technology generation, but do not balance their spending on R&D and foreign licensing well, it is logical to argue that these two methods of technology generation do not reinforce each other.

This study also contributes by zooming in on the heterogeneity among relevant industries. The main part of the literature focusing on external technology acquisition and innovation does not distinguish between the supplier-dominated industry and the science-based industry. Evidence is provided that when firms are operating in the science-based industry, this negatively influences, or weakens, the relation between foreign technology licensing and process innovation, compared to supplier-dominated firms. An explanation for this result is that in this industry, technological knowledge is mainly processed in machinery, equipment and capital assets while in the science-based industry, one important source of knowledge is internal R&D (Vega-Jurado et al., 2009). Since an important determinant for innovation within supplier-dominated firms is the acquisition of external information, it seems logical that the effect of foreign licensing on process innovation is larger among these firms. This finding thus emphasizes the usefulness of distinguishing between relevant industry groups.

Another remarkable outcome is that if firms provide training to their employees related to the introduction of new innovations, this weakens the positive relation between foreign technology licensing and process innovation compared to firms that do not provide training regarding innovation. This might seem strange, since training is expected to enhance the ability of firms to translate foreign technology licensing into process innovation activities. However, it is possible that if firms provide training to their employees regarding internal innovations, it is not perceived as necessary anymore to also license technologies from foreign owned companies. Thus, these two might be regarded as substitutes. Furthermore, it might be the case that in developing countries such as India, the provided training is not effective in terms of human capital. Firms in need of training could be seen as having a performance deficiency, and increasing an employee's knowledge and skills does not necessarily solve the problem, in that case which is a waste of time and resources (Cekada, 2010). If Indian companies provide relevant training with the right content on how to use foreign knowledge, it might benefit the relation between foreign technology licensing and process innovation to a large extent. Arvanitis et al., (2016) find no association between training and the propensity to innovate, but do find that training positively influences innovation success. These innovation variables measure different things and thus the negative association found in this research might be explained by the fact that training only influences whether innovation is successful, not the decision of firms to engage in innovation or not.

Even though this study contributes to existing literature by acknowledging the different nature of the relation between foreign technology licensing and process innovation at the firm level, evidence could not be provided for the heterogeneous effects of several firm characteristics. Although it was expected that the relation between foreign technology licensing and process innovation is stronger for small and medium firms, the results indicate otherwise. This means that according to the analysis, the relation does not differ significantly between small- and medium firms and large firms. Nonetheless, existing literature finds evidence that foreign licensing has a larger impact on the innovative performance of smaller firms compared to larger firms (Avarmaete et al., 2004; Tether, 2002; Rogers, 2004). Therefore, it is interesting to dive deeper into these effects and for example test smaller or larger categories in terms of firm size. Secondly, also no effect was detected for whether firms applied for a patent regarding process innovation. According to some of the literature, patenting reflects the internal effort to develop an idea of technology. However, the findings confirm part of the literature that mention that using patents as an indicator for innovation output can be problematic since in India, it takes a long time before a patent is granted. It takes a while before a patent application is transmitted into a new product or process, so it is logical that it does not influence the relation between licensing and process innovation. It might be interesting for future research to dive deeper into this topic by using panel data, controlling for the delay in the application process. Lastly, export does not seem to influence the relation between foreign technology licensing and process innovation. A part of the literature finds that by exposing to foreign knowledge and technology, the innovation performance and productivity of exporting firms is boosted (Ganotakis & Love, 2011; Filatotchex et al., (2009). However, this topic has been debated extensively and some studies find that exporting might also negatively influence foreign licensing and innovation (Aghion et al., 2018; Keller, 2004). This can be explained by different country- and firm characteristics. Some exporting firms profit from strong competition from abroad, but others do not. Also, the learning-from-exporting hypothesis does not seem to hold in this case, for firms that for example already have a lower productivity. In sum, for these aspects that do not seem to influence the main relation in this study, it might be argued that both positive and negative effects play a role, which might balance each other out.

This research might support policy makers in their decision to favor foreign technology acquisition by, for example, initiating policies toward higher efficiency of inward technology flows. As mentioned before, India is lagging when it comes to the development in technology and the 'Make in India' campaign is aiming to improve this. Technologies have resulted in higher productivity of production processes. Therefore, it can be of great importance for the country to license more foreign technology, which will cause them to rely less on their old methods. According to the results, licensing is expected to increase their process innovation performance and thus the chances for the Indian manufacturing sector of leapfrogging into the fourth industrial revolution. Therefore, this report also provides managers with the insight in the role of technology licensing. It might help to redirect their decisions to investing more in foreign technology acquisition instead of internal R&D, as these two are found to be substitutes. Managers could also focus on providing more efficient and improved training to their employees on how to deal with external technologies. Especially in supplier-dominated industries, the stimulation of licensing could make a significant difference.

