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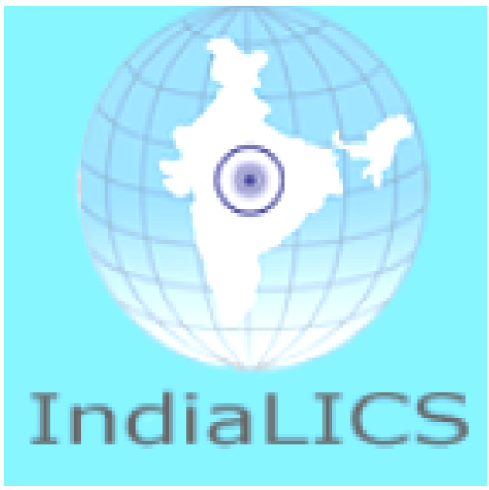

Indian Ayurvedic Medicine Industry at a Crossroads: Exploring Technological Capabilities in the Post-WTO Policy Regime

Abha Arya and
Saradindu Bhaduri

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Abha Arya[*]
Saradindu Bhaduri[**]

Abstract

This paper tries to explore technological change; the motivations and pattern of technological capabilities in the Ayurveda medicine industry. It would investigate the different kinds of learning and technological innovations taking place in the post-WTO regime in the industry to enable it to cater the global market. The paper discusses assimilative capabilities, collaborative learning and path-dependence of Ayurveda industry with the help of primary data collected from firms, research institutes and individual scientists. It also discusses how changing formulation technology poses challenge for existing delivery mechanism of Ayurvedic dosage.

[*] Centre for Studies in Science Policy, Jawaharlal Nehru University, New Delhi. abha.jnu@gmail.com
[**] Centre for Studies in Science Policy, Jawaharlal Nehru University, New Delhi and Prince Claus Chair in Development and Equity (2015-17), Centre for Frugal Innovation in Africa, International Institute of Social Studies, The Hague. Saradindu@jnu.ac.in

1. Introduction

Ayurvedic medicine industry has, of late, been exposed to the requirement of 'global market' in the post-WTO[1] period. This exposure to global market has, however, also meant greater emphases on stricter regulation and standardization of products. In this context, the paper analyses the nature and pattern of technological capabilities acquisition process of the Ayurvedic medicine firms in India.

The colonial policy-makers viewed traditional medicinal system through the lenses of western sciences which, interestingly, continued after independence. However, the increasing expenses on health care, side effects of allopathic drugs have gradually shifted the attention of policy makers to complimentary health care practices, including Ayurveda. As a consequence, the policy stance changed and Ayurveda got renewed policy attention along with other traditional medicinal system like Siddha[2], Unani[3], Naturopathy[4], Yoga[5] and Homeopathy[6].

Acquisition of capabilities in manufacturing technologies has been discussed by the scholars of technological capabilities, who argue that, at the firm level, acquisition of technological capability involves the capabilities to search, assimilate, adapt to existing technologies leading to the capability to innovate new technologies (Fransman 1984, Lall 1987, 1992, Gonsen 1998). The literature of technological capabilities has never been studied for sectors such as Ayurveda, which, according to many, draw upon a completely different knowledge base, and technological practices rendering use of many 'modern technologies' unsuitable. This paper takes up this question in analyzing the ways through which Ayurvedic firms adopt the so called modern technologies of manufacturing and quality control in the post-WTO regime. We would like to make it clear that Ayurvedic drugs and food products which come under clause 3a and 3h[7]. The Ayurvedic medicine industry is different from other industries because of the different knowledge system attached to it. It is also different from allopathic medicinal industry because it follows the classical Ayurvedic textbooks[8]. This paper also intends to look into the challenges faced by manufacturers, practitioners and scientists due to the difference in the knowledge system between Ayurveda and modern sciences. In this backdrop, the present study will provide a perspective of the different stakeholders of Ayurveda and the path of acquisition of technological capabilities in the Ayurveda medicine industry.

The paper is divided into following sections: the second section outlines the theory of technological capabilities and technological innovations, their typologies and firm specific development; third section explores Ayurveda pharmaceutical industry and the policies related to it; fourth section is data, sample and research methods; fifth section is observation and analysis of the data collected; sixth is the synthesis and seventh concludes the paper.

2. Acquisition of Technological Capabilities (TC) and Advancement of Technological Innovations

Westphal et al (1985) defined technological capabilities as the ability to make effective use of present technological knowledge. Fransman (1984) disaggregated TC as acquisition capability, assimilative capability, adaptive capability, minor innovation and major innovation like R&D. Likewise, Chang (2003) cites Fransman's (1984) TC stages while talking about policy

making for the developing economies; and Chantanaphant et al (2011:4) cite Lall (1984), Bell (1984) and Westphal et al (1985) and maintains that their work had established that TC is an important factor for firms in emerging economies. Chantanaphant et al (2011) classify TC as technological acquiring capability, technological operating capability and technological upgrading capability. In the context of developing economies, Lall (as cited in Gonsen, 1998) divides TC at three different levels: at the firm level or micro-level, at the industrial branch level and at the national level, however, in this paper we focus on firm-level capacity building. This includes capabilities at various steps as the capacity to select, assimilate, adapt and improve existing or imported technology and/or create new technology.

2.1 Typologies of TC

Acquisition capability is related to the process of technological learning (Gonsen, 1998). For this purpose 'technological effort' (Bell, 1984) is necessary which signifies the conscious use of technological information and the accumulation of technological knowledge, together with other resources to choose, assimilate, and adapt existing technology and/or to create new technology.

Assimilative capability, also known as technology mastery or operational capability, refers to the successful use of technology in transforming input into outputs which involves the learning of basic operating skills (Gonsen, 1998). Morrison et al (2008:42) following the argument of Fransman and King (1984), Katz (1987), Wignaraja (2002), they argue, TC categorisation depends upon "the functions they perform and their degree of complexity". They maintain the taxonomy of capabilities given by Lall (1992) on investment capability, production capability and linkage capability which are interdependent and strongly overlapping. Modifying capability is the ability to modify existing technology (Gonsen, 1998). This definition is substantiated by Katz (1987) as imported technology is often best suited to the factor endowments of the developed countries and adaptation is required to match transferred technology to the conditions prevailing in LDCs (Least Developed Countries). Gonsen (1998) maintains that technology assimilation and modification refer to imported technology whereas innovation is the creation of new technology. Antonelli (2003:168) elaborates in the line of Katz (1987), Lall (1987), and argues that the efficiency of any technology depends upon the context of its adoption. In that particular context, the applicability of a technology depends upon its adoption capabilities and incremental innovations. Rosenberg and Steinmueller (1988) propounds that innovation may happen outside R&D set ups.

