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Sanjaya Kumar Malik

ISID

Institute for Studies in Industrial Development
4, Institutional Area, Vasant Kunj Phase II, New Delhi - 110 070
Phone: +91 11 2676 4600 / 2689 1111; *Fax:* +91 11 2612 2448
E-mail: info@isid.org.in; *Website:* http://isid.org.in

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*Sanjaya Kumar Malik**

*[**Abstract**: This paper examines the technological change in India's spinning machinery manufacturing sector. This is accomplished by employing the sectoral system of innovation framework that identifies three important building blocks—technological regimes, demand regimes and the lead actor—in the spinning machinery manufacturing sector. The paper underscores that Lakshmi machine works limited (LMW)—the leading producer of spinning machinery—explains most of innovations occurred in the spinning machinery manufacturing sector of the country. The favourable demand conditions and the access to external knowledge base through the long-term international collaborations are very crucial complements to the innovation-accomplishment by the leading actor. Nevertheless, because of the imports of advanced spinning machineries and the second-hand spinning machineries in particular, the technological success of the sector is restricted to the conventional spinning machinery, i.e., ring spinning machinery, not to the advanced spinning machineries (e.g., rotor and air-jet spinning).]*

Keywords: LMW; technological change; sectoral system of innovation, spinning machinery manufacturing sector; India

1. Introduction

Firms in developing countries, like India, are not the original producers of technologies. They hardly allocate any resources on research; rather make investment in emulation of technologies or products already introduced by the western developed countries. Technological change in India is defined as adaptation of already-developed products or technologies to the local conditions as they are new to the local firms, even though not new to the world (Nelson and Rosenberg, 1993; Mani 2006). India's spinning machinery is an

* *Assistant Professor* at Institute for Studies in Industrial Development (ISID), New Delhi. Email: mksanjaya@gmail.com; sanjaya@isid.org.in

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example of the successful emulation and adaption of the western technologies to the local condition.

The spinning machinery manufacturing has a serious niche in the machinery manufacturing sector of the country. It is an integral part of textile industry becasue the spinning machine lies in the heart of the process of yarn production. In India, the textile machinery manufacturing is largley represented by the spinning machinery manufacturing as the latter claims a lion-share of the total production and innovation in the former.[1] The spinning machinery manufacturing in India is more than six decade old; and during this period it has brought about many innovations useful to the domestic users and the users from other develping counries. Accroding to Indian patent data, the patent in spinning machinery granted to the Indian patentees increased cumulatively from one to sixty four between 1995 and 2008, registering around one-fourth of total Indian patents in spinning machinery granted to all the patentees including foreign ones. In the light of above, the purpose of this paper is to delineate the process of technological change in the spinning machinery manufacturing sector.

This paper is an important contribution to the industrial economic literature in developing countries. It is the first academic effort to understand the spinning machinery manufacturing sector in India. Employing sectoral system of innovation framework of Malerba (2004), the paper has highlighed the following. The technological progress in spinning machinery manufacturing is found to have evolved around th lead actor, Lakshmi Machine Works (LMW), which explains the entire innovation process of the spinning machinery manufacturing in India. The conducive demand conditions and the access to foreign knowledge are also crucial complements to the innovation accomplishment by the lead actor.

The remainder of this paper is organised as follows. The framework of the study, i.e., sectoral system of innovation framework, is presented in the Section 2. Section 3 maps out the important building blocks of the sector—technological regime, demand regime, and the lead actor—to analyse sources of technological changes in the sector. The final section summarises the discussion and provides concluding remarks.

2. Framework for Analysis

We employ the sectoral system of innovation (SSI) framework, developed by Malerba (2004), to analyse the process of technological change in the spinning machinery manufacturing sector. The sectoral system of innovation comprises a set of new and established products for specific uses, and a set of agents or actors which carry out

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[1] The spinning machinery manufacturing accounted for a three-fifth of total production of the textile machinery manufacturing in India during 2004-05 to 2013-14 (see Appendix 1); and around four-fifth of total innovation (measured in terms of Indian patent grants) of India's textile machinery manufacturing during 1995 to 2010 was attributed to the spinning machinery manufacturing.

activities and market and non-market interactions for generation, introduction, and diffusion of those products (Malerba, 2004). The SSI framework has four building blocks, viz., technology regimes, demand conditions, actors and networks, and institutions (rules, regulations, policies and so on) to study the difference in innovation activities across sectors in a country. The framework is useful in illuminating the innovation processes in highly industrialised countries. However, it needs to be modified if one intends to apply it to the context of developing countries because the process of innovation in developing countries is not the same as that in industrialised countries. In general, technological change in developing countries is to emulate and develop the technologies of industrially advanced countries. Therefore, the SSI framework requires some modifications to be fit in the context of developing countries. We follow the work of Lee and Lim (2001) to modify the framework for the Indian context.

Technological change in developing countries, according to Lee & Lim (2001), depends on availability of knowledge (internal knowledge base and financial and other resources) and R&D efforts (or technological efforts). Since the available knowledge is more or less fixed in the short-run, the future technological change depends on the current R&D efforts of firms. The level of firms' R&D efforts depends on the probability of success of the R&D efforts. And, this success needs to be understood in terms of probability of actual development of target products, and expected marketability (competitiveness) of to-be-developed products. Here, the physical development of products is separated from the market success since the market success of the product is not guaranteed even if the target product is developed. Therefore, firms in developing countries will devote more resources towards R&D if they are certain about the linkage between more R&D input and more R&D output (i.e. product development and market success of the products). It is further clear that the chance of product development is determined by technological regimes; and the marketability of to-be-developed products is determined by the demand conditions (regimes) in developing countries (Lee and Lim, 2001; Mu and Lee, 2005; and Lee, Mani and Mu, 2012). In other words, both technological regimes and demand conditions are essential for the technological success of the latecomer-firms in developing countries.

In what follows, we have discussed three important building blocks—technological regimes, demand conditions, and actors—which are important in explaining the process of technological change in an industrial sector in developing countries.