6. Limitations and future research

Even though the findings of this study are mainly robust to several additional checks, there are a couple of limitations due to the availability of data, which might provide areas for future research. Firstly, only data on whether firms license technology from foreign firms was available, but not how many technologies were licensed per company, as researched by Fosfuri (2006). As mentioned, distinguishing between firms that innovate frequently and firms that do so occasionally would give a more extensive insight in the size of the effect of technology licensing. Therefore, using a variable that measures the number of technologies that were licensed, or the amount of costs spent on licensing would be a valuable addition to the literature. Also, only data on whether firms licensed foreign technology was available, not external technology. Many existing papers use external technology licensing as the independent variable, since this provides a more extensive insight which also includes licensed technology from other Indian firms. Besides, innovation success which is researched by Arvanitis et al., (2016) might be an interesting alternative measure for innovation instead of the propensity to innovate. Furthermore, the dependent variable that measures whether companies introduced innovative supporting activities is measured in the fiscal year 2012/2013, while most of the independent variables such as *LicensedTech* are measured from the years 2011-2013, which can lead to reverse causality. Even though the time slot 2010-2013 is analyzed, this does not take away the reverse causality problem as it is not clear when exactly the companies introduced process innovations in this time slot. Unfortunately, the dataset does not allow to use lagged variables and since the data is cross-sectional, future research would profit from longitudinal data. Reverse causality could be accounted for when the innovation survey data for 2014 until 2017 becomes available in the database of the World Bank. Furthermore, there may be a broader endogeneity problem, as firm fixed effects cannot be used with cross-sectional data. This means that there might be unobserved variables that are not considered in the model that could drive both foreign technology licensing and process innovation.

What also should be noted is that the robustness analysis in this research indicates that R&D and foreign licensing are complements, which differs from the main results. This may be explained by the fact that firms could view the other indicator for process innovation differently and this changes the way they think about the effect of R&D investment on process innovation. It could be suggested that there exist different types of process innovation, and this research has only focused on one. Even though the relationship between foreign technology licensing and process innovation is robust for different perceptions of process innovation, the substitutive relation found between R&D and licensing is not. Future research could therefore dive more deeply into process innovation as a concept, hereby distinguishing between 1) introducing new or improved supporting activities for processes on the one hand, and 2) introducing improved methods of manufacturing products or offering services on the other hand. R&D weakens the relation between foreign technology licensing and the first-mentioned concept of process innovation, but strengthens the relation between licensing and the second-mentioned concept. This means that both external and internal generation of technology is suitable for developing improved methods of manufacturing, but only either R&D or foreign licensing should be conducted for introducing new supporting activities for processes. Lastly, by generating interaction terms, the sample was split in different groups. Some of the groups do have quite a small sample size, which is less than 10% of the full sample size. This might also be considered as a limitation of the dataset.

In sum, even though the data used in this study has some limitations, it allowed to provide evidence that the specific strategy of licensing foreign technology could help Indian manufacturing companies to move towards Industry 4.0 by engaging in process innovation.

References

Abraham, B. P., & Moitra, S. D. (2001). Innovation assessment through patent analysis. *Technovation*, *21*(4), 245-252.

Acs, J.Z., & Audretsch, D. (1989). Patents as a measure of innovative activity. *Kyklos, 42*(2), 171-180.

Aghion, P., Bergeaud, A., Lequien, M., & Melitz, M. J. (2018). *The heterogeneous impact of market size on innovation: evidence from French firm-level exports.* Cambridge: National Bureau of Economic Research.

Ahuja, G., & Katila, R. (2001). Technological acquisitions and the innovation performance of acquiring firms: A longitudinal study. *Strategic Management Journal*, *22*(3), 197-220.

Alicke, K., Rachor, J., & Seyfert, A. (2016). Supply Chain 4.0 - the next generation digital supply chain. Retrieved from McKinsey & Company, 20-03-2020. https://www.mckinsey.com/business-functions/operations/our-insights/supply-chain-40--the-next-generation-digital-supply-chain

Anand, R., Kochhar, M., & Mishra, M. (2015). *Make in India: which exports can drive the next wave of growth?* Asia & Pacific: International Monetary Fund.