The literature that analyses the technological behaviour of the firms belonging to the developing countries considers innovation capabilities as important phenomenon to explain the improvement of existing technologies. This is majorly incremental innovation. Fransman (1984) maintains that innovation is important in acquisition of TC. He emphasizes on formal R&D for minor and major innovations. The literature of TC emphasizes that for acquisition and assimilation of TC firms depends on interactions between different stakeholders. Technological innovations being an important factor could not occur in isolation. As Rosenberg (1976: 79) observes, innovation in social sciences is a complex process as it involves various interactions. This is further substantiated by Kline and Rosenberg (1986) that innovation is not linear and constitutes various "sociotechnical systems". Arundel and Geuna (2004), Bathelt et al (2004),

Carca, Lundvall and Mendonca (2009:864), and Lundvall (2010:326) maintain Kline and Rosenberg (1986) model and argue that innovation is an interactive process; no firm works in isolation; firms acquire technological knowledge from outside sources and include this knowledge in their innovative activities; and knowledge creation is an interactive process amongst several firms.
Rosenberg (1986: 288) argues that we should recognize that "most innovation is done with the available knowledge already in the heads of the people in the organization doing the work, and, to a lesser extent, with other information readily accessible to them." He further substantiates it by observing that coupling and cooperation among the activities in the marketing, R&D and production functions are important for technological innovations.

Among the various types of innovations, one kind of technological innovations is highlighted by Rosenberg (1976). He argues, "the most intractable problems associated with the introduction of techniques of 'manufacture' lay in the inability to produce machines which would perform according to the special and exacting requirements and specifications of the machine users", Rosenberg (1976:12). To solve the technical problems, the machine users interact and make modifications according to their utilization. Amongst several innovative activities, machine created and/or modified in manufacturing units are the most frequent innovation taking place in developing countries. This amounts to incremental innovation which is a trend seen in developing economies. In their recent paper, Arora and Nath (2015) observe 'new machines' are the most common innovative activity across the sector which indicates 'predominance of incremental innovation'.

2.2 Firm-level Development of TC

Besides the contributions mentioned above, TC focused on scale of economies, resources and factor endowments on main reasons of adaptation. Lall suggests that firms in developing countries may not easily imitate or transfer technology as technological capabilities in firms are not homogenous (Lall, 1992). This differs due to the financial and personnel resources. Lall (1992) argues that for transferring technologies, continuous learning of firms is necessary. As technologies require tacit skills, efforts and investments, hence, the command over technologies varies in different firms. To substantiate it further, Mokyr (2002:166) argues that 'much of what the new technology required was un-codified or 'tacit' knowledge that was hard to buy, sell, or obtain from books and periodicals'. He further maintains to learn codified knowledge one requires un-codified knowledge. Applying codified knowledge also needs tacit knowledge. It is not easy to acquire it, thus, 'large plants could train or hire specialists who possessed it', (Mokyr, 2002). Lall (1992) and Wignaraja (2002) observe that for a conscious capacity building firms depend on interaction with other agents which amounts to collective learning. Due to the tacit knowledge acquired by the personnel resources and the technological learning the use of similar technology may vary.

Lall (1992:168) divided assimilative capability into: a) investment capability, b) production capability, and c) linkage capability. According to the author, *Investment capability* can be understood as the skill needed to identify, prepare, and obtain a new technology, and build a new facility with equipments and staff. This is the skill needed to construct a new model with the help of already existed skill and technology. It may also help in operating an improved

technology or imported technology efficiently by skilled personnel. The author suggests that *Production capability* is the skill needed for functioning of a plant with given technology, and its improvement over time. It is the basic skill such as quality control, operation, maintenance, trouble-shooting, inventory control, work-flow schedule, improvement of equipment, research and design. It covers both process and product design. Moreover, as the author suggests *Linkage capability* is the skills needed to transmit information, skills and technology to, and receive them from supplier, contractor, vendor, consultant, service firm, and technology institutions. The author identifies the above mentioned factors and considers them responsible for development of technological capability in firms.

2.3 Variables in Acquisition of TC

As discussed above, firms develop by acquiring technological capabilities based on different factors. One such factor is the age of firms. Lall (1992) enunciates that starters are more intended towards efforts to industrialise. However, Katz (2000) in his studies on TC of Latin American countries' TC put that the newcomers after market deregulation and trade liberalisation not necessarily succeeded. Whereas he notes, the firms which were already involved in technological effort has been smoothly able to deliver good even after the country experienced recent changes in the global incentive regime. Author also observes that older firms which are historically involved with the technological learning have higher rates of success. This highlights the importance of technological learning and path-dependency.

3. Ayurveda Pharmaceutical Industry in India

This section outlines the major issues that the industry is poised to deal with for a sustainable future.

3.1 Ayurveda Medicine Industry

The word Ayurveda is made up of two Sanskrit words *ayus* means longevity and *veda* means knowledge[9]. Several authors have defined Ayurveda as science of life and longevity. Recent estimates show that the total number of firms is around 9000 (Harilal, 2009). However, only 2% of them constitute more than 80% of the market share. They manufacture various kinds of Ayurvedic medicines which could be over-the-counter or prescriptive drugs. An estimate classifies the domestic market for AYUSH[10] drugs as 84% for Ayurveda, 13% for Homeopathy and 3% for Unani and Siddha (Harilal, 2009:48). The annual turnover of the herbal industry in the country has been estimated at rupees 8,800 crores in the year 2005-2006 (Dev and Goraya, 2008). However, Ayurvedic products are not only made up of herbal raw materials, a good number of products are made up of animal and mineral based ingredients. Although the main focus remained the consumption of herbal raw materials from the wild, own cultivation and imports. If the quantity of herbal raw drugs are divided into the above classified three sections then the value is: 1, 20,000 MT collected from the forest area of the country; 24,000 MT consumed/traded form the cultivated lands of 24,000 hectares in the country; and for the year 2004-05, the quantity of imported botanical raw drugs added up to 37,483 MT. The author observe when all of these values are added up in the report, they do not show the exact number when the whole industry both licensed and unlicensed is looked upon. The mineral and metal based products in Ayurveda, in the forms of *bhasma*[11] and *pishti*[12] are prepared by almost every big firm. Moreover, this medicinal form is always under scrutiny due to the controversy on presence of heavy metals in them. For animal and marine based raw materials often bio-diversity becomes an issue.