Technological Regimes

According to Breschi, Malerba and Orsenigo (2000), a specific pattern of innovation activities can be explained by the prevailing technological regimes. Technological regime is characterised by the combination of technological opportunities, appropriability of innovations, cumulativeness of technical advances, and the property of knowledge base (Nelson and Winter, 1982; Malerba and Orsenigo, 1990). However, for technological change in developing countries, as argued by Lee and Lim (2001), not all the components are relevant. For example, for R&D activities of latecomer firms, appropriability of innovation would be less relevant, since the latecomers are trying to emulate the existing technologies developed in industrialized countries. They rather suggested three components, viz., predictability of technological trajectory, cumulativeness of innovation, and access to foreign knowledge, which are critical in determining the chances of physical product development by firms in developing countries.

Firstly, a technological trajectory with greater uncertainty or fluidity indicates a smaller chance of success, for it will be harder for the latecomer firms to predict the direction of future development of technology to fix the R&D target. Secondly, if a sector experiences low cumulativeness of technological change, it will generate incentives for R&D efforts by latecomer firms and thus increase the chances for physical product development in developing countries. Lastly, Lee & Lim (2001) assert that the access to external knowledge base (technology transfer) is one element that is relevant to the success of R&D projects by the latecomer-firms. This access can be arranged in diverse forms: informal learning, licensing, foreign direct investment (FDI), strategic alliance, co-development, and so on. The difficulty in obtaining foreign knowledge affects the chance of product development by the latecomer firms in developing countries. Even a predictable technological trajectory and less cumulativeness of innovation may not lead to the development of product by the latecomer firms unless there is adequate access to foreign knowledge.

Demand Conditions

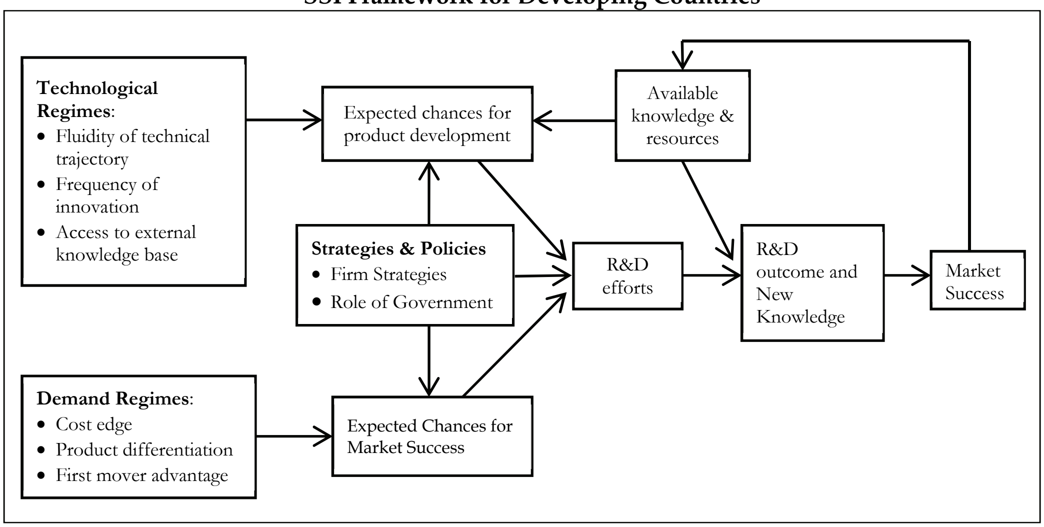
The demand condition is very crucial for technological emulation by firms in latecomer countries, for it determines the expected chances of market success of future products to be developed by the latecomer-firms. The demand or market success of to-be-developed products is conditional upon three elements such as cost edge, product differentiation, and first mover advantage which are influenced by the firms' strategies and the government interventions (Lee and Lim, 2001). In developed countries, firms' competitiveness is based on first mover advantages and product differentiation for higher-end markets; however, in developing countries, firms focus on cost edge and product differentiation for lower-end markets to gain market competitiveness (Lee, Mani and Mu, 2012). It is to note that just having the expected chances of physical product development does not lead to any technological efforts by the firms unless there is any chance of market success of products to be developed by firms in developing countries.

Actors

The actors, particularly firms and the government, have the great influence on the process of innovation in latecomer countries. Not only do they, as depicted in Figure 1, affect the expected chances for physical product development and marketability of the to-be-developed products, but they also impact the level of firms' R&D efforts. The firms innovate, produce and sell the sectoral products and consequently have an influence on the product development as well as on the marketability of the products; and are also responsible for R&D efforts in developing countries. Specifically, firms' strategies, competencies, skills, and experiences affect their chances of product development and marketability of to-be-developed products. Further, firms' interactions with users also affect both the physical product development and marketability of the future products to be developed by the firms. More importantly, the government has an important bearing on the innovation processes in developing countries. Through various policies and regulations it can insert enormous effect on process of innovation in developing countries. The government can influence the chances for physical product development as well as the chances of market success of firms in the developing countries.

Up until now, we have discussed the building blocks of the SSI framework. In what follows, we proceed to see the technological emulation by firms in developing countries. Once the R&D efforts along with the available knowledge lead to the development of the target product (R&D outcome), the new R&D outcome is then combined with the firms' capabilities in manufacturing, marketing, logistics and so on, as parts of the value chain to produce a product whose validity which will be tested in the market. The product may succeed or fail in the market. If it is successful, the profits from the market success are, of course, a source of investment for future R&D, which thus constitutes one element of the firms' R&D capabilities (see the line connecting the market success box with the available knowledge and resources box in Figure 1).

Figure 1
SSI Framework for Developing Countries



Source: Lee and Lim (2001)

3. SSI of Spinning Machinery Manufacturing Sector

3.1. Technological Regime and Chances of Product Development

Here, we examine the technological regime of spinning machinery and to discuss the access to external knowledge by domestic spinning machinery manufacturers. Following Mu and Lee (2005), the nature of technological trajectory of spinning machinery can be evaluated by examining ages or life-cycles of spinning machinery; and by counting patents in spinning machinery the cumulativeness of innovation in spinning machinery can be examined.