Andersson, M., & Lööf, H. (2009). Learning-by-exporting revisited: The role of intensity and persistence. *Scandinavian Journal of Economics*, *111*(4), 893-916.

Aquilar, G. (2014). Led by India, South Asia Economic Growth to Accelerate. Retrieved from The World Bank, 11-07-2020. https://www.worldbank.org/en/news/press-release/2014/10/06/led-india-south-asia-economic-growth-accelerate

Arundel, A., & Kabla, I. (1998). What percentage of innovations are patented? Empirical estimates for European firms. *Research Policy*, *27*(2), 127-141.

Arundel, A., van de Paal, G., & Soete, L. (1995*). Innovation strategies of Europe's largest industrial firms*. Maastricht: PACE Report, MERIT, University of Limburg.

Arvanitis, S., Seliger, F., & Stucki, T. (2016). The relative importance of human resource management practices for innovation. *Economics of Innovation and New Technology*, *25*(8), 769-800.

Atuahene-Gima, K. (1993). Determinants of inward technology licensing intentions: An empirical analysis of Australian engineering firms. *Journal of Product Innovation Management, 10*(3), 230-240.

Atuahene-Gima, K., & Patterson, P. (1993). Managerial perceptions of technology licensing as an alternative to internal R&D in new product development: an empirical investigation. *R&D Management*, *23*(4), 327-336.

Avermaete, T., Viaene, J., Morgan, E. J., Pitts, E., Crawford, N., & Mahon, D. (2004). Determinants of product and process innovation in small food manufacturing firms. *Trends in Food Science & Technology*, *15*(10), 474-483.

Aw, B. Y., & Batra, G. (1998). Technological capability and firm efficiency in Taiwan (China). *The World Bank Economic Review*, *12*(1), 59-79.

Aw, B. Y., Roberts, M. J., & Winston, T. (2007). Export market participation, investments in R&D and worker training, and the evolution of firm productivity. *World Economy*, *30*(1), 83-104.

Baldwin, J., & Gu, W. (2004). Trade liberalization: Export-market participation, productivity growth, and innovation. *Oxford Review of Economic Policy*, *20*(3), 372-392.

Baldwin, J., Hanel, P., & Sabourin, D. (2002*). Determinants of innovative activity in Canadian manufacturing firms*. London: Innovation and Firm Performance, Palgrave Macmillan.

Basant, R., & Fikkert, B. (1993). *Impact of R & D, Foreign Technology Purchase and Technology Spillovers on Indian Industrial Productivity*. Maastricht: United Nations Univ., Institute for New Technologies.

Basant, R., & Fikkert, B. (1996). The effects of R&D, foreign technology purchase, and domestic and international spillovers on productivity in Indian firms. *The Review of Economics and Statistics*, *78*(2), 187-199.

Berchicci, L. (2013). Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance. *Research Policy*, *42*(1), 117-127.

Bergfors, M. E., & Larsson, A. (2009). Product and process innovation in process industry: a new perspective on development. *Journal of Strategy and Management*, *2*(3), 261-276.

Bhaskarabhatla, A., Chatterjee, C., Anurag, P., & Pennings, E. (2017). Mitigating regulatory impact: the case of partial price controls on metformin in India. *Health Policy and Planning, 32*(2), 194-204.

Bogliacino, F., & Pianta, M. (2016). The Pavitt Taxonomy, revisited: patterns of innovation in manufacturing and services. *Economia Politica*, *33*(2), 153-180.

Brettel, M., Friederichsen, N., Keller, M., & Rosenberg, M. (2014). How virtualization, decentralization and network building change the manufacturing landscape: An Industry 4.0 Perspective. *International Journal of Mechanical, Industrial Science and Engineering, 8*(1), 37-44.

Brouwer, E., & Kleinknecht, A. (1999). Innovative output, and a firm's propensity to patent.: An exploration of CIS micro data. *Research Policy*, *28*(6), 615-624.

Cabagnols, A., & Le Bas, C. (2002*). Differences in the determinants of product and process innovations: the French case*. London: Innovation and Firm Performance, Palgrave Macmillan.

Caloghirou, Y., Giotopoulos, I., Korra, E., & Tsakanikas, A. (2018). How do employee training and knowledge stocks affect product innovation?. *Economics of Innovation and New Technology*, *27*(4), 343-360.

