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Abstract

Given the globalized economic order, achieving a high order of growth by industrialization has been a priority for the developing countries. In which, diffusion of technology have its own important role in contributing to economic growth. This study deals with the impact of liberalization on the diffusion of Computer Numerically Controlled Machine Tool (CNCMT) technology in its embodied form during the pre and post economic liberalization period. Apart from the 'net addition' and 'relative stock' methods, Ray's method is chiefly used to measure the extent of diffusion of CNCMT in India. It is found that liberalization has favoured the diffusion of CNCMT technology. However, the increasing share of the imports contributing to the increasing diffusion of CNCMT technology is noticed since 2000-01. Unlike in the past, the spread of CNCMT technology among the small scale industries after 2000-02 marks the beginning of a new dimension in the diffusion of CNCMT technology in India as it further widens the scope of CNCMT technology becoming available to a range of small scale industries in the near future but compromising with employment aspects. To this extent, it may also be viewed as a failure in fulfilling the United Nation's Sustainable Development Goals (SDGs) of achieving inclusive development.

Keywords: diffusion; computer numerically controlled machine tool; technology; and liberalization.

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1. Introduction

Examining of diffusion of Computer-Numerically Controlled Machine Tool (henceforth CNCMT) technology in India in its embodied form being the prime concern of this paper it also attempts to offer some explanations for the trends observed. The term 'CNCMT technology' used here refers only to the technology embodied in the CNC machines and not the technology involved in manufacturing of these machines. Diffusion of CNCMT technology is possible either through domestic production or/and through import and hence, in the present study, a distinction has been made between these two.

As a newly industrializing country (NIC), even though India does not have a good track record for generating many innovations, India is definitely considered as one of the NICs that adopt and adapt innovations/technologies from abroad at a faster rate (Albin, 1992). Economic historians are of the view that, there is a considerable time lag for an innovation to reach most potential users in developing countries, owing to several reasons (Albin, 1992). For example, new technologies are not easily revealed and transferred from the country of its origin for fear of losing competitive advantage. Transfer of technology is often carried out in the form of product (*that is,* as 'black box') and not in the form of product along with its process (Albin, 1992). Transfer of technology generally involves a huge payment and demands a strong in house Research and Development (R&D) activity also on the part of the NICs who try to get the technology/innovation from the industrialized countries. In house R&D indeed plays a vital role in making the transfer of technology more effective and helps in spreading them domestically faster and better. Greater diffusion of a successful technology in the manufacturing field is likely to bring about cost effectiveness, flexibility and impart dynamisms to the industry's manufacturing system and consequently open up new growth opportunities for the economy. Thus, this paper, along with examining the extent of diffusion of CNCMT technology, also tries to offer some plausible explanations to the diffusion of CNCMT technology in India.

Including introduction, this paper is organized into seven sections. The meaning of diffusion and how different authors have viewed diffusion of technology and its related concepts are presented in section 2, while the importance of the diffusion of CNCMT is dealt in section 3. A discussion on different methods available to measure the diffusion of CNCMT technology is carried out in section 4. Section 5 explains the three different methods employed in the present study to measure the diffusion of CNCMT. Section 5 further has three more sub-sections to separately discuss the results obtained by the different methods adopted. Some explanations for the rate of diffusion of CNCMT technology experienced by the country is offered in section 6 and the summary of the paper is provided in section 7.

2. Diffusion and its related concepts

Diffusion is a "…process by which an innovation is communicated through certain channels over time among the members of social system" (Rogers, 1983, p.5). According to Stoneman and Karshenas (1995), diffusion can be defined in terms of movement of the stock of potential adopters from a point where there are only a few early adopters to a point where all potential adopters have adopted the technology[1]. Suppose D_t is the current stock of a new technology owned by a group of population and D^* is the potential level of use of that technology, diffusion entail how D_t approaches D^* over the time period. The term therefore can be interpreted in two different senses: the level of diffusion, which is a stock concept; and the speed of diffusion, which is a flow concept (Satheesh, 2009). According to Sarkar (1998), the mechanisms that help spreading a new technology, process or a new machine (or a new product) in an economy; and displace completely or partially the existing technology that are inferior or less efficient can be considered as diffusion.