3.2 Public Policies

In this section, we present an outline of the policies made on health related traditional knowledge systems. We have sub-divided this section, which is as follows:

Pre-Independence Era:

Before independence India was divided into provinces and some of these governments have formulated committees to strengthen the indigenous medicinal system. to name a few of these efforts, All India Ayurveda Mahamandal, All India Ayurvedic Congress (1911), Indian National Congress on Ayurveda (1920-38), Bengal Committee (1921-22), Usman Report (1923) was a regional Madras report, UP committee (1925), etc. Years later Bhore Committee (1946) came up under the chairpersonship of Sir Joseph Bhore. The report mentions about the importance of indigenous medicinal system and it also observes that it is connected with patriotic feeling of the country. They feel that they are not competent enough to comment on the system, however, to cater the need of such a large population this system is necessary.

Post-Independence to Liberalisation Era:

After the first health minister's conference of 1946, it was brought into notice that there should be a proper training and research on indigenous systems of medicine. As a result, a committee was formed under the chairpersonship of Lt. Col. R N Chopra and it was popularly

known as Chopra committee. The report came out in 1948. The committee comprehensively recommended on education system, teaching system, regulations of education and research, drug standardization and medical relief. The then central government of India took decisions on the recommendations where the central and provincial government had to take some steps regarding the integration of modern scientific medicine and Indigenous medicinal system. According to them this was necessary for building up a National Health Service. To follow up Chopra committee Pandit committee was formed and its report came out in 1951. It was called as Report of the Committee Appointed by the Government of India to Advise them on the Steps to be Taken to Establish a Research Centre in the Indigenous Systems of Medicine and Other Cognate Matters in 1951. Dr C G Pandit and his team recommended a central research institute in traditional medicinal system. It also mentions about the integrated version of education system and demands a uniform course of training in Ayurveda.

We have observed that in the first five year plan[13] of 1951 to 1956 these recommendations were taken into consideration. In this plan, government has sanctioned a budget for research into indigenous and other systems of medicine and also decided to establish a central institute for research at Jamnagar. They complied to make a provision for comparative clinical study of different technique. The report mentions that government institutes like Central Institute for Ayurvedic Research and Central Drug Research Institute should undertake studies on collection, standardization, storage and distribution of medical herbs. This could also be seen in the recommendations of Chopra committee. The plan has heavily talked about professional training education and research of the indigenous medicinal systems they also urged to established central councils for the same. The first five year plan also mentions verification of herbs, identification of indigenous drugs and detecting adulteration of crude drugs. It also mentions the formation of pharmacopeia and formularies. It could be observed that based on Chopra committee recommendations and Pandit committee recommendations, the first and second five year plans mentions the necessity to establish teaching and research institute of Ayurvedic medicinal system; the latter plan sanctions budget for the research centre and post graduate institute at Jamnagar. It is observed that the first few decades of independent India focused on establishing the standards in education and regulation of practice of indigenous systems of medicine. Subsequently, Government of India appointed another committee headed by DT Dave as the central Council of health has passed a resolution to address the question of standards in education. Dave Report is also known as Interim Report of the Committee Approved by the Government of India to Study and Report on the Question of Establishing Uniform Standards in Respect of Education and Practice of Vaidyas, Hakims[14] and Homeopaths which came up in 1954. It looks into the education system of the indigenous systems of medicine and the regulation of practice. This includes the syllabus and regularity of education, its integration, importance of pharmacopoeias and dictionary. It is the first report which looks into the debates of *Shuddh* and *Ashuddha*[15] Ayurveda education.

If we will look into the third five year plan (1961-1966) we can see the coming up of new research institutes and the government has a started talking about Siddha units. This plan also carries forward the discussions on education research and training programs in the indigenous systems of medicine, however, in this plan it specifically mentions the variations among States. It laboriously talks on the necessity of conducting research. Moreover, if we would go through Udupa committee report then we could find some leads. Under the chairpersonship of K N

Udupa, this report meticulously traces the emergence of Ayurveda and its decadence over a period of time. Udupa committee reports mentions the status of the state governments of the time, training, existing faculties, colleges and hospitals. It also has a section on "Is Integration Necessary?" where they dealt with the questions on challenges in integration of indigenous and Western systems of medicine. In between, Mudaliar Committee recommendation of 1962 is published. Headed by Dr A L Mudaliar, the committee is also known as "Health Survey and Planning Committee" consists of the evaluation of the performance of health sector. The report observes the evolving status of different diseases in different areas is evaluated and role of various organizations are assessed. It also observes the role of indigenous system of medicine in different field of medicine and health. After a three year plan holiday, fourth five year plan (1969-1974), we see that the plan made in previous session was carried forward. However, a necessity of formation of pharmacopoeia of Ayurveda and Unani was expressed.

Most of these policies have talked about the integration of the Western and indigenous medicinal system, education system, research and training. Banerjee (2009) cites the Report of Committee to Assess and Evaluate Present Status of Ayurvedic System of Medicine in 1959 observed that the preparations made by hands by *vaidyas* made Ayurveda treatment less popular among the new generation. This is further noted that such hand-made preparations are considered unhygienic to those who are convinced that through the mechanized process high-quality product is prepared. The following sub-section briefly mentions about the policies which came after the advent of liberalisation.

Post-liberalisation Era:

Guidelines of Good Manufacturing Practices

Schedule T[16] was tabled in the year 2000 and 2003. Later the standards to be followed by the manufacturing units came up in 1970s. Final notification of GMP guidelines for manufacturing of herbo-mineral-metallic compounds came forth in 2009 (Singh, 2016). In the same year, the shelf life matter was amended in the Act. In order to understand the formation of GMP, international debates on heavy metals is important to consider[17].

National Policy for ISM and H 2002

The policy has identified debates on knowledge systems, the need on integration, education system and research; and the kind of attitude which has always dominated policy makers since independence. It focuses on a range of issues like depleting ecology, growing number of manufacturing units, need for a wide range of research, a regularized educational system, safety and efficacy of drugs, pharmacopoeial standards and different stakeholders in the industry. Interestingly, it also observes the problem of adhering to the guidelines of GMP on the part of a large number of manufacturing units. Considering the fact that the industry has potential, it has not been provided with proper support from the government. It says the government will provide with them special packages.

By looking at the evolution of various committee recommendations and policies, it seems that most of the guidelines related to manufacturing came after liberalisation period. However,

several issues which are faced by small and medium sized enterprises (SMEs) are not dealt by the government properly. There is also no proper literature dealing with the manufacturing practices of indigenous medicinal products. This research will help in putting forth the challenges and problems by SMEs, and tries to fill in the gap in the literature. A policy framework on the issue can be made after the study of the industry and the capability it has acquired over a period of time. Also it becomes important to understand the kinds of innovations taking place in the industry. Through this we can comprehend the motivations of firms behind adoption of modern technologies; and the pattern of acquisition, assimilative, modifying and innovative capabilities.