Caloghirou, Y., Kastelli, I. and Tsakanikas, A. (2004) Internal capabilities and external knowledge sources: complements or substitutes for innovative performance? *Technovation, 24*(1), 29–39.

Cassiman, B., & Veugelers, R. (2006). In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Management Science*, *52*(1), 68-82.

Cekada, T. L. (2010). Training needs assessment: Understanding what employees need to know. *Professional Safety*, *55*(03), 28-33.

Chakrabarti, A. K., & Bhaumik, P. K. (2010). Globalisation of technology development: offshoring of R&D to China, India and Brazil. *International Journal of Engineering Management and Economics*, *1*(1), 68-79.

Chudnovsky, D., López, A., & Pupato, G. (2006). Innovation and productivity in developing countries: A study of Argentine manufacturing firms' behavior (1992–2001). *Research Policy*, *35*(2), 266-288.

Cohen, W. M., & Klepper, S. (1996). A reprise of size and R & D. *The Economic Journal*, *106*(437), 925-951.

Cohen, W. M., & Levin, R. C. (1989). Empirical studies of innovation and market structure. *Handbook of Industrial Organization*, *2*, 1059-1107.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, *35*(1), 128-152.

Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2002). Links and impacts: the influence of public research on industrial R&D. *Management Science, 48*(1), 1-23.

Dalenogare, L., Benitez, G., Ayala, N., & Frank, A. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics, 204,* 383-394.

Damijan, J. P., Kostevc, Č., & Polanec, S. (2010). From innovation to exporting or vice versa? *World Economy*, *33*(3), 374-398.

De Loecker, J. (2013). Detecting learning by exporting. *American Economic Journal: Microeconomics*, *5*(3), 1-21.

De Mel, S., McKenzie, D., & Woodruff, C. (2009). *Innovative firms or innovative owners? Determinants of innovation in micro, small, and medium enterprises*. Bonn: The World Bank.

Deeds, D. L. (2001). The role of R&D intensity, technical development and absorptive capacity in creating entrepreneurial wealth in high technology start-ups. *Journal of Engineering and Technology management*, *18*(1), 29-47.

Dupraz, Y. (2013). Using weights in Stata. Retrieved from Paris School of Economics, 01-06-2020. https://www.parisschoolofeconomics.eu/docs/dupraz-yannick/using-weights-in-stata(1).pdf

Edmondson, A. C., Bohmer, R. M., & Pisano, G. P. (2001). Disrupted routines: Team learning and new technology implementation in hospitals. *Administrative Science Quarterly*, *46*(4), 685-716.

Evangelista, R., Sandven, T., Sirilli, G., & Smith, K. (1998). Measuring innovation in European industry. *International Journal of the Economics of Business*, *5*(3), 311-333.

Evans, D. S. (1987). The relationship between firm growth, size, and age: Estimates for 100 manufacturing industries. *The Journal of Industrial Economics*, *35*(4), 567-581.

Evenson, R. E., & Joseph, K. J. (1999). Foreign technology licensing in Indian Industry: an econometric analysis of the choice of partners, terms of contract and the effect on licensees' performance. *Economic and Political Weekly*, *34*(27), 1801-1809.

Filatotchev, I., Liu, X., Buck, T., & Wright, M. (2009). The export orientation and export performance of high-technology SMEs in emerging markets: The effects of knowledge transfer by returnee entrepreneurs. *Journal of International Business Studies*, *40*(6), 1005-1021.

Fosfuri, A. (2006). The licensing dilemma: understanding the determinants of the rate of technology licensing. *Strategic Management Journal*, *27*(12), 1141-1158.

Freel, M. S. (2003). Sectoral patterns of small firm innovation, networking and proximity. *Research Policy*, *32*(5), 751-770.

Freeman, C., & Soete, L. (1997). *The economics of industrial innovation.* London & New York: Routledge.

Fritsch, M., & Meschede, M. (2001). Product innovation, process innovation, and size. *Review of Industrial Organization*, *19*(3), 335-350.

Fu, X., Pietrobelli, C., & Soete, L. (2011). The role of foreign technology and indigenous innovation in the emerging economies: technological change and catching-up. *World Development*, *39*(7), 1204-1212.

Gallié, E. P., & Legros, D. (2012). Firms' human capital, R&D and innovation: a study on French firms. *Empirical Economics*, *43*(2), 581-596.