Among the three technologies of spinning machinery, the ring spinning technology is 188 years old, and its life cycle is quite long and matured, and the life cycle of open-end spinning machine and air-jet spinning machine are 53 years and 38 years, respectively.[2] These machines are matured and old which defines the technological trajectory of spinning machinery as a more predictable and less fluid in nature.

Next, the trend of patent counts (and the three year moving average of patent counts) in spinning machinery, which took a declining trend during 1986 through 2015, indicates a low cumulativeness of innovation in spinning machinery technology (see Table 1). Further, the growth of patent counts in spinning machinery is minus 5.66 between 1976 and 2015 and, even the sub-periods growth rates are also negative which confirm low cumulativeness of technical advances in spinning machinery (see Table 2). It can thus be argued that the predictable technological trajectory and low cumulativeness of innovation in spinning machinery can be linked to the age of the spinning machinery.

With regard to arranging access to external knowledge in spinning machinery manufacturing, the government played a crucial role in facilitating the access of global technologies to local manufacturers in India. During the Second Five-Year Plan (1956–1961), the government introduced the stringent restriction on import of items in which no import of machinery was allowed if there was adequate indigenous production. This

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[2] The ring spinning machine was invented by an American named Thorp in 1828, and Jenk—another American—added the traveller rotating around the ring in 1830 (Ahmed *et al*, 2015, p. 413). Over the last 186 years, the ring spinning has undergone considerable modification in detail, but the basic concept has remained constant (Ahmed *et al*, 2015, p. 413).
The open-end (rotor) spinning machine was invented in 1937, but the commercial success of the machine came about in 1965 when the KS 200 rotor spinning machine was introduced to the market (Hearle, 2013, p. 89). It was the result of research and development by Jaromir Kasparek and colleagues at the Cotton Research Institute in Ústi nad Orlici during a period of great innovation in Czechoslovakia (Hearle, 2013, p. 89).
Air-jet spinning machinery was originated from fascinated yarn proposed by DuPont Co. The fascinated yarn was commercialized as MJS using two serial air-jet nozzles by Murata Machinery Co. in 1980.

Table 1
Trends of the US Patents in Spinning Machinery

Year	Counts	Three Years Moving Average
1986	122	
1987	174	139.33
1988	122	149.33
1989	152	151.33
1990	180	148.33
1991	113	144.00
1992	139	124.00
1993	120	134.33
1994	144	127.67
1995	119	124.67
1996	111	111.00
1997	103	114.33
1998	129	113.67
1999	109	113.00
2000	101	105.67
2001	107	89.67
2002	61	69.33
2003	40	46.67
2004	39	37.33
2005	33	34.33
2006	31	28.67
2007	22	26.67
2008	27	21.33
2009	15	24.33
2010	31	22.00
2011	20	21.00
2012	12	14.67
2013	12	13.33
2014	16	13.00
2015	11	

Source: USPTO website (quick search by current Cooperative Patent Classification (CPC) Classification)

Table 2
Growth Rates of Patent, Value in Percentage

Time Period	Spinning Machinery
1976-1985	-2.16
1986-1995	-1.42
1996-2005	-14.19
2006-2015	-9.63
1976-2015	-5.66

Source: USPTO website (quick search by current Cooperative Patent Classification (CPC) Classification)

import substitution policy was more or less in operation till the mid-1980s, and it compelled foreign manufacturers to enter into collaborations with local producers of spinning machinery. Besides the international collaborations, there used to be liberal import assistance for essential components for domestic production of spinning machinery. All these arrangements facilitated by the import-substitution policy boosted the chances of product development amongst local machinery manufacturers during the import-substitution regime.

Furthermore, the economic reforms initiated in the mid-1980s and the early 1990s facilitated imports of both embodied and disembodied technologies from the leading machinery manufacturers in advanced countries. As will be discussed in Section 3.3, the liberalisation policy in 1991 helped the market leaders in local spinning machinery manufacturing arrange access to foreign knowledge through the imports of technologies or through technological collaborations with the machinery producers from European countries such as Germany and Switzerland. The access to foreign knowledge was mostly in conventional spinning machine, i.e., ring spinning, not in advanced spinning machineries. This access to external knowledge in ring spinning technology accentuated the likelihood for physical development of ring-spinning machine by the local machinery makers in India during the 1990s through the mid-2010s.

3.2. Demand Conditions and chances of market success

Demand success in India's spinning machinery is found to have relied mainly upon cost edge and product differentiation in old or conventional technologies. During the import-substitution regime, the local spinning machinery firms, especially the leading firms, is seen to have had an enormous cost advantage over international manufacturers (Khanna, 1989). The World Bank study shows that Indian machinery producers were found to have sold ring frame for Rs 1.96 lakh compared to Reiter's price of Rs 3.45 lakh and speed frame for Rs 2.4 lakh against Reiter's price of 5.4 lakh (World Bank, 1979, p. 40). This comparative advantage of domestic spinning machinery manufacturers was attributed to cost advantage in all factors of production, especially in labour and overhead cost (World Bank, 1979, p. 41).

However, after the mid-1980s, especially since the early 1990s, the government policy reforms, particularly the trade liberalisation, which sharply slashed the average tariff rate on import of spinning machinery from 35 percent in 1990 to 5 percent in 2013, reduced the expected marketability of domestic spinning machinery. In other words, the easy imports of spinning machinery owing to sharp reduction in tariff rate took away the price competitiveness of local spinning machinery manufacturers. In addition, the policy of second-hand imports in the 1990s and 2000s (as will be discussed in Section 3.3) eroded the expected marketability of domestic spinning machines.

Nonetheless, local producers had a considerable amount of market competitiveness in conventional spinning machines, namely ring spinning machine, during the 1990s through 2015-16. The availability of cheap labour and the capability development in local supplier base for components and intermediate inputs were the sources of cost advantage for local spinning machinery manufacturers. Additionally, the knowledge transfer from international collaborations helped domestic machinery manufacturers build capability to undertake some essential product differentiation to meet the needs of local yarn producers. Both cost advantages and product differentiation in ring spinning brought about the expected chance of market competitiveness by the domestic manufacturers and that helped them attract a significant share in local markets during the post-liberalisation period. The market success of local spinning machinery producers is also corroborated by Table 3 which shows that domestic manufacturers had an average share of 60 percent in total domestic demand for spinning machinery during 2004-05 through 2012-13.