4. Data, Sample and Research Methods

In this research, secondary and primary sources have been used. For secondary data, government documents and reports, legislations and online materials have been used. Historical background of Ayurveda medicinal system and pharmaceutical industry is studied through English version of Ayurveda texts and government websites like AYUSH, CCRAS[18], etc. Primary data collected from firms through a semi-structured open-ended questionnaire from three places in India. Personal interviews have conducted with the owners of Ayurveda manufacturing units, heads of their production unit and/or heads of their in-house laboratory units. A total of 17 firms were interviewed in which 12 were manufacturing units, 2 were those units which have accommodated manufacturing units with their hospitals. In addition, three scholars of prominent research institutes were interviewed. The data collection involved visits to manufacturing units of almost all the firms.

4.1 Basic Information about the Sample

Here, we present some basic background information.

4.1.1 Background of Firms

Among the two institutes interviewed, one has clinic with in-patient facility and a small manufacturing unit attached for manufacturing medicines for their own patients. Another institute has an educational facility, a hospital and a small manufacturing unit. This information is tabulated in Table 1. Scientists are not included in this table.

Location of Firms

Three areas are selected for conducting interviews which are Lucknow (Uttar Pradesh), Haridwar (Uttarakhand) and NCR (National Capital Region). In Lucknow, various research institutes are established for research on herbal products and drugs. These establishments would have influenced the Ayurvedic manufacturing units. Haridwar was selected due to the religiosity attached to it. The area has a cluster of small and medium sized Ayurveda manufacturing units. Some old teaching and manufacturing units are established in this region; as a result, several *vaidyas*, Ayurvedic manufacturing units and related trades have similar kinds of education. Finally, the NCR is a hub of manufacturing units, headquarters and R&D units of big firms. The details are mentioned in Table 1.

Size of firms

The categorization is according to the sales turnover of the firm, however, the slabs are taken from the categorization done by Dev and Goraya (2008). In the data collected, there is a discrepancy in the division because of the skewed ratio of the sales turnover among the firms. The authors decided that there should be three slabs whereby the second slab is between Rs. 5 crores and Rs. 50 crores. Thus, it is decided that the firms will be categorized as follows: below Rs. 5 crores (four manufacturing units), between Rs. 5 crores and Rs. 25 crores (four manufacturing units), between Rs. 25 crores and Rs. 50 crores (two units) and above Rs. 50 crores (four units).

Ownership Category

There are three types of ownership structures: proprietary and partnership, limited companies and trust. Table 1 shows the number of cases in this category. The institutes are not included in this category. There are four firms in proprietary and partnership, two firms belong to trust and six firms are limited companies.

Educational Background of Owner

We divided this into two broad categories viz. technical (science graduates) and non-technical (non-science graduates). The table shows the educational background of the founder of the firm, whereas the subsequent section shows the educational background of the current owner. Trusts are not included in this section because the trust members have different educational background.

Age Profile of Firms and Institutes

We found that the age profile of the firms and institutes can be classified into three groups as one can see in the table. These age groups have different policy regimes.

Table: 1. Background Information of the firms[19]

Location of manufacturing units	
Name of the place	Number of firms interviewed
Lucknow	1
Haridwar	9
National Capital Region	2
Total	12
Turnover of the manufacturing units	
Turnover	Number of firms interviewed
Below Rs 5 crores	4
Between Rs. 5 crores and 25 crores	4
Between Rs. 25 crores and 50 crores	2
Above Rs. 50 crores	2
Total	12
Ownership Categories	
Ownership Structure	Number of firms interviewed
Proprietary and partnership	4
Trust	2
Limited	6
Educational background of the founder	
Background of founder	Number of firms interviewed
Technical (science educated)	6
Non-technical	4
Educational background of the current owner[20]	
Background of current owner	Number of firms interviewed
Technical	6
Non-technical	4
Age profile of the firms[21]	
Age categories	Number of firms interviewed
Pre-independence (Before 1947)	6
Between 1947 and 1990	2
Post-liberalization (After 1990)	6
Total	14

Source: Field Work

5. Technological Capability and Innovations: A Discussion

Here, we discuss the observations and analysis.

5.1 Reasons to Use Modern Manufacturing Technologies

There are several reasons attached with the adoption of modern technologies in manufacturing units and in in-house laboratories. These responses, as shown in Table 2, form the causality for assimilation of TC and research capabilities in firms. The motivations for adopting modern technologies are as follows: increasing production, meeting the increased demand of the market, and saving time and labour. Technological innovations increased as firms' annual sales turnover increased. Like some of them expressed, quality control can be well maintained through modern machines as man-handling and inconsistency of the product can be reduced.

Firms with high turnover prefer modern technologies in manufacturing units and in in-house R&D laboratories. Almost, every firm has modern equipments in 'in-house' laboratory, like, centrifugal machine, ovens, incubators, liquid chromatography, autoclave, air sampling, etc. which can signify that for maintaining quality control modern technologies are used. Despite this, the firms have modernized its production process partly. An interviewee explained that quality requirement for every step is mentioned in the classical texts. The usage of modern machines makes these testing and experimenting easy. While using modern technologies, they keep ancient techniques of formulations in mind to avoid discrepancies in formulations. Some challenges in the adoption of technologies are: a) fear that originality of Ayurveda will get lost; and b) interference with drug delivery system.

Table: 2. Reasons for adoption of automated technologies

Reasons for adoption of modern formulation manufacturing technologies	Number of responses
To increase production	14
To save time and labour	12
To increase quality of products	7
To reduce man-handling of products	5

Source: Field Work

Note: The numbers of responses are exceeding than the number of firms due to the multiple responses

Perception of the owner shapes the adoption pattern of modern technologies. As evident in Table 3, maximum firms adopted modern technologies due to the growth of modern and global market whereas a handful of firms have adopted in response emergent regulation. Institutes who have their own hospitals and manufacturing units have more space than the manufacturers in adoption and conducting research in modern technologies.