Ganotakis, P., & Love, J. H. (2011). R&D, product innovation, and exporting: evidence from UK new technology based firms. *Oxford Economic Papers*, *63*(2), 279-306.

Gentile, E. (2020). Intellectual property rights and foreign technology licensing in developing countries: An empirical investigation. *Economic Development and Cultural Change*, *68*(2), 655-698.

Goedhuys, M., & Veugelers, R. (2012). Innovation strategies, process and product innovations and growth: Firm-level evidence from Brazil. *Structural Change and Economic Dynamics*, *23*(4), 516-529.

Goel, R. K., & Nelson, M. A. (2018). Determinants of process innovation introductions: Evidence from 115 developing countries. *Managerial and Decision Economics*, *39*(5), 515-525.

Golovko, E., & Valentini, G. (2014). Selective learning-by-exporting: Firm size and product versus process innovation. *Global Strategy Journal*, *4*(3), 161-180.

González, X., Miles-Touya, D., & Pazó, C. (2016). R&D, worker training and innovation: Firm-level evidence. *Industry and Innovation*, *23*(8), 694-712.

Hagedoorn, J., & Duysters, G. (2002) The effect of mergers and acquisitions on the technological performance of companies in a high tech environment. *Technology Analysis & Strategic Management, 14*(1), 67–82.

Huergo, E., & Jaumandreu, J. (2004). How does probability of innovation change with firm age? *Small Business Economics*, *22*(3-4), 193-207.

Iyer, A. (2018). Moving from Industry 2.0 to Industry 4.0: A case study from India on leapfrogging in smart manufacturing. *Procedia Manufacturing, 21,* 663-670.

Jeschke, S., Brecher, C., Meisen, T., Özdemir, D., & Eschert, T. (2017). *Industrial internet of things and cyber manufacturing systems*. Switzerland: Springer International Publishing.

Johnson, D. K. (2002). Learning-by-Licensing: R&D and Technology Licensing in Brazilian Invention. *Economics of Innovation and New Technology, 11*(3), 163-177.

Jones, G. K., Lanctot Jr, A., & Teegen, H. J. (2001). Determinants and performance impacts of external technology acquisition. *Journal of Business venturing, 16*(3), 255-283.

Katz, R., & Allen, T. J. (1982). Investigating the Not Invented Here (NIH) syndrome: A look at the performance, tenure, and communication patterns of 50 R & D Project Groups. *R&D Management*, *12*(1), 7-20.

Keller, W. (2004). International technology diffusion. *Journal of Economic Literature*, *42*(3), 752-782.

Kessler, E.H., Bierly, P.E. and Gopalakrishnan, S. (2000) Internal vs. external learning in new product development: effects on speed, costs and competitive advantage. *R&D Management, 30*(3), 213–223.

Kim, Y. (2004). Market structure and technology licensing: evidence from US manufacturing. *Applied Economics Letters*, *11*(10), 631-637.

Kim, Y. (2005). The impact of firm and industry characteristics on technology licensing. *SAM Advanced Management Journal*, *70*(1), 42.

King, J. E. (2008). *Binary logistic regression.* North Carolina: Sage Publications, Best Practices in Quantitative Methods.

Klepper, S. (1996). Entry, exit, growth, and innovation over the product life cycle. *The American Economic Review*, *86*(3), 562-583.

Kumar, A., & Singh. (2018). How Industry 4.0 can help India escape the Western labor-productivity paradox. Retrieved from McKinsey & Company, 18-02-2020. https://www.mckinsey.com/business-functions/operations/our-insights/operations-blog/how-industry-40-can-help-india-escape-the-western-labor-productivity-paradox

Lall, S., & Kumar, R. (1981). Firm-level export performance in an inward-looking economy: The Indian engineering industry. *World Development*, *9(5)*, 453-463.

Lall, S. (2000). *Technological change and industrialization in the Asian newly industrializing economies: achievements and challenges.* Columbia: Cambridge University Press.

Lambe, C. J., & Spekman, R. E. (1997). Alliances, external technology acquisition, and discontinuous technological change. *Journal of Product Innovation Management: An International Publication Of The Product Development & Management Association*, *14*(2), 102-116.

Laursen, K., & Salter, A. (2006). Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal*, *27*(2), 131-150.

Leone, M. I., & Reichstein, T. (2012). Licensing-in fosters rapid invention! The effect of the grant-back clause and technological unfamiliarity. *Strategic Management Journal*, *33*(8), 965-985.