Table 3
Domestic Demand for Spinning Machinery at 2004-05 Prices (Value in Million US$)

Year	Production	Imports	Domestic demand	Production share in domestic demand (percent)
2004-05	490.64	205.40	600.76	78
2005-06	498.22	404.51	815.00	60
2006-07	564.58	628.22	1094.73	50
2007-08	682.13	489.66	1046.27	63
2008-09	383.09	294.30	604.18	61
2009-10	329.14	198.98	467.08	68
2010-11	585.47	320.28	794.94	71
2011-12	399.95	454.98	713.50	45
2012-13	305.37	341.35	539.19	45

Note: Domestic demand for spinning machinery is calculated as sum of production (minus exports) and import of spinning machinery. Here, the import of spinning machinery is net of parts imported by machinery manufacturers, i.e., 15 percent of production (and this method is also employed to calculated indigenous demand for textile machinery by the Ministry of Textiles, Government of India).

Source: Calculated using data from Ministry of Textiles, Government of India

3.3. The Lead Actor and Technological Progress

LMW of Coimbatore, Tamil Nadu (the southern part of India) is a leading textile machinery manufacturer in India and one among the three in the world to produce the entire range of spinning machinery starting from blow room operation to yarn making machines (particularly, ring spinning machine). Besides spinning machinery, it has diversified into the manufacturing of machine tools, heavy castings and parts and components for the aerospace industry.[3] In 1962, LMW was founded as a joint venture between Lakshmi Group (a cotton ginning and textile firms) and Rieter Machine Works of Switzerland. LMW has been occupying a dominating share of the domestic market for spinning machinery since the 1970s and currently it has a 60 percent of market share in India. LMW accounts majority of innovations in spinning machinery and spinning preparatory machinery since the mid-1960s.

There have been many innovations in spinning preparatory machinery as well as in spinning machinery undertaken by LMW since its inception. For example, as provided in Table 4, LMW brought about some important innovations in ring spinning technology during 1968 through 2013. Moreover, during 1995 through 2008 total patents awarded to LMW accumulated from 1 to 41, registering 64 percent of the total patents granted to the local spinning machinery manufacturing sector (see Table 5).

Table 4
Technological Innovations in Ring Spinning by LMW

Year of Innovation	Name of Model
1968	Ring Frame DJ5
1982	Ring Frame LG5/1
1987	Ring Frame LG5/1M
1999	Ring Frame LR6
2007	Ring Frame LR60
2010	Ring Frame LR9
2013	Ring Frame LRJ9

Source: Annual Reports of LMW (1985 to 2015-16)

The technological success of LMW relied on its technological efforts or R&D efforts. Before the late 1970s, all the technological improvements in LMW were undertaken by its production engineering department under the stringent guidance of Rieter, but since the early 1980s, all the technological efforts were undertaken by its R&D unit. As depicted in Figure 2, the R&D efforts increased from less than Rs. 3 million in 1983 to Rs. 164 million

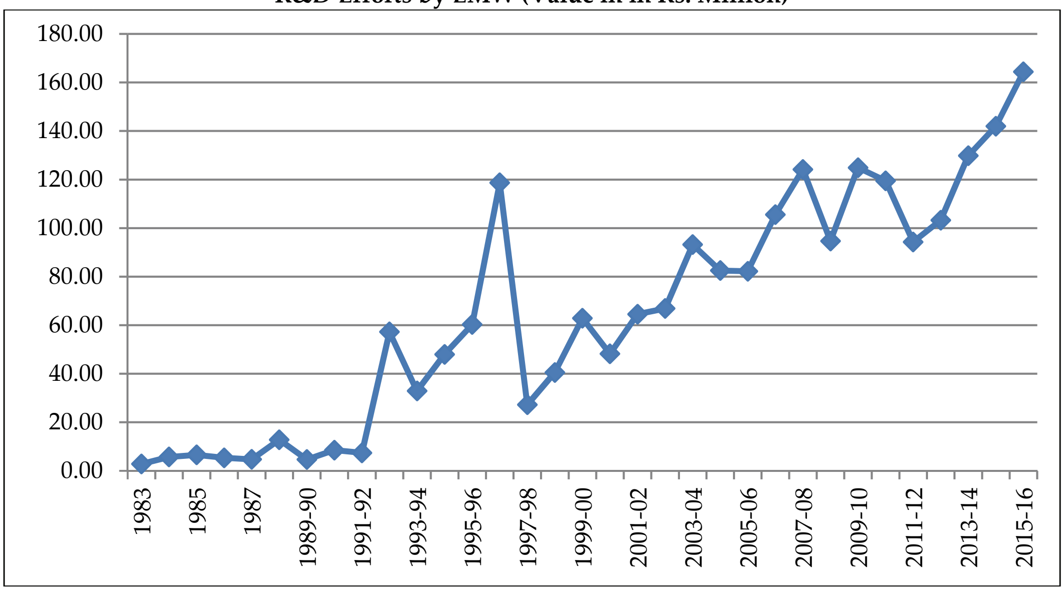
[3] In 2008, LMW established a wholly-owned subsidiary—LMW Textile Machinery (Suzhou) in China. It has also installed windmill with total power generation capacity of 36.50 M.G. in 2007.

Table 5
Trend of Indian Patent in Spinning Machinery Granted to LMW

Year	Spinning Machinery Manufacturing	LMW	Cumulative Patent Counts of LMW
1995	1	1	1
1996	5	4	5
1997	3	1	6
1998	0	0	6
1999	3	3	9
2000	7	7	16
2001	11	9	25
2002	3	3	28
2003	2	1	29
2004	13	7	36
2005	2	0	36
2006	4	1	37
2007	5	2	39
2008	5	2	41
Total	64	41	

Source: Controller General of Patents Designs and Trademarks, Government of India

Figure 2
R&D Efforts by LMW (Value in in Rs. Million)



Source: Data from Annual Reports of LMW (1985 to 2015-16) in 2015-16. There was a flat increase in R&D efforts from the early 1980s to the beginning of the 1990s, but, after that, there was an increasing trend in R&D efforts, though with some fluctuations. Further, though the R&D intensity (a ratio of R&D expenses to sales of LMW) was found to be around 0.9 percent, on an average, during the entire period since 1983, there was an increasing allocation of resources made towards R&D efforts of LMW. The trend of R&D efforts by LMW, especially after the early 1990s, accounted for all the technological emulation and product development undertaken by the lead actor.