Table: 3. Reasons for automating manufacturing technologies

Reason for modernizing formulation manufacturing technology as perceived by interviewee	Number of responses
Due to regulation	8
Due to modern and global market	12

Source: Field Work

Note: The numbers of responses are exceeding than the number of firms due to the multiple responses

5.2 Pattern/Nature of Technological capability: At Firm Level

This section comprehends the pattern of acquisition, assimilative, modification and innovative capabilities of Ayurveda medicine industry. We found that industry have acquired capabilities over a period of time. As already discussed in the above section that there are independent variables on which the pattern of acquisition capabilities depend upon. For this purpose we are taking into consideration some variables like turnover, age of the firms, ownership structure and educational background of the owners. Turnover is necessary as it suggests the capability to invest. Age of the firm is important as it will help us in locating the establishment of the firm in a particular policy regime. Policy regime is a factor for a firm to grow. Ownership structure is a factor which would determine both past experiences and participatory process. Bhaduri and Worch (2008:35) observe that the firms belonging to the

limited companies have benefited from a "more participatory process of decision-making and an intra-firm knowledge creation process that such a decision-making a structure entails[22]".Educational background is taken as Gonsen (1998: 36) says "Educational and technological training (including in-firm training) are essential to the provision of skills required in all the forms of TC, from the most basic engineering activities to the most advanced R&D". Based on these independent variables following capabilities have been explained.

Acquisition Capabilities*:*

Acquisition of TC refers to the capability to search for, assess, negotiate, procure and transfer of technology. The above mentioned variables are responsible for the technological learning. The table below shows the relationship between turnover and automation level; automation level and educational background of current owner; and automation level and ownership structure. A pattern is seen to emerge that firms with high turnover, and with technical background of owner have searched, assessed and got transferred newer technologies. Out of 4 fully automated firms 1 has a trust ownership and 1 has partnership and proprietary while 2 are limited companies. The latter might have more participation in decision making and their past experiences have also played a very important role in acquisition capabilities. One of them is established in the British India and its human and financial resources have played important role in accumulation of technological knowledge. Most of them have chosen and adapted existing technology. This has become a part of technological efforts in order to achieve indigenous TC. Technological knowledge and information are of various kinds which also depend upon the market regime. Thus, in our case old firm with limited ownership, technical educational background and who have identified resources are able to adapt relevant technologies. This also depends upon the institutional behavior and government policies.

The other eight manufacturing units are semi-automated. The technologies they have adopted include grinders, mixers, tablet punching machine, syrup filling machine, driers, packaging and labeling machines, etc. But the process of manufacturing is not completely mechanized. Mostly these firms have proprietary and partnership structure and their owners (both founders and current owners) have an educational background of *vaidya*. It is shown in the above tables. We found that in this category there are some exceptions also, like, there are some limited companies which have a non-technical founder and current owner. They are incorporated before liberalisation and some are established in pre-independence era. They all have small turnover. In this category, some firms reported that automation and the use of modern equipment can alter the activities and effects of Ayurvedic medicines.

Table: 4. Relationship between Turnover and Automation Level

Turnover	Automation Level		Total
	Semi-Automated	Fully-Automated	
Below Rs. 5 crores	3	1	4
Between Rs. 5 crores and 25 crores	4	0	4
Between Rs. 25 crores and 50 crores	1	1	2
Above Rs. 50 crores	0	2	2
Total	8	4	12

Source: Field Work

Note: Institutes and scientists are not included in this table

Table: 5. Relationship between Automation Level and Educational Background of Current Owner

Automation Level	Educational Background of Current Owner			Total
	Not Applicable	Technical	Non-Technical	
Semi-Automated	1	4	3	8
Fully-Automated	1	2	1	4
Total	2	4	6	12

Source: Field Work

Note: Institutes and scientists are not included in this table.

Table: 6. Relationship between Automation Level and Ownership Structure

Automation Level	Ownership Structure			Total
	Proprietary and Partnership	Trust	Limited	
Semi-Automated	3	1	4	8
Fully-Automated	1	1	2	4
Total	4	2	6	12

Source: Field Work

Note: Institutes and scientists are not included in this table.

Table: 7. Automation level in in-house laboratories

Automation level in in-house laboratories	Number of firms and institutes interviewed
Semi-automated	4
Fully-automated	10
Total	14

Source: Field Work

Assimilative Capabilities*:*

This section deals with the mastery of technology in the industry which is the second stage in the development of TC. This is the process of know how where the firm implements technology. This stage specifies the mastery over technology and adequate quality control. In this stage, the firm understands its technological complexities and improves over time. The acquisition of technological learning in the first stage consists into its better usage. This may take time. This is not a linear process, thus, the categories of Lall (1992) vis-à-vis investment capability, productive capability and linkage capability become important. This taxonomy is overlapping but can be used in understanding this stage of TC with respect to Ayurvedic medicinal industry. A pattern, which is seen here, is the ways in which old firms in all ownership structures have tried to formulate standards for new technologies. Old firms with high turnover

have invested in technology in different policy regime and have utilized their knowledge effectively. In this case, linkages with different stakeholders outside the firm are important.

As per Lall's (1992) division of assimilative capability, linkage capability is stronger in small and medium enterprises as they form association or cluster among themselves. Firms with high turnover possess investment capability as small and medium enterprises cannot afford a new facility with skill and equipments for obtaining a new technology. They can be classified in the 'technologically matured' firm as they have mastered the technologies with the skills and knowledge facilities. Production capabilities are stronger in the old and large firms as their continuous learning in knowledge and capabilities of research have substantiated their technological learning. Their technological effort is notable as the technologies produced and modified by them are contextual. This investment was done in the period of pre-liberalisation when the policies made by our government focused on self-reliance. In the process, firms built a conscious technological learning through different stakeholders. As mentioned above, firms are no homogenous in nature (Lall, 1992), thus, their learning capabilities are also not homogenous. Through different agents in the society and in their firms, they undergo collective learning. Different agents which are involved in collective learning are different firms, human resource (scientists and machine-workers), vendors (providing raw materials and technologies), policies and historicity of the firms. Learning is an interaction between these agents and mutual learning between agents is responsible for contextual technological innovations. As Mokyr (2002) argues that technological learning is a work of tacit knowledge holders who interact and come up with a new set of knowledge, these firms through collective learning build knowledge for process and product technologies.

It is important to note that these technological innovations are not necessarily come up through R&D activities but collective learning of different agents. This could be an example of non-linear model of innovations which is highly contextual in nature. Most of the contributions are made from machine-users, as argued by Rosenberg (1976). The modifications of 'new machines' is a part of incremental nature of innovations which are characteristics of developing economies.

Modifying and Innovative Capability

These capabilities are clubbed together as the adaptive modifications of the existing technology took place to make it appropriate for local conditions. While doing this, minor and incremental modifications are done to improve existing technologies for technical progress; this refers to incremental and minor innovations. This is mostly seen in the industry because creating new technology is difficult with adequate technical infrastructure and R&D. There are times when the modifications are made keeping in mind the formulation procedures mentioned in the ancient texts. A simplest example is the preparation of powdered drug which are made through manual grinding in pestle and mortar. The modification made is the electrification of grinder keeping in mind the pressure and frequency of trituration which are in accordance with the ancient texts.