Lewis, J. I. (2007). Technology acquisition and innovation in the developing world: Wind turbine development in China and India. *Studies in Comparative International Development*, *42*(3-4), 208-232.

Li, X. (2011). Sources of external technology, absorptive capacity, and innovation capability in Chinese state-owned high-tech enterprises. *World Development*, *39*(7), 1240-1248.

Li, Y., Liu, Y., & Ren, F. (2007). Product innovation and process innovation in SOEs: evidence from the Chinese transition. *The Journal of Technology Transfer*, *32*(1-2), 63-85.

Linder, J. C. (2006). Does innovation drive profitable growth? New metrics for a complete picture. *Journal of Business Strategy, 27*(5), 38-44.

Liu, X., & Buck, T. (2007). Innovation performance and channels for international technology spillovers: Evidence from Chinese high-tech industries. *Research Policy*, *36*(3), 355-366.

Lopez, R. A. (2008). Foreign technology licensing, productivity, and spillovers. *World Development*, *36*(4), 560-574.

Mairesse, J., & Mohnen, P. (2002). Accounting for innovation and measuring innovativeness: an illustrative framework and an application. *American Economic Review*, *92*(2), 226-230.

Malerba, F. (2005). Sectoral systems of innovation: a framework for linking innovation to the knowledge base, structure and dynamics of sectors. *Economics of Innovation and New Technology*, *14*(1-2), 63-82.

Mansfield, E. (1985). How rapidly does new industrial technology leak out?. *The Journal of Industrial Economics*, *34*(2) 217-223.

Martínez-Ros, E. (1999). Explaining the decisions to carry out product and process innovations: the Spanish case. *The Journal of High Technology Management Research*, *10*(2), 223-242.

Martínez-Ros, E., & Labeaga, J. M. (2009). Product and process innovation: Persistence and complementarities. *European Management Review*, *6*(1), 64-75.

McDonald, D.W., & Leahey, H.S. (1985). Licensing has a role in technology strategic planning. *Research Management, 28(1),* 35-40.

McNally, R. C., Akdeniz, M. B., & Calantone, R. J. (2011). New product development processes and new product profitability: Exploring the mediating role of speed to market and product quality. *Journal of Product Innovation Management*, *28*(1), 63-77.

Milgrom, P., & Roberts, J. (1990). The economics of modern manufacturing: Technology, strategy, and organization. *The American Economic Review*, *80*(3), 511-528.

Mowery, D. C. (1983). The relationship between intrafirm and contractual forms of industrial research in American manufacturing, 1900-1940. *Explorations in Economic History*, *20*(4), 351.

Mytelka, L. K. (1978). Licensing and technology dependence in the Andean group. *World Development*, *6*(4), 447-459.

Narayanan, K. (1998). Technology acquisition, de-regulation and competitiveness: a study of Indian automobile industry. *Research Policy*, *27*(2), 215-228.

Nelson, R., & Winter. S. (1982). *An evolutionary theory of economic change.* Boston: Belknap Press of Harvard University Press.

Overvest, B. M., & Veldman, J. (2008). Managerial incentives for process innovation. *Managerial and Decision Economics*, *29*(7), 539-545.
Pavitt, K. (1984). *Sectoral patterns of technical change: towards a taxonomy and a theory.* Brighton: Technology, Management and Systems of Innovation.

Piening, E. P., & Salge, T. O. (2015). Understanding the antecedents, contingencies, and performance implications of process innovation: A dynamic capabilities perspective. *Journal of Product Innovation Management*, *32*(1), 80-97.

Pilav-Velić, A., & Marjanovic, O. (2016). Integrating open innovation and business process innovation: Insights from a large-scale study on a transition economy. *Information & Management*, *53*(3), 398-408.

Raymond, L., & St-Pierre, J. (2010). R&D as a determinant of innovation in manufacturing SMEs: An attempt at empirical clarification. *Technovation*, *30*(1), 48-56.

Reichstein, T., & Salter, A. (2006). Investigating the sources of process innovation among UK manufacturing firms. *Industrial and Corporate change*, *15*(4), 653-682.

Reichstein, T., Salter, A. J., & Gann, D. M. (2008). Break on through: Sources and determinants of product and process innovation among UK construction firms. *Industry and Innovation*, *15*(6), 601-625.

Rogers, M. (2004). Networks, Firm Size and Innovation. *Small Business Economics 22*, 141–153.

Rouvinen, P. (2002). Characteristics of product and process innovators: some evidence from the Finnish innovation survey. *Applied Economics Letters*, *9*(9), 575-580.