Diffusion is an integral part of the technical change because technical change, as noted by Schumpeter (1939), consists of three phases - invention, innovation and diffusion. The concept of diffusion is therefore better understood when it is discussed along with its related concepts of invention and innovation; as diffusion is realised only after the completion of invention and innovation (Parker, 1978).

For Usher (1954) invention is a result arising from a cumulative synthesis of what has preceded and it is an early part of the process to innovations. But innovation is the process by which an invention is commercialized, *i.e.*, the process through which an invention is incorporated in the production process. Innovation is a function of invention, entrepreneurship, investment and development[2]. Innovation covers all the activities existing between invention and diffusion that together bring a new product or process to the market and it is a time consuming extensive process. What follows invention and innovation, as the third stage in the process of technical change is diffusion. Diffusion is essentially the rate at which innovations spread among the user industries (Parker, 1978). In other words diffusion of a technology is a process by which the use of an innovation spreads and grows. Diffusion of technology is thus an evolutionary process that it travels through the stages of invention – innovation – diffusion necessarily involving considerable time tag between the stages, and one following the other[3].

In the present context of the study, the term technical change means change in the method of production that increases the productivity. The change in the method of production in machine tool from its conventional status to the CNCMT status necessarily involves three stages of technical change: invention, innovation and diffusion[4]. The present study, however, is concerned about the last of these – *that is*, the diffusion of CNCMT technology because, as Greenaway says, diffusion has the most decisive impact on economic welfare.

Edquist and Jacobsson (1988) view the diffusion process as follows. (a) Within the business conglomerate or independent firms in an economy and (b) between firms in different economies. This can be illustrated as shown in Figure 1. The two squares on the left explains the diffusion within the country; while the other two squares on the right deal with the international diffusion – often known as the transfer of technology. In the case of the international diffusion barriers such as institutional and cultural differences among countries, differences in the relative factor prices and information gaps etc. explain a lot. However, these barriers may not be severe in international diffusion across transnational corporations as compared to the international diffusion across independent firms. Except the third square in Figure 1, the present study covers all the other squares as it does not exclude the imported CNCMT while dealing with the diffusion of CNCMTs in India.

Figure 1. Micro Perspective of the Diffusion of Technology

	Within Countries	Between Countries
Within Corporation	1. Between branches of the same corporation in a certain country.	3. Within Transnational Corporations and between countries.
Between Corporation	2. Between independent firms within a certain country.	4. Between independent corporations in different countries.

Source: Edquist and Jacobsson (1988), p.10.

3. Importance of the Diffusion of CNCMT technology

Since the industrial revolution the machinery-producing sector (*that is,* the machine tool industry) has been at the hub of the economic development process of all industrializing countries. The relationship between the machine tool producers and its user industries is so close that any technological improvement occuring in any one of these industries has a direct influence on the other. The machine tools are therefore often viewed not only as a means of production but also as a medium for translating the ideas of new inventions into tangible results. It is the machine tool industry that carries the hope of raising productivity in manufacturing industry by bringing about technical change – an important aspect which Abramovitz (1956) and Solow (1957) demonstrated empirically. And it is the technical change rather than accumulation of capital that explains the economic growth (Greenaway, 1994. p.916). The economic impact of an invention is realised only when it is diffused (Parker, 1978).