The R&D efforts of the firm, as emphasised earlier, depend on its expected chance for product development and market success. We, therefore, analyse the expected chance of physical product development and market competitiveness of LMW. Before examining the likelihood of actual product development and its chance of market success since the mid-1980s, it is essential to understand the evolution of LMW before the mid-1980s. The evolution of LMW before the mid-1980s was discussed by Lall (1987). In what follows, we review it briefly to understand the status of LMW during 1962 through the mid-1980s.

Since its inception up to 1984, LMW introduced 14 products, including two ring frames and one open-end rotor; and 12 out of 14 were licensed by Rieter and one by Schweiter Engineering Works, another firm from Switzerland (Lall, 1987). LMW imported technologies (which were lagging few years behind the leading edge ones) from Rieter and other western manufacturers and assimilated and adapted them to Indian conditions. As will be discussed in the subsequent sub-section too, the technological success of LMW during the mid-1960s through the mid-1980s can be explained by the following. Firstly, the joint venture of LMW with Rieter, which provided all the know-how and know-why to start the manufacture of spinning machinery, was very much part of the entire emulation process of LMW. Secondly, before the commencement of production, Rieter set up an in-house training centre in LMW in 1963, and it also took some 500 LMW personals, from top executives to some skilled workers, to Switzerland for the training up to two years (Lall, 1987; and World Bank, 1979). Lastly, LMW set up a captive foundry for the requirement of high-quality castings for the production of spinning machinery in 1966. The foundry unit of LMW was started with the help of technology and machinery sourced from Switzerland and Germany, respectively, and it was expanded twice, in 1976 and 1982, with the assistance of German machines (Lall, 1987).

The effort of LMW before the mid-1980s was to absorb the Western technology and adapt it to the Indian conditions. The captive supplier base (i.e. foundry unit) and in-house training school along with the knowledge transfer from Rieter generated expected chance for development of spinning machinery for domestic usage. Also, as already discussed in Section 3.2, the local spinning machinery makers had the cost advantage over their Western counterparts in all factors of production, particularly in labour and overhead cost (World Bank, 1979, p. 41). The knowledge transfer from the foreign collaborators and the captive foundry unit helped LMW manufacture the cost-effective spinning machinery and thereby generated the expected chance of market success for LMW during the mid-1960s through the mid-1980s. The likelihood of physical product development and its subsequent marketability enabled LMW to emulate, develop and produce spinning machinery for domestic consumption and exports as well before the mid-1980s.

Chances of Physical Product Development by LMW

As provided in Table 6, arranging access to foreign knowledge has been the most important strategy of LMW since its inception. LMW's chances of physical product development have been largely dependent upon the access to external knowledge via various international collaborations with the leading machinery manufacturers. As discussed earlier, the important collaboration of LMW with Rieter, which remained intact till 2011, though with a meagre share after the late 1980s, provided the essential know-how to emulate or develop spinning machinery for domestic users. Apart from Rieter, as is evident from Table 6, LMW had collaborations with various other machinery manufacturers from Germany and Switzerland to manufacture different kinds of spinning machinery ranging from spinning preparatory machines to the ring frame and open-end rotor.

The objective of LMW has, so far, been to procure advanced quality technologies from the leading manufacturers of the world and adapt them to Indian conditions. Since 1965, LMW has been importing various technologies from its collaborators and these technologies have been absorbed and adapted in phased manner over time by LMW. It is further corroborated by the available data on the import of technology by LMW which shows that LMW has been spending continuously towards the imports of technologies (see Table 7). In addition to the import of (disembodied) technology, LMW has been allocating resources towards the imports of capital goods (embodied technology) since 1983. Both the import of technology and import of capital goods are the external sources of knowledge for LMW. As given in Table 7, on an average during 1983 through 2015-16, LMW has allocated 2.55 percent of its turnover on the purchase of technology (including embodied and disembodied ones).[4] These imports of technology have been providing the expected chance for physical product development by LMW since its inception.

Besides the access to external knowledge, the chance of product development depends on the imports of essential raw materials and components.[5] Table 8 shows that both raw materials and components constitute around 50 to 60 percent share in total sales of LMW during 1986 through 2014-15. The components, in particular, have an average share of around 40 percent in the total sales of LMW during the period mentioned above (see Table

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[4] External knowledge intensity is calculated as a ratio of external knowledge base (which is sum of expenses on embodied technology imports as well as on disembodied technology imports) to the sales or turnovers of LMW.
Average external knowledge intensity is 2.75 percent during 1983 through 1989-90, 3.05 percent during 1990-91 through 1999-2000; and 2.14 percent from 2000-01 through 2015-16.

[5] Components comprise both spare parts and components.

8). The significant proportion of raw materials and components in sales of LMW shows the increasing significance of raw materials and components in product development and production of spinning machinery in India. It is seen that LMW has been dependent on imports for raw materials and components since 1986. The import share in total consumption of raw materials and components was averaged 35 percent during 1986 through 1999-2000 and this value started declining after 1999-2000 and reduced to 19 percent in 2014-15. The declining share of import in the consumption of raw materials and components after 2000-01 indicates the increasing accumulation of capability by the local downstream manufacturers to support the physical product development by the local spinning machinery manufacturers.