The variations in the reasons for adopting modern equipment and manufacturing technology can be explained in terms of various factors. For instance, a firm established before

independence has modified its technology for fermentation and replaced wooden tanks by steep tanks after liberalization, as the new GMP guidelines made it mandatory to use steel tanks for the preparation of *asava* and *arishta*. As already discussed, the regulation and standards are created by WTO to maintain quality in the international market. It is important to note here that the technologies for manufacturing units are purchased from the domestic market. The vendors who approach the firms belong to the domestic market. In another case, an institute who is exempted from GMP guidelines has made muffle furnace for *bhasma* preparation. This institute is exempted from Schedule T because it does not sell its product outside the premise, and use only for the treatments of in-house patients. Muffle furnace as technological innovation is acquired from the domestic market from an engineer based in western India. Muffle furnace is a specialized furnace customized for the preparation of *bhasma*. As it has a specific characteristic of increasing and decreasing of temperature at the same rate. This is important for *bhasmikaran*[23].

From the above findings, it can be inferred that there is a collective learning in the firms as they interact with different stakeholders like vendors, suppliers, public and private research institutes, other manufacturers, customers and service firms. Lall (1992) argues that technological learning can be enhanced through knowledge sharing which is also a feature of linkage capability. UNCTAD publication of Technology and Innovation Report (2012) augments that post 1990s there is an increment in developing countries in knowledge and technology sharing and exchange. In our analysis we found that the source of knowledge and technological capabilities is acquired through the interaction in the domestic market and with other developing countries (discussing advancement of technologies in international seminars of South Asia, as told by an interviewee). This is also acquired in the customer-supplier-retail chain. In this backdrop, the technological learning, both produced and modified are contextual to the local market and knowledge base.

The adaptations and modifications of technologies are not done in isolation, these are either in the firm at shop-floor or customized through the vendors. In-house modification of technology refers to the modifications/changes made to the technology/machinery by the machine-user at shop-floor of firm. This type of technological innovation was explained by Rosenberg (1976) where machine-user makes modifications in the machinery according to his utilization. Although, we observed that such activities are limited and almost all of them depend on vendors. Majority of firms place order with the vendors and they customize it for the manufacturers. Vendors send their experts with the machine to train the workers of the firm who are in close proximity with the machine. Often, it's the size of firms which determines the pattern and frequency of technological innovations. Another important factor responsible for technological innovation in the industry is the exemption from provisions of Schedule T. This gave those institutes a space to experiment with the machines and introduce innovations in the processes.

However, the modifications of machines are dependent on the educational background of the owner. This is shown in Table 16. It is observed that *vaidyas* believe that if they use modern technologies then the originality of Ayurveda medicines will be lost. Some *vaidya*-scientists have adopted modern technologies in manufacturing and are also using it in sustainable development of raw materials.

Table: 8. Relationship between Educational Background of Current Owner and Modification in Machine

Background of Current Owner	Modification in Machines		Total
	Vendors customise machines	Modifications done after purchasing	
Trust	2	0	2
Technical	5	1	6
Non-Technical	4	0	4
Total	11	1	12

Source: Field Work

Note: Institutes and Scientists are not included.

As we mentioned already, trust structure have both kinds of members and the person responsible for the manufacturing might change after a period of time. It is presented in the cross tabulations done above that both the trusts employ vendors in modifying technologies for manufacturing. This does not mean that their workers are not capable of doing modifications. It is mentioned by an interviewee of a trust that after a long experience their workers get to know a lot about the machines. Yet they could not introduce any innovations at their own level as the process of introducing such changes may affect the structure of the organization. He argued that this happened because the trust members are not much interested in the manufacturing of medicines due to their educational training. The institutes which are not included in the cross tabulations above are customizing machines at their shop-floor. This is taking place as they have human agencies to deal with it and better linkage capacities. In all these cases, machines are customized and innovations are introduced outside the boundary of the firms.

As discussed already, Arora and Nath (2015) argued that innovations in machines are done only in the boundaries of firms, however, we observed that these innovations are also taking place outside the boundaries of firms. In our case, we found interactions with vendors played an important role in technological innovations. Perhaps, there is a difference in knowledge systems and the machine users in these settings are not always engineers. Due to this they interact with other firms, institutes and vendors.

Also, some old firms have innovative capabilities and they produced as well as modified machines as per the knowledge system of Ayurveda. Due to the pre-liberalisation thrust on self-reliance and owner's background, the behaviour of firms towards technologies is completely different course of movement. This was not export oriented. The path-dependence of old firms can be understood in this backdrop, these firms have transformed technologies for the local market and for self-reliance of science and technology. The national policies in the pre-liberalisation period, focused on the self-reliance and concentrated in meeting the needs of new generation customers. These firms undertook a conscious capacity building over a period of time, as mentioned by Lall (1992) and Wignaraja (2002).

Anomalies:

Our data set has shown some kinds of anomalies which say a different story. The firm with partnership and proprietary ownership was incorporated before independence and the founder was a *vaidya*. The current owner accepted GMP guidelines to maintain quality of products, however, owner expressed that due to the kind of product his firm manufacture he has to 'modernise' his unit. Another exception is a firm under the ownership structure of trust with

high turnover does not use modern equipment and technologies for those formulations, which they cannot standardize. Another exception is an SME who uses modern technologies only for products produced in large quantities. For small quantity, manual preparation is used.

Other than the above mentioned exceptions, one instance we have seen was the case of overlapping of the stages of technological capabilities. The tablet punching machine, which is already present in domestic market, is used for the preparation of *vati* and *gutika*. Earlier it was made from hands by rolling the material between palms. When they have started mastering the technology, they have realised that they would be needing binders, diluents, coating agents, etc. These excipients got official permission in the year 2005 in 2008 which is the part of Drugs and Cosmetics Act 1940. The reason why we say that this is a possible overlap of different stages of technological capabilities as it is a stage of assimilative capabilities when they master the operational Technology and also the stage of modifying capability. As they have made modification in the formulation by adding experience.