Between invention and diffusion the technology of CNCMT has passed through many processes/stages of its product evolution and involved considerable time lag as well. The origin of CNCMT was in the form of Numerically Controlled (NC) machine tools. In 1952, paper tape output from a computer was used to control a milling machine in USA to have the first NC machines; and it lent flexibility to automation in the whole process of production. USA developed its first machine tool with a CNC system in 1972[5]. In the mid-1970, Fanuc Company in Japan introduced micro-computer as the basic for the NC machine tools and lead to the effective formation of the CNCMTs commercially; and this revolutionized the machine tool industry by imparting and improving the flexibility, accuracy and versatility. Since then the machine tool industry worldwide began to experience dynamic technological changes. The application of computers and micro-electronics in complex metal transformation operations at the global level clearly points to this (Albin, 1992). The growing technological complexity of machine tools necessitates close co-ordination between various specialized disciplines, including electronics and metallurgy; and the user industries, in the design and production of CNCMTs (UNIDO, 1981). The development of Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Flexible Manufacturing System (FMS) and Unmanned Manufacturing System (UMS) are some of the outcomes of continuous research and development; and interactions between different agents taking place in the field of machine tool industry. Thus at every stages of improvement in the machine tool technology an invention is said to have been made and an innovation when it is commercialized. In the case of CNCMTs, the commercial applications have become successful, worldwide, only after the mid-1970s even though NC and CNC machine tools were invented in the late 1940s and early 1970s respectively. In India too, even though: (a) the first NC machine tool technology came into the country in the 1960s through imports and (b) the HMT produced its first NC/CNC machine tool during the seventies (Albin, 1992 p.39), it took nearly 15 years for the CNCMT technology to become commercially successful in the country. In other words, wide acceptance to the CNCMTs came from the user industries in India only since the mid-1980s. The organized production of the CNCMT in India started only in 1984/85 and it can be understood from the high rate of growth of the CNCMT that began from the mid-1980s (Albin, 2012 p.182). Since then, CNCMT technology has begun to diffuse into the Indian manufacturing system. In establishing the user-producer interactions at different stages, the role of many agents such as: R&D units, exhibitions, seminars, workshops and technical magazines etc. remained very crucial during the process of diffusion[6].

4. Measuring the diffusion of CNCMT technology

We learn from literature that different studies have used different methods to measure the diffusion of CNCMT technology. Some of the important methods are:

Pillai and Subrahmanian (1989) measured the diffusion of CNCMT technology in India in terms of the net addition of CNCMTs at different points of time in quantity terms. This method however, can explain only the direction (*that is*, whether the net addition is on the increasing or decreasing trend) of diffusion rather than the extent of diffusion.

UNCTAD (1986) studied the diffusion of CNCMT technology in Yugoslavia in terms of the percentage share of the net availability of CNCMTs in the net availability of the total machine tools in the country in terms of quantity. It is only a relative stock of the CNCMTs at different time points in quantity terms.

Ray (1984) measured the rate of diffusion of CNCMT technology in European countries in terms of the percentage share of CNCMTs produced in total machine tool production in value terms. He found that the rate of diffusion of CNCMT technology was higher in Italy, Sweden, US and Japan (ranged between 23 and 50 per cent) than in the UK and Germany as it was found to be less than 20 per cent in the UK and Germany during 1981. An important limitation of this method is that while measuring the internal or domestic rate of diffusion of CNCMT technology for a specific country, Ray did not subtract the export of CNCMTs from total production.

Edquist and Jacobsson (1988) used investments as the criteria to measure diffusion. According to them the percentage share of investment on CNCMTs in the total investment on the machine tool industry would measure the diffusion of CNCMT technology. Using this method, between 1978 and 1984, Edquist and Jacobsson calculated rate of diffusion of NC/CNCMT technology for Sweden, UK, Japan and USA as 37, 45, 34 and 36 per cent per annum respectively (Albin, 1992 p.71). In the Indian context, nevertheless, we could not apply this method as we did not find investment data available at the disaggregated level for CNCMT.

Another method used to measure the diffusion of CNCMT technology is the absolute stock of CNCMTs and the rate of growth of CNCMTs stock in quantity terms (*that is,* in numbers). Chudnovsky (1986) adopted this method to measure the rate of diffusion of CNCMT technology in Argentina and Brazil; Korea Machine Tool Manufacturers Association (KMTMA) followed this method in Korea; and for Yugoslavia, the UNCTAD TT/67 used this method for the period 1978 to 1985. Taking the stock of CNCMTs jointly, from 1980 to 1985, for Argentina, Brazil, India and Korea – Edquist and Jacobsson (1988) also calculated the cumulative growth rate of stock, and found the diffusion rate of CNCMT technology for these countries to be at 23 per cent per annum. An important limitation of this method is that, the mere stock of CNCMTs cannot be a good indicator of the extent to which a country invests in order to benefit from the new technique. This is because, even if the share of CNCMTs in total machine tool investment is low in value terms, the growth rate in stock of CNCMTs can be high[7].