Table 6
Arranging Access to Foreign Knowledge by LMW

Name of Technology	Year of Collaboration	Name of Collaborator	Absorption of Technology
Spinning machinery	1965 to 1987-88	Rieter Machine Works Ltd., Switzerland	Absorbed in phases
Spinning Machinery	1965 to 1987-88	Schweiter Engineering Works Ltd., Switzerland	Absorbed in phases
Roving frame	1980	Grossenhainer, Germany	Absorbed in phases
Sophisticated Ring Frame & Blow Room lines	1987 & 1987-88 respectively	Rieter Machine Works Ltd., Switzerland	Absorbed in phases
Open End Rotor Spinning	1989	Schubert & Salzer, Ingolstadt, West Germany	Absorbed in phases
High Speed Draw Frame	1992	Rieter Ingolstadt, Germany	Absorbed in phases
Bale Plucking Machine	1998	-	Absorbed in 1998-99
Condenser	1999	-	absorbed in phases
Design and Drawing for Bale Plucker	1999	H. Hergeth Gmbh, Germany	Absorbed in 2000-01
Roving Frame	2007	Grossenhainer, Germany	Absorbed in 2007-08
Swiftfloc and Blow room machine	2012	Hubert HERGETH, Germany	Absorbed in 2012-13
Ultra Blend LA 9	2013	-	Absorbed in 2014-15

Source: Annual Reports, LMW (1984 to 2015-16)

Table 7
Trends of External Knowledge Base (In Rs. Million)

Year	Capital Goods Imports	Technology Imports	External Knowledge Base	External Knowledge Intensity
1983	14.42	2.85	17.27	2.67
1984	2.54	1.56	4.10	0.46
1985	16.35	8.04	24.39	2.90
1986	5.24	5.29	10.53	1.29
1987	15.03	6.40	21.43	2.22
1988-89	121.04	8.97	130.01	7.92
1989-90	16.91	15.73	32.64	1.76
1990-91	55.94	15.84	71.78	2.66
1991-92	21.98	70.56	92.53	2.87
1992-93	118.62	36.45	155.07	4.34
1993-94	120.05	46.00	166.05	4.39
1994-95	237.68	24.74	262.42	5.33
1995-96	252.09	29.00	281.10	4.69
1996-97	108.36	29.33	137.69	2.55
1997-98	84.68	26.88	111.56	2.17
1998-99	27.86	19.57	47.43	1.15
1999-00	1.02	13.96	14.97	0.35
2000-01	0.10	14.17	14.27	0.27
2001-02	0.18	11.67	11.86	0.28
2002-03	6.64	3.62	10.26	0.20
2003-04	107.77	0.42	108.20	1.63
2004-05	18.10	2.09	20.18	0.20
2005-06	522.39	1.89	524.28	4.03
2006-07	1111.36	10.36	1121.72	6.05
2007-08	1615.59	5.17	1620.76	7.35
2008-09	420.55	3.92	424.47	3.17
2009-10	183.37	0.26	183.62	1.62
2010-11	701.22	2.58	703.79	3.97
2011-12	631.21	10.64	641.85	3.10
2012-13	134.35	11.75	146.10	0.78
2013-14	64.50	21.48	85.98	0.40
2014-15	150.25	14.18	164.43	0.71
2015-16	115.51	12.961	128.47	0.52

Source: Annual Reports of LMW, various years

Table 8
Trends in Import Share in Usage of Raw Materials and Components in LMW

Year	Raw material intensity	Component intensity	Raw material-component intensity	Import share in raw material usage	Import share in component usage	Import share in usages of raw material & component
1986	15	35	50	32	39	37
1987	18	36	54	30	39	36
1988-89	17	37	54	33	39	37
1989-90	21	36	56	34	38	36
1990-91	19	40	59	37	38	37
1991-92	15	38	53	32	37	35
1992-93	14	35	49	27	38	34
1993-94	16	34	49	42	34	36
1994-95	16	36	52	31	33	32
1995-96	15	36	51	32	36	35
1996-97	12	33	45	31	33	33
1997-98	13	36	49	33	33	33
1998-99	9	34	43	34	37	36
1999-00	10	35	46	30	36	35
2000-01	12	34	46	21	31	28
2001-02	13	32	45	21	27	25
2002-03	14	36	49	9	28	23
2003-04	15	33	48	12	27	22
2004-05	18	41	59	9	27	22
2005-06	18	40	57	7	27	21
2006-07	19	41	60	9	26	21
2007-08	16	43	60	12	27	23
2008-09	16	41	57	18	30	26
2009-10	15	43	58	15	25	23
2010-11	18	45	63	25	24	24
2011-12	17	46	63	19	25	24
2012-13	17	47	64	20	25	24
2013-14	17	48	65	14	25	22
2014-15	17	47	63	14	21	19

Source: Annual Reports of LMW, various years

Table 9
Capacity Utilisation by LMW

Time	Spinning preparatory machines			Spinning Machines		
	Installed capacity (Nos.)	Actual production (Nos.)	Capacity utilisation (percent)	Installed capacity (Nos.)	Actual production (Nos.)	Capacity utilisation (percent)
1985	1,303	1,189	91	1,160	729	63
1986	1,364	1,014	74	1,160	481	41
1987	1,440	1,133	79	1,160	668	58
1988-89	1,440	1,602	111	1,200	1,080	90
1989-90	1,710	1,455	85	1,200	985	82
1990-91	1,735	1,727	100	1,200	1,054	88
1991-92	2,060	1,762	86	1,200	919	77
1992-93	2,060	1,674	81	1,200	980	82
1993-94	2,060	1,496	73	1,200	1,042	87
1994-95	2,060	1,990	97	1,200	1,246	104
1995-96	2,600	2,192	84	1,860	1,384	74
1996-97	2,800	1,962	70	2,160	936	43
1997-98	2,800	1,729	62	2,160	970	45
1998-99	2,800	1,170	42	2,160	789	37
1999-00	2,800	1,314	47	2,160	731	34
2000-01	2,800	1,323	47	2,160	1,017	47
2001-02	2,800	737	26	2,160	872	40
2002-03	2,800	1,073	38	2,160	982	45
2003-04	3,040	1,192	39	3,000	1,072	36
2004-05	3,112	1,778	57	3,000	1,579	53
2005-06	4,200	2,486	59	3,300	1,701	52
2006-07	4,200	3,833	91	3,300	2,433	74
2007-08	5,000	4,551	91	3,300	2,801	85
2008-09	5,000	2,486	50	3,300	1,651	50
2009-10	5,000	1,483	30	3,300	1,503	46
Average	2,759	1,774	68	2,054	1,184	61

Source: Annual Reports of LMW (1985 to 2015-16)

Further, the foundry and machine tools of LMW have not only developed the production capability over time but, with the help of technical assistance from overseas manufacturers, they have also grown substantially to support the production of LMW. The development of supplier base over time brought down the import dominance in the consumption of raw materials and components by LMW.