6. A Synthesis:

As we have discussed above, the guidelines on manufacturing had come at a later stage whereas there was a serious discussion on education, training and research of the indigenous systems of medicine. The work on pharmacopoeial standards has started in 1960, and compilation of Indian medical herbs has started before that. However, we see that firms with limited ownership structure have invested in technological advancement. This happened as Indian government has emphasized on self reliance of industries; and the Limited structure firms are more inclusive in decision making as compared to partnership and proprietary firms and trust ownerships. It is notable that most of the policy level changes in manufacturing took place after the year 2000. Firms got established in the post liberalisation era have no reluctance in adopting equipment and technologies as compared to the firms established before that. While doing so, the educational background of the owner also matters. Like what we have seen in one of the anomalies that the eye drops were prepared from traditional means, however, the current owner who is a trained allopathic doctor has modified the whole procedure and the eye-drops are now prepared according to the GMP guidelines. Moreover, this firm has been established before independence. Similarly, we could observe a path dependence in the firms which was established before liberalization and experienced the self reliance movement by Government of India. Firms which were financially rich have invested in technological advancement and have conducted clinical trials as well.

Post-independence, the policies made for the manufacturers of Ayurveda focused on the customer preferences and the market demands. Also, the policies heavily stressed on the self-reliant activities of science and technology. Firms established in pre and post independence period have invested in technologies by keeping in mind the self-reliant activity of technological development. But all the firms in this category have not grown in the same fashion as mentioned above. Other than the education background of the owner, three other components seem to play important role in it as mentioned by Lall (1992), that are financial resources, personnel resources and compatible policy regime. Few firms have all the three advantages. Latecomers are established in a different policy regime. This is evident from the post-liberalisation global policy imposition on regulation and standards. Also, the scientists of large scale firms have included

regulators while making some new formulations or any outcome of the research. Due to the imposition of Schedule T of DCA (1940) in the post-liberalisation era, firms have to assimilate automated technologies.

Our finding supports the argument of Bhaduri and Ray (2004) who found that latecomers in E&E industries have flourished in post-liberalisation era due to substantive acquisition of technological capabilities with regard to growth of export market. Adding further to the argument, latecomers in Ayurvedic manufacturing have more successfully adopted automated technologies in manufacturing and quality control as they eye global market. This is in line with the findings of Lall (1992).

We also feel that this technological advancement has raised some issues on the drug delivery mechanisms. This issue has not been dealt with importance yet. In the post-liberalisation era, the formulation manufacturing technology and testing methodologies have been influenced by global standards. The delivery systems have also been influenced by Western medicinal system. The products are classified in two categories, those which should be prescribed by Ayurveda practitioners and those medicines which are available without the prescription of doctors. This is known as over-the-counter (OTC) drugs. Most of the products manufactured by large manufacturers are the products of preventive health care. These are marketed as OTC drugs. Some of the products are also sold as health supplement like *chawanprash*, digestive tablets of *Pachnol*[24] and *Hajmola*[25], skin care and personal care products, etc.

The tablets manufactured by Ayurvedic firms are the small quantities of formulations. For the treatment purposes, the quantities of tablets are increased. This is problematic from the side of the customers. As this may increase to more than 2 tablets at one time and more than three times in a day. As already discussed, the policies for Ayurveda are customer-centered. This is also observed by a *vaidya*-scientist that the development of the Ayurvedic products is for the customers and not for the development of the Ayurveda medicinal system.

7. **Conclusion**:

The paper discusses the acquisition of technological capabilities and the factors responsible for it. Through the secondary review of literature, we know that there were policies which talked about the importance of traditional medicinal systems. They talked about the integration of Western medicinal system and traditional medicinal system, and the recognized the 'modernization' of Ayurvedic firms. There are case studies available on the transformation of formulation technology of some firms and the concerns of some scholars on the likely impact of using such machines for effectiveness of drugs. In this backdrop, we critically analysed the behaviour of Ayurveda firms into adoption of 'modern' formulation technologies.

The study indicates that acquisition of knowledge and capabilities of technology is a collaborative learning through the interaction among vendors, suppliers, firms, public and private research institute, and customers. This is the linkage capability of the firm and through this the assimilative capability of the firm grew stronger. This is mainly done in the domestic market whereas in the pre-liberalisation period the firms mostly imported technologies from advanced countries. Due to the distinct nature of Ayurveda, adoption of these technologies is not

straightforward. Old firms with high turnover have adopted such manufacturing technologies but modified it extensively to match the standards of ancient formulation. Latecomers have adopted it due to the imposition of GMP guidelines. We found that there is diversity in adoption of modern equipment and manufacturing technology as firms in every age profile have to adopt modern manufacturing technologies but it depended heavily on the educational backgrounds of the owners and the firm's ownership structure. Some firms have modifying capabilities where they purchase technologies and modify and/or improvise it at their shop-floor. Some of them have well trained workers, thus, adding to machine-user innovations. These innovations are usually done in incremental steps according to the purpose of manufacturing and workers, incorporate their tacit knowing in the process. We found that most of the firms innovate outside the firm boundaries.

Notes:

1. World Trade Organization (WTO) is an organization where member governments try to negotiate trade problems they face. http://www.wto.org/english/thewto_e/whatis_e/who_we_are_e.htm. Retrieved on 19/7/2014.
2. Siddha medicinal system is originated in southern India. It is considered to be more than 5000 years old.
3. Unani medicinal system is practiced in middle-east and south Asia. It is a part of traditional knowledge systems.
4. Naturopathy is an alternative treatment based on the concepts of vital-energy and it generally avoids the usage of drugs in the therapy.
5. Yoga is a traditional therapy focusing on physical and spiritual self.
6. Homeopathy is an alternative medicinal system created in 1796 by Samuel Hahnemann.
7. Clause 3a of Drugs and Cosmetics Act (1940) defines drugs which are mentioned in Ayurveda, Siddha and Unani textbooks which is recognized by Government of India. Its clause 3h defines the patent and proprietary drugs.
8. The First Schedule of Drugs and Cosmetics Act (1940) mentions textbooks belonging to Ayurvedic and Siddha systems.
9. It is important to note the caution Debiprasad Chattopadhyay has sounded, by pointing out that Ayurveda texts may have gone through many distortions, and, as a result, it's not surprising to see coexistence of 'science' and 'non-science' in many ayurvedic texts.
10. AYUSH stands for Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy medicinal systems.
11. *Bashma* is an Ayurvedic formulation made up of poly herbs and metals through the process of detoxification, purification and incineration.
12. *Pishti* is considered as the powdered gem or metal used as Ayurvedic medicine.
13. It is observed that from First Five Year Plan to Third Five Year Plan, these reports have chapters on Health. In Fourth Five Year Plan, this chapter is named as Health and Family Welfare. After this none of the plans, focused on indigenous systems of medicine.
14. Hakims are practitioners of Unani Medicinal System.
15. *Shuddha* (pure) educational system refers to the syllabus on *shashtric* or classical textbook whereas *Ashuddha* (impure) refers to the integration of traditional Ayurveda education with that of modern sciences.
16. Schedule T of Drugs and Cosmetics Act, 1940 is the Good Manufacturing Practices for Ayurveda, Siddha and Unani drugs
17. Robert Saper's paper on heavy metal content found in Ayurvedic medicine products has raised these disputes in 2004.
18. CCRAS stands for Central Council for Research in Ayurveda and Siddha.
19. The source is Field Work.
20. Educational background of the founder and the current owner does not include firms having trust ownership structure because the position of the head changes regularly.
21. The total number is 14 because the two cases which have accommodated manufacturing units with their hospitals are included in it.
22. This is said in contrast to partnership and proprietary ownership structure. This is important to note that the authors analysed data on Indian pharmaceutical firms.
23. *Bhasmikaran* is a process of preparing *bhasma* by certain processes.
24. *Pachnol* is a digestive chewable tablet manufactured by Hamdard.
25. Hajmola is a digestive chewable tablet manufactured by Dabur.