Another method used to measure the rate of diffusion of CNCMT technology is the density. It measures the availability of a new technology per one million inhabitant or employees of a country. The UNCTAD (1986), for Yugoslavia; and the Science Advisory Council to Prime Minister (1989) of India have used this method to measure the diffusion of high technology. However, this method underestimates the diffusion rate especially, in a country like India with its high population and firms with large number of labourers.

Albin (1992) studied the diffusion of CNCMT technology in India by adopting three methods. They were: (i) Pillai and Subrahmanian's method of overall net addition of CNCMTs at different time points in terms of the number of machine tools. Data supplied by the Survey of Machine Tools in India was used; and it was identified that a note worthy diffusion of CNCMT technology in India began only from the 1980s; (ii) UNCTAD's relative stock method for the period from 1965 to 1985 in terms of quantity. Survey of Machine Tools in India data was used and found that the rate of diffusion of CNCMT technology remained very low until 1985 (*that is,* 0.29 per cent per annum during 1980-85) even though a momentum had set in for technology from 1980 through 1985; and (iii) Ray's method with due correction (*that is,* export is subtracted from the production to get the domestic diffusion of the CNCMT technology in India). The IMTMA data was used[8] and found that the rate of diffusion of CNCMT technology in India was at 13.7 per cent per annum during 1984 to1990. This was higher than what was achieved in the UK and Germany by then. While using Ray's method, Albin (1992) did not include the import of machine tools due to the non availability of regular data on the import of machine tools by then at a disaggregated level. To this extent, the study of Albin (1992) was able to estimate only the extent of diffusion of the domestically produced CNCMT technology and not the overall diffusion of CNCMT technology in India. This limitation however is overcome by the present study.

In short, some of the available methods to measure the rate of diffusion of the embodied CNCMT technology have been summarized in Table 1.

Table 1 Methods of measuring the rate of diffusion of CNCMT technology

S.No.	Author	Study Period	Country	Method used to measure the Rate of Diffusion of CNCMT technology
1	Pillai and Subrahmanian (1989)	1965 through 1984	India	Overall **net addition** of CNCMTs at different time points in quantity terms for the overall diffusion. Net addition of the domestic CNCMTs at different time points in quantity terms for domestic diffusion.
2	UNCTAD (1986)	1978 & 1983	Yugoslavia	**Relative stock** of CNCMTs at different time points in quantity terms. *i.e* (Number of overall net availability of CNCMT ÷ Number of overall net availability of total machine tools) x 100 for the overall diffusion and (Number of net availability of the domestic CNCMT ÷ Number of net availability of the total domestic machine tools) x 100 for the domestic diffusion.
3	Ray, G.F. (1984)	1972 through 1981	Japan, US, UK, Germany, Italy and Sweden	(Value of CNCMT produced ÷ Value of total Machine Tool produced) x 100. However, with suitable modification it would be (i) (Value of the overall net availability of CNCMT ÷ Value of the overall net availability of total machine tools) x 100 for the overall diffusion of CNCMT technology and (ii) (Value of net availability of domestic CNCMT ÷ Value of net availability of total domestic machine tools) x 100 for the domestic diffusion of CNCMT technology.
4	Chudnovsky (1986)	1978 through 1985	Argentina, Brazil, S.Korea, and Yugoslavia	Rate of growth of the physical stock of CNCMTs.
5	Edquist and Jacobsson (1988)	1978 through 1984	UK, USA, Sweden and Japan	(Investment in CNCMT ÷ Investment in the total machine tools) x 100.
6	UNCTAD (1986)	1976 and 1979	Yugoslavia	
7	UNCTAD (1986)	1980/81	Yugoslavia	(Number of CNCMT ÷ One million Inhabitant) x 100.
8	Science Advisory Council, India (1989)	--	India	(Number of CNCMT ÷ One million Labourers) x 100.

Note: (Q+M) – X = net availability or overall net availability; (Q – X) = domestic net availability. Where, Q = output at home, M = import and X = export.

5. Diffusion of CNCMT technology in India

As observed in the previous section, even though many approaches are available to measure the diffusion of CNCMT technology, we are unable to apply all of them in the present study except a few. The choice of the methods adopted in the present study is primarily constrained and determined by the nature and availability of data.