Schumpeter, J. (1934). *The theory of economic development.* Cambridge: Harvard University Press.

Sen, F., & Rubenstein, A.H. (1989). External technology and in-house R&D's facilitative role. *Journal of Product Innovation Management: An International Publication of the Product Development & Management Association, 6*(2), 123-138.

Shah, V. (2019). Industry 4.0: How India can build for the future. Retrieved from Forbes India, 19-02-2020.
http://www.forbesindia.com/blog/technology/industry-4-0-how-india-can-build-for-the-future/

Souitaris, V. (2002). Technological trajectories as moderators of firm-level determinants of innovation. *Research Policy*, *31*(6), 877-898.

Subrahmanya, M. H., Hussain, Z., & Chand, M. A. (2014). External technology acquisition of SMEs in the machinery industry of Bangalore. *Asian Journal of Innovation and Policy*, *3*(1), 50-71.

Tether, B. S. (2002). Who co-operates for innovation, and why: an empirical analysis. *Research Policy*, *31*(6), 947-967.

Torvinen, P., Podmetina, D., Hinkkanen, J. J., & Väätänen, J. (2014). External technology acquisition in Russian firms. *International Journal of Procurement Management*, *7*(3), 257-278.

Tsai, K. H., Hsieh, M. H., & Hultink, E. J. (2011). External technology acquisition and product innovativeness: The moderating roles of R&D investment and configurational context. *Journal of Engineering and Technology Management*, *28*(3), 184-200.

Tsai, K.H., & Wang, J.C. (2008). External technology acquisition and firm performance: A longitudinal study. *Journal of Business Venturing, 23*(1), 91-112.

Tsai, K. H., & Wang, J. C. (2007). Inward technology licensing and firm performance: a longitudinal study. *R&d Management*, *37*(2), 151-160.

Utterback, J.M. (1994). *Mastering the dynamics of innovation: How companies can seize opportunities in the face of technological change.* Illinois: University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship.

Utterback, J. M., & Abernathy, W. J. (1975). A dynamic model of process and product innovation. *The International Journal of Management Science, 3*(6), 639-656.

Vaona, A., & Pianta, M. (2008). Firm size and innovation in European manufacturing. *Small Business Economics*, *30*(3), 283-299.

Van Wijk, R., Jansen, J. J., & Lyles, M. A. (2008). Inter-and intra-organizational knowledge transfer: a meta-analytic review and assessment of its antecedents and consequences. *Journal of Management Studies*, *45*(4), 830-853.

Vega-Jurado, J., Gutiérrez-Gracia, A., & Fernández-de-Lucio, I. (2009). Does external knowledge sourcing matter for innovation? Evidence from the Spanish manufacturing industry. *Industrial and Corporate Change*, *18*(4), 637-670.

Von Hippel, E. (1988). *The Sources of Innovation.* New York: Oxford University Press.

Wagner, J. (2007). Exports and productivity: A survey of the evidence from firm-level data. *World Economy*, *30*(1), 60-82.

Walter, J. (2012). The influence of firm and industry characteristics on returns from technology licensing deals: evidence from the US computer and pharmaceutical sectors. *R&D Management*, *42*(5), 435-454.

Wang, Y., Cao, W., Zhou, Z., & Ning, L. (2013). Does external technology acquisition determine export performance? Evidence from Chinese manufacturing firms. *International Business Review*, *22*(6), 1079-1091.

Wang, Y., & Li-Ying, J. (2014). When does inward technology licensing facilitate firms' NPD performance? A contingency perspective. *Technovation*, *34*(1), 44-53.

Wang, Y., Li-Ying, J., Chen, J., & Lu, Z. (2015). Technology licensing in China. *Science and Public Policy*, *42*(3), 293-299.

Weiss, P. (2003). Adoption of product and process innovations in differentiated markets: The impact of competition. *Review of Industrial Organization*, *23*(3-4), 301-314.

Yi, J., Wang, C., & Kafouros, M. (2013). The effects of innovative capabilities on exporting: Do institutional forces matter?. *International Business Review*, *22*(2), 392-406.