From the above analysis, it is clear that imports of technologies (both embodied and disembodied) and imports of raw materials and components have enabled LMW to develop and manufacture the foreign products. It is further confirmed from Table 9 that the installed capacity of LMW grown substantially for spinning preparatory and spinning machines during 1985 through 2009-10. In the preparatory spinning machines, LMW's capability to produce increased from 1,303 units to 5,000 units and in the spinning machines it rose from 1,160 units to 3,300 units between 1985 and 2009-10. Therefore, it can be said that the access to knowledge base through foreign technological collaborations and imports of raw materials and components were vital for LMW to produce the expected chance of product development during the early 1980s to 2015-16. Moreover, the reduction in import share in the usage of raw material and components after the 2000-01 indicates the capability development brought about by LMW.

Chance of Market Success by LMW

LMW has employed various strategies to bring about the cost efficient and better quality products for domestic usage and exports. As already mentioned, the effort of LMW has always been towards the emulation of western technologies and adaptation of them to local conditions since the mid-1960s. The fortune of working together with Rieter for a long time helped LMW accumulate knowledge required to manufacture spinning machinery according to the needs of local users. It is already emphasised that the foundry unit and the Computer Numeric Control (CNC) machine tool unit, established in 1987-88, have been the great support system of LMW and have thus helped LMW introduce many product differentiations to meet the need of yarn makers. Also, learning by emulating and producing the western technology for a long time since 1962 have been very much helpful for LMW to devise new products in accord with the needs of users. Moreover, the interaction with users, especially from Coimbatore of Tamil Nadu, has also been a great learning experience for LMW which has helped it understand and thus incorporate the users' needs or feedbacks into the new products.

Since the early 1990s, the liberal imports of machinery, the second-hand machinery imports, particularly from Europe at discounted prices, and the inverted duty structure[6]

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[6] Inverted duty structure is a situation where import duty on finished goods is lower compared to the import duty on raw materials that are used in the production of such finished goods. For example, suppose the tariff (import tax) on the import of spinning machine is 10percent and the tariff on the imports of steel which is used in the production of spinning machine is 20percent; this is a case of inverted duty structure.

severely affected local spinning machinery manufacturers and thus made most of them shut down their business forever. However, LMW resorted to various strategic measures such as decentralisation of manufacturing activities, optimum utilisation of resources, launching of new machines, better after-sale-services and so on, and could compete with imports and thus managed to retain its market competitiveness in domestic spinning machinery. Some other situations such as the government's Technological Upgradation Fund (TUF) scheme since 1999, the policy of allowing second-hand imports and the phasing out of quota regime in 2005 have resulted in an increasing demand for spinning machinery during the 2000s.[7] All these policy changes also led to the import of spinning machinery, particularly second-hand machinery. To address the situations during the 2000s, LMW adopted a continuous modification and improvements in manufacture of spinning machines and brought about cost-efficient machines to meet the needs of domestic users. Further, for the early delivery of machinery, it consolidated its manufacturing activities which were located in different places of Coimbatore (Tamil Nadu). For example, LMW shifted its Cots and Aprons unit from Eloor to unit II at Kaniyur and Flyer unit from Muthugoundenpudur to Unit I to have product compatibility. This consolidation process of different units helped LMW reduce the waiting period for delivery of machines and successfully compete with imports and other MNCs in India.

The different strategies mentioned above which were adopted by LMW to gain market success resulted in an increase in domestic sales and exports sales between 1990-91 and 2015-16. Table 10 shows that the local sale of LMW was increased from Rs.7.5 billion to Rs.17 billion during the above-specified period. Similarly, the exports sale of LMW was increased from Rs.1 billion to around Rs.4 billion from 1991-91 through 2015-16. Moreover, there were fluctuations in the trend of sales of LMW during the mid-1990s to 2002-03 due to the Asian financial crisis and in 2008-09 and 2009-10 owing to global financial meltdown. Nevertheless, the firm base of LMW in domestic market because of a long association with users and its various strategies helped it to wave across the crisis and maintain the satisfactory market success during the years of crisis.

It is true that LMW applied different strategies to protect and capture its dominating share in domestic demand for spinning machinery from 1985 through 2015-16. As noticed in Table 9 that LMW's capability to manufacture spinning machinery increased substantially between 1985 and 2009-10, but, there was no corresponding growth in capacity utilisation by LMW during the same period. On an average, the capacity utilizations by LMW in spinning preparatory machines and spinning machines were 68 percent and 61 percent respectively between 1985 and 2009-10. Furthermore, a minute observation of Table 9 shows that there was high underutilisation of installed capacity, especially after the mid-

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[7] TUF scheme is meant to provide interest rate subsidy and capital subsidy to the textile manufacturing units.
The EXIM policy of the government allowed the import of second-hand machinery of 10 years old in 2001-02.

1990s. From 1985 through the mid-1990s, the capacity utilisations in spinning preparatory and spinning machines were averaged at 87 percent and 77 percent respectively, but after the mid-1990s, the capacity utilisations declined to 54 percent and 49 percent, respectively. The massive under-utilisation of manufacturing capacity in LMW after the mid-1990s is attributed to the reduced off-take and demand for spinning machinery produced by LMW.