Methodologies adopted for the present study are:

(a) Pillai and Subrahmanian's method of net addition of CNCMTs at different time points in quantity terms as it helps to be aware of the direction of the diffusion in India.
(b) UNCTAD's method of the relative stock of CNCMTs at different time points in quantity terms as it helps to know the overall and domestic diffusion of CNCMT technology in India in quantity terms and
(c) With due corrections, Ray's method of the share of net availability of CNCMTs in the net availability of the total machine tools in the country in value terms to understand the overall and domestic diffusion of CNCMT technology in India.

Although the current study uses the above three methods, it relies more on the Ray's method as it suits better for the available data on the machine tools in India.

5.1 Diffusion of CNCMT as per the Pillai and Subrahmanian's Net Addition method

Manufacturing of the CNCMTs in India on a large scale, even though, began only from the year 1984/85, there are evidences to show that India had produced five NC machines (*that is,* the first generation of the CNCMTs) between 1965 and 1969; prior to this, in the early sixties itself, India had imported 26 NC machines[9]. It is also learned from the Survey of Machine Tools in India that the diffusion of NC technology among the small scale industries has begun in the seventies but to a very limited extent only. Of the total NC/CNC machine tool technology available in the country in 1985, 83 per cent of them were found in the large and medium industries and the defence; Educational, Training and R&D organizations accounted for 11 per cent of the NC/CNC technology diffusion; small scale sector was responsible for only 6 per cent of the diffusion. Even though the presence of CNCMTs in India was felt prior to the 1980s, the diffusion of CNCMTs, expressed in terms of the overall net addition, in a noteworthy manner is felt only from the 1980s[10]. Diffusion of CNCMT technology, expressed in terms of the overall net addition of CNCMTs, in general, remained less during the entire protected regime even though 160 CNCMTs were added per year during 1980 to 1985 (column 7, Table 2). Instead of the overall net addition, if one goes by the net addition of the domestically produced CNCMTs alone, the magnitude of the diffusion is noticed to be much less as, on an average, only 16.5 domestically produced CNCMTs were added per year during 1980 to 1985. Until the mid-1980s the diffusion gap[11] between the overall net addition of the CNCMTs and the net addition of the domestically produced CNCMTs was met by imports. But over the years, the diffusion gap is reduced by the domestic production of CNCMTs. In other words, the diffusion of CNCMT technology in India was influenced more by imports during the protected regime. Since liberalization, the domestically produced CNCMT technology considerably began to contribute to the diffusion (Table 2, Figure 2 and Figure 3). Nevertheless, the diffusion gap between the overall net addition of the CNCMTs and the net addition of the domestically produced CNCMTs seems to be widening since 2002/03 (Figure 2(b) and Figure 3(c)). This indicates the prominent role of import in the country's diffusion of CNCMT technology during the high growth phase.

In accordance with the abbreviated S-curve (Albin 2012, p.56), the general slowness in the spread of a technology during the initial period of the diffusion process, is very much noticed in India also (Figure 2 and Figure 3). Until 1986/87, the rate of diffusion of CNCMT technology in India remained very low. However, the diffusion of CNCMT in India seems to have entered into its high growth phase ever since the year 1987/88 (Figure 3 and Figure 3(a)) *that is,* soon after the liberal policy announcements in 1985/86. This is understandable because with the advent of liberalization measures technological up-gradation became a compulsion for the manufacturing sector to survive in the competitive market and this resulted in an increase in the demand for CNCMTs since 1987/88. Accordingly, the diffusion of CNCMTs in India also began to increase at a higher rate. A spurt in the diffusion noticed in 1991/92 (Figure 3(b)) marks the beginning of the second liberal phase. From 2002/03, the rate of diffusion of the CNCMT technology got intensified further as it can be observed from the differences in the slopes of the diffusion curve in Figure 3 and Figure 3(c).

Table 2 The Net Addition of CNCMTs at different time points (in numbers).