APPENDIX A: Description of the variables

Variable	Sample	Mean	Std.Dev.	Description
Processinnov	1594	.597	.491	Dummy variable: 1 if the firm introduced any new or significantly improved supporting activities for processes in the last three years and 0 if not.
LicensedTech	1594	.107	.309	Dummy variable: 1 if the firm uses technology licensed from a foreign-owned company at the time of the interview and 0 if not.
RDinvestment	1594	.471	.499	Dummy variable: 1 if the firm spent on formal Research & Development activities, either in-house or contracted with other companies in the last three years and 0 if not.
Processpatent	1594	.118	.323	Dummy variable: 1 if the firm applied for a patent concerning a process innovation in the last three years and 0 if not.
Largefirm	1594	.271	.445	Dummy variable: 1 if the firm has 100 or more than 100 employees and 0 if less.
Export	1594	.26	.439	Dummy variable: 1 if the firm exports at the time of the interview or considered entering the export market in the next 12 months and 0 if not.
Training	1594	0.488	0.50	Dummy variable: 1 if the firm provided formal training to its employees specifically for the development and/or introduction of innovative products or services and processes in the last three years and 0 if not.
Sciencebased	1594	.45	.498	Dummy variable: 1 if the firm is active in a science-based industry and 0 if it is active in a supplier-dominated industry.
Firmage	1594	20.659	14.738	Continuous variable: difference in years between the time of the interview and the founding year of the firm.
Ownership	1594	.413	.492	Dummy variable: 1 if the firm is owned by a sole proprietor and 0 if not.
Competition	1594	3.015	1.217	Categorical variable with four categories: 0-5, 6-20, 21-100 and >100 competitors.
Productinnov	1594	.616	.487	Dummy variable: 1 if the firm introduced new or significantly improved products or services in the past three years and 0 if not.

APPENDIX B Distribution of sample by Sectoral Classification

Pavitt's category	Economic activity	Sample	Sample%
Supplier-dominated			
	Food	189	7.70
	Tobacco	32	1.30
	Textiles	155	6.31
	Garments	97	3.95
	Leather	38	1.55
	Wood	51	2.08
	Paper	54	2.20
	Fabricated metal products	219	8.92
	Furniture	28	1.14
	Recycling	13	0.53
	Wholesale	1	0.04
	Total	*876*	*35.67%*
Science-based	Chemicals	223	9.08
	Machinery and equipment	268	10.91
	Electronics	202	8.22
	Precision instruments	25	1.02
	Total	*718*	*29.23%*
Information-intensive	Transport machines	193	7.86
	Total	*193*	*7.86%*
Specialized-supplier	Publishing, printing	58	2.36
	Plastics, rubber	257	10.46
	Non-metallic minerals	140	5.70
	Basic metals	206	8.39
	Total	*669*	*27.24%*
Total		*2456*	*100%*

APPENDIX C Tabulation of innovation activity among regions

Region Of The Establishment	Innovation Activity						
	No Process innovator	Process innovator	%	*Total*	%	Product Innovator	No Product Innovator
Andhra Pradesh	14	66	82.50	*80*	66.25	53	27
Arunachal Pradesh, Nagaland, Manipur, Tripura, and Meghalaya	26	7	21.21	*33*	57.58	19	14
Assam	32	26	44.83	*58*	46.55	27	31
Bihar	23	25	52.08	*48*	56.25	27	21
Chhattisgarh	45	9	16.67	*54*	70.37	38	16
Delhi	39	50	56.18	*89*	73.03	65	24
Goa	5	21	80.77	*26*	80.77	21	5
Gujarat	43	54	55.67	*97*	57.73	56	41
Haryana	10	74	88.10	*84*	82.14	69	15
Himachal Pradesh	7	40	85.11	*47*	91.49	43	4
Jammu & Kashmir	4	40	90.91	*44*	52.27	23	21
Jharkhand	11	37	77.08	*48*	56.25	27	21
Karnataka	15	73	82.95	*88*	87.50	77	11
Kerala	54	34	38.64	*88*	80.68	71	17
Madhya Pradesh	50	52	50.98	*102*	47.06	48	54
Maharashtra	69	30	30.30	*99*	44.44	44	55
Orissa	22	19	46.34	*41*	75.61	31	10
Punjab	23	28	54.90	*51*	52.94	27	24
Rajasthan	34	44	56.41	*78*	71.79	56	22
Tamil Nadu	8	98	92.45	*106*	97.17	103	3
Uttar Pradesh	49	42	46.15	*91*	67.03	61	30
Uttaranchal	2	45	95.74	*47*	87.23	41	6
West Bengal	57	38	40.00	*95*	63.16	60	35
Total	*642*	*952*	*100%*	*1594*	*100%*	*1087*	*507*