Table 10
Trends in Sales of LMW at 2004-05 Prices (Value in Rs. Billion)

Year	Domestic Sales	Exports Sales
1990-91	7.47	1.12
1991-92	8.26	0.90
1992-93	8.87	1.10
1993-94	8.52	0.84
1994-95	11.24	1.29
1995-96	13.09	1.11
1996-97	9.93	1.05
1997-98	9.02	0.52
1998-99	6.70	0.51
1999-2000	7.02	0.52
2000-01	7.74	0.67
2001-02	5.11	0.69
2002-03	5.77	0.60
2003-04	7.18	0.99
2004-05	9.69	1.05
2005-06	10.83	1.10
2006-07	13.51	0.60
2007-08	16.36	0.96
2008-09	9.50	0.69
2009-10	8.39	0.55
2010-11	13.59	1.93
2011-12	15.33	2.38
2012-13	13.03	1.62
2013-14	14.97	3.29
2014-15	15.76	3.37
2015-16	16.88	3.77

Source: Annual Reports of LMW, various years

It is evident from the above that the imports of spinning machinery due to continuous slashing of import duties since 1991 took away the domestic demand for spinning machinery and thus brought about the under-utilisation of production capacity in LMW during 1996-97 through 2009-10. In other words, the imports of spinning machinery, particularly of the used ones, worsened the marketability and market for spinning machines produced by LMW during the mid-1990s to 2009-10. Notwithstanding the effect of the second-hand imports, LMW could manage to own the 60 percent share in the local demand for spinning machinery in India.

4. Conclusion and Discussion

This paper has analysed the process of technological change in India's spinning machinery manufacturing sector. It relies upon the sectoral system of innovation framework for analysis. The framework has mapped out three building blocks, viz., technological regime, demand condition, and the lead actor in the spinning machinery manufacturing sector. It is found that the lead actor, LMW, is found to have brought about most of innovations in India's spinning machinery manufacturing sector and to have explained the entire process of these innovations in the sector.

A predictable technological path and low cumulativeness of innovation characterise the technological regime of the spinning machinery manufacturing. This regime along with the access to external knowledge base via international technological collaborations has created the expected chances of physical product development by the local spinning machinery manufacturing since the mid-1950s. It is seen that the long-term technological collaborations with the leading western textile machinery manufacturers such as Rieter Machine Works (Switzerland) and other technological collaborations with other leading machinery makers from Germany and Switzerland have enhanced the chances of physical product development by LMW.

The relatively cheap labour and the presence of the local supplier base and the development of the supplier base over time have provided the cost edge to the lead actor. Further, the long-term technological collaborations with leading international machinery manufacturers have enabled LMW to bring about many product differentiations and thereby to retain the dominating market shares in the spinning machinery in India. Cost advantage and product differentiation are two principal sources which have generated the expected chance of market competitiveness for the leading spinning machinery producer. However, the liberal import policy and the policy for second-hand imports affected the sources of market success by the lead actor during the post-liberalisation period.

It is therefore understood that the expected chance of physical product development and market success in the spinning machinery manufacturing have brought about the technological efforts and thus technological progress by the LMW. However, the innovations in LMW are in conventional spinning machinery, i.e., ring spinning machinery, not in advanced spinning machinery (e.g., rotor and air-jet spinning). The non-development of advanced spinning machinery in India may be owing to the following reasons:

There is no access to the foreign knowledge in the advanced spinning machinery in the local spinning machinery manufacturing which is not providing any likelihood for product development by the local manufacturers. Secondly, the imports of advanced spinning machinery and second-hand spinning machinery, in particular, have been eroding the expected chances of market success by the domestic spinning machinery manufacturers since the economic reforms in 1991. It is to mention that the development of advanced spinning machinery has been affected mostly by the imports of second-hand machinery, not by the absence of access to the foreign knowledge. It is so because the expected chances for product development may not necessarily guarantee the physical product development unless there is chance for market competitiveness of the to-be-developed product by the domestic producers.

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Appendix

Appendix 1
Distribution of Production of Textile Machinery Industry (Value in Percentage)

Year	Spinning Machinery	Weaving Machinery	Processing machinery	Other Machineries	Total
2004-05	62	11	11	17	100
2005-06	62	11	11	17	100
2006-07	62	11	11	17	100
2007-08	62	11	11	17	100
2008-09	62	11	11	17	100
2009-10	52	12	11	25	100
2010-11	59	10	12	19	100
2011-12	52	10	15	23	100
2012-13	47	9	19	25	100
Average	58	10	12	19	100.00

Source: Calculated using data from annual reports of TMMA, India.

Appendix 2
Trend of Trade in Spinning Machinery, Value in US$ Million

Year	Export	Import	Trade	Import share in Trade (percent)
1988	27.62	13.47	41.09	32.79
1989	39.68	47.55	87.24	54.51
1990	45.19	100.87	146.06	69.06
1991	30.81	51.34	82.16	62.49
1992	32.02	96.10	128.12	75.01
1993	20.00	155.94	175.94	88.63
1994	34.06	274.81	308.88	88.97
1995	22.31	296.08	318.40	92.99
1996	29.92	232.42	262.34	88.59
1997	23.62	193.33	216.95	89.11
1998	13.59	115.65	129.23	89.49
1999	11.29	78.32	89.60	87.40
2000	13.01	62.65	75.66	82.81
2001	33.48	56.73	90.21	62.88
2002	14.18	93.31	107.49	86.81
2003	24.21	124.35	148.56	83.70
2004	13.25	147.65	160.91	91.76
2005	25.72	392.52	418.24	93.85
2006	15.60	780.05	795.65	98.04
2007	26.66	713.15	739.81	96.40
2008	24.53	542.70	567.23	95.67
2009	14.20	212.45	226.64	93.74
2010	25.69	378.85	404.54	93.65
2011	92.02	617.27	709.29	87.03
2012	94.18	471.95	566.13	83.36
2013	141.98	456.92	598.91	76.29
2014	163.30	373.97	537.27	69.61
2015	200.02	364.86	564.87	64.59

Source: United Nations Commodity Trade Statistics Database

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ISID

Institute for Studies in Industrial Development

4, Institutional Area, Vasant Kunj Phase II, New Delhi - 110 070

Phone: +91 11 2676 4600 / 2689 1111; Fax: +91 11 2612 2448

E-mail: info@isid.org.in; Website: http://isid.org.in