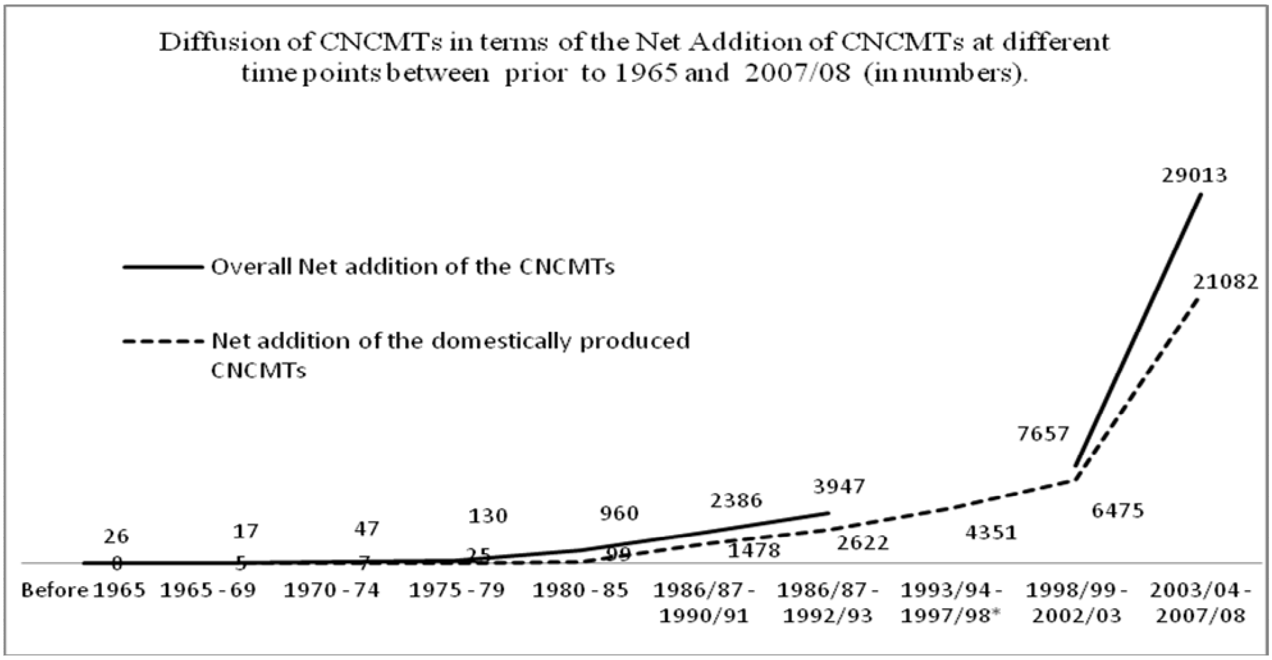
Period	**CNCMT Output Q**	**CNCMT Import M**	**CNCMT Export X**	**Overall Net Addition or Net Availability of the CNCMT (Q + M) - X**	**Net Addition or Net Availability of the Domestically Produced CNCMT (Q - X)**	**Overall Net Addition of CNCMTs per annum**	**Net Addition of the Domestically Produced CNCMTs per annum**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Before 1965	0	26	0	26 (100.0)	0	-	-
1965 - 69	5	12	0	17 (70.59)	5	3.40	1.00
1970 - 74	7	40	0	47 (85.11)	7	9.40	1.40
1975 - 79	25	105	0	130 (80.77)	25	26.00	5.00
1980 - 85	99	861	0	960 (89.69)	99	160.00	16.50
1986/87 - 1990/91	1600	908	122	2386 (38.06)	1478	477.20	295.60
1986/87 - 1992/93	2796	1325	174	3947 (33.57)	2622	563.86	374.57
1993/94 - 1997/98*	4555	-	204	4351* (-)	4351	870.20*	870.20
1998/99 - 2002/03	6983	1182	508	7657 (15.44)	6475	1531.40	1295.00
2003/04 - 2007/08	21932	7931	850	29013 (27.34)	21082	5802.60	4216.40

Source: Albin 1992 p.77 and own calculation from the IMTMA documents.
Note: Q = output at home, M = import and X = export.
Figures in brackets refer to the percentage share of the imported CNCMT in the overall net availability. Overall net addition of CNCMTs given in column 5 and the average of overall net addition of CNCMTs given in column 7 does not contain the import of CNCMT for the periods from 1993/94 to 1997/98* as it could not be obtained from the IMTMA. Until 1980-

85 the data on calendar year is availed from the Survey of Machine Tools in India, 1986. Since 1986/87, on financial year, the data is availed from the IMTMA documents. The class intervals of Table 2 and Table 3 do not remain the same as they are determined by the availability of the data.