References:

Antonelli, Cristiano. (2003). *The Economics of Innovation, New Technologies and Structural Change*. London: Routledge.

Arora, Parveen and Pradosh Nath. (2015). Innovation in Indian Industries: Insights from the First National Innovation Survey. *Asian Journal of Innovation and Policy*. 4(3): 360- 380.

Arundel, Anthony and Geuna, Aldo. (2004). Proximity and the use of public science by innovative European firms. *Economics of Innovation and New Technology*, 13:6, 559-580.

Bathelt, Harald, Malmberg, Anders and Maskell, Peter. (2004). Clusters and Knowledge: Local Buss, Global Pipelines and the Process of Knowledge Creation. *Progress in Human Geography*, 28(1): 31-56.

Bhaduri, Saradindu and Amit S. Ray. (2004). Exporting through Technological Capability: Econometric evidence from India's Pharmaceutical and Electrical/Electronics Firms. *Oxford Development Studies*. 32(1): 87-100.

Bhaduri, S., & Worch, H. (2008). Past experience, cognitive frames, and entrepreneurship: some econometric evidence from the Indian pharmaceutical industry. *Papers on Economics and Evolution*. Retrieved from http://hdl.handle.net/10419/31818

Banerjee, Madhulika. (2009). *Power, Knowledge, Medicine: Ayurvedic Pharmaceuticals at Home and in the World*. Hyderabad: Orient Black Swan.

Bell, M. (1984). 'Learning' and the accumulation of industrial technological capacity I developing countries. In M. Fransman and K. King (Eds.), Technological capability in the Third World (pp. 187-209). London: Macmillan Press.

Caraca, Joao, Lundvall, Bengt-Ake, Mendonca, Sandro. (2009). The Changing Role of Science in the Innovation Process: From Queen to Cinderella? *Technological Forecasting and Social Change*, 76: 861-867.

Chang, Ha-Joon. (2003). *Kicking Away the Ladder: Development Strategy in Historical Perspective.* London: Anthem Press.

Chantanaphant, Jiyaruth, Nabi, Md. Noor Un, and Dornberger, Utz. (2011). Impact of Technological Capability on the Export Performance of SMEs in Thailand. Retrieved from http://pyk2.aalto.fi/ncsb2012/Chantanaphant.pdf on 19/9/2016.

Chaudhri, R D. (2004). *Herbal Drugs Industry: A Practical Approach to Industrial Pharmacognosy.* New Delhi: Eastern Publishers.

Dahanukar, Sharadini and Urmila Thatte. (1993). *Ayurveda Revisited.* Bombay: Popular Prakashan.

Dev, D. K. and G. S. Goraya. (2008). *Demand and Supply of Medicinal Plants in India.* Bishen Singh Mahendra Pal Singh, Dehra Dun and FRLHT, Bangalore, India.

Fransman, Martin and Kenneth King. (1984). *Technological Capability in the Third World*. London: Macmillan Press Ltd.

Gonsen, Ruby. (1998). *Technological Capabilities in Developing Countries: Industrial Biotechnology in Mexico*. London: Macmillan Press Ltd.

Harilal, M. S. (2009). 'Commercializing Traditional Medicine': Ayurvedic Manufacturing in Kerala. *Economic and Political Weekly*. 44(16): 44-51.

Katz, Jorge. (1987). Domestic Technology Generation in LDCs: A Review of Research Findings in Jorge Katz (Ed.), *Technology Generation in Latin American Manufacturing Industries*. London: Macmillan.

Katz, Jorge. (2000). Structural Change and Labour Productivity Growth in Latin American Manufacturing Industries 1970-1996. *World Development*, 28(9), 1583-1596.

Kline, S. J. and N Rosenberg. (1986). "An overview of innovation." In R. Landau & N. Rosenberg (eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. Washington, D.C.: National Academy Press, pp. 275–305.

Lall, Sanjay. (1987). *Learning to Industrialise: The Acquisition of Technological Capability by India*. London: Macmillan Press.

Lall, Sanjaya. (1992). Technological Capabilities and Industrialization. *Institute of Economics and Statistics*. 20(2), 165-186.

Lundvall, Bengt-Ake. (2010). *National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning*. UK: Anthem Press.

Mokyr, Joel. (1990). Evolutionary Biology, Technological Change and Economic History. *Bulletein of Economic Research,* 43, 127-147.

Mokyr, Joel. (2002). *The Gifts of Athena: Historical Origins of Knowledge Economy*. Princeton University Press.

Morrison, Andrea, Pietrobelli, Carlo and Rabellotti, Roberta. (2008). Global Value Chains and Technological Capabilities: A Framework to Study Learning and Innovation in Developing Countries. *Oxford Development Studies*, 36(1), 39-58. DOI: 10.1080/13600810701848144

Rosenberg, Nathan and W. Edwar Steinmueller. (1988). Why are Americans Such Poor Imitators? *The American Economic Review*. 78 (2), 229-234.

Rosenberg, Nathan. (1976). *Perspective on Technology*. New York: Cambridge University Press.

Singh, Amritpal. (2016). *Regulatory and Pharmacological Bases of Ayurvedic Formulations.* CRC Press.

UNCTAD (2012). *Technology and Innovation Report: Innovation, Technology and South-South Collaboration*. United Nations Conference on Trade and Development. Geneva, Switzerland.

Westphal, L, L. Kim and C. Dahlman (1985), 'Reflections on the Republic of Korea's Acquisition of Technological Capability', in N. Rosenberg and C. Frischtak, eds, *International Technology*. New York: Praeger Publishers, pp. 167–221.

Wignaraja, Ganeshan. (2002). Firm Size, Technological Capabilities and Market-oriented Policies in Mauritius. *Oxford Development Studies*, 30 (1), 87-104.