As already noted, the method of net addition of CNCMT, as used by Pillai and Subrahmanian, to measure the diffusion of CNCMT technology in India tells more about the direction of diffusion than the actual diffusion or the extent of diffusion of CNCMT technology. Hence, we intend to apply UNCTAD's method of using relative stock of CNCMTs at different time points (in quantity terms) to measure as it helps to know the extent of overall and domestic diffusion of CNCMT technology in India in terms of quantity in the next section 5.2.

Figure 2



Source : As same as in Table 2.

Note: The result of the overall net addition of CNCMT has a discontinuity in 1993/94 to 1997/98* because, information on the import of CNCMTs could not be obtained from the IMTMA. For more visual clarity, Figure 2 is further split into two as Figure 2(a) and Figure 2(b).

Figure 2 (a)

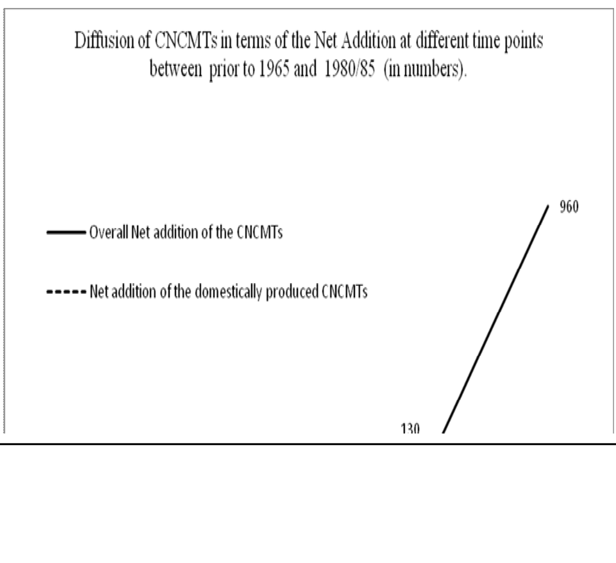


Figure 2 (b)

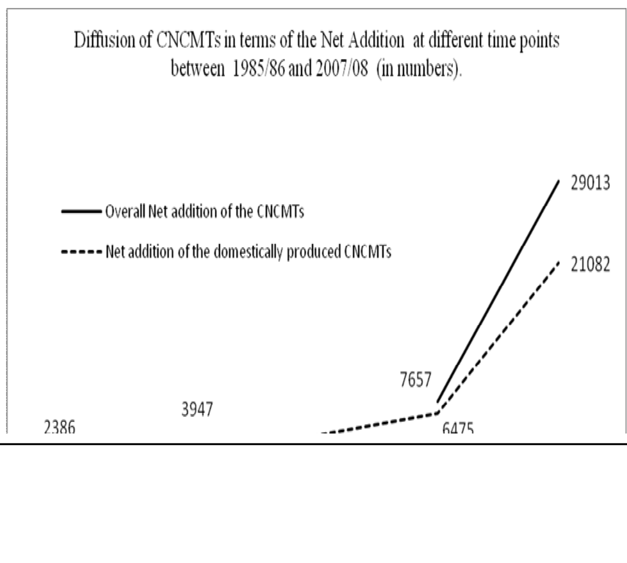
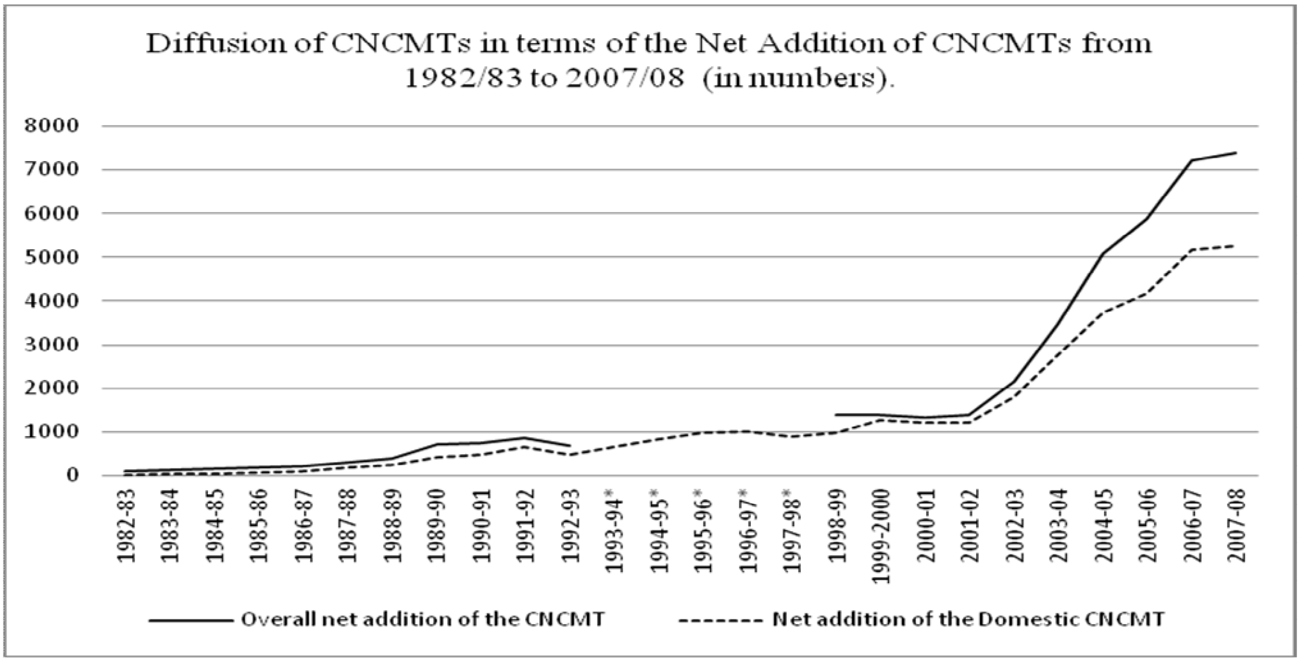


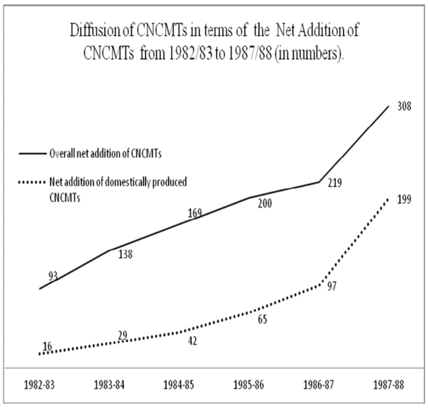
Figure 3



Source: Own calculation from the IMTMA documents.

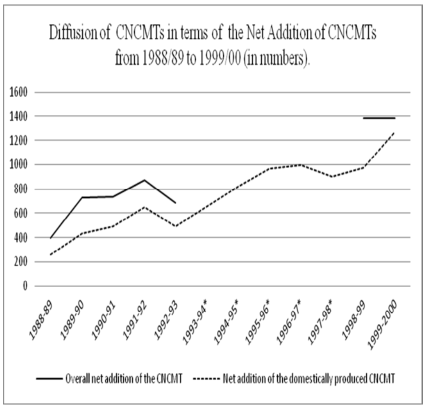
Note: The overall net addition of CNCMT has a discontinuity from 1993/94* to 1997/98* because, information on the import of CNCMTs could not be obtained from the IMTMA. For more visual clarity, Figure 3 is further split into three as Figure 3(a), Figure 3(b) and Figure 3(c).

Figure 3 (a)



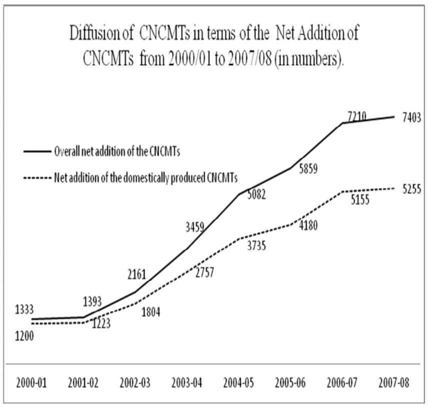
Source: Figure 3

Figure 3 (b)



Source: Figure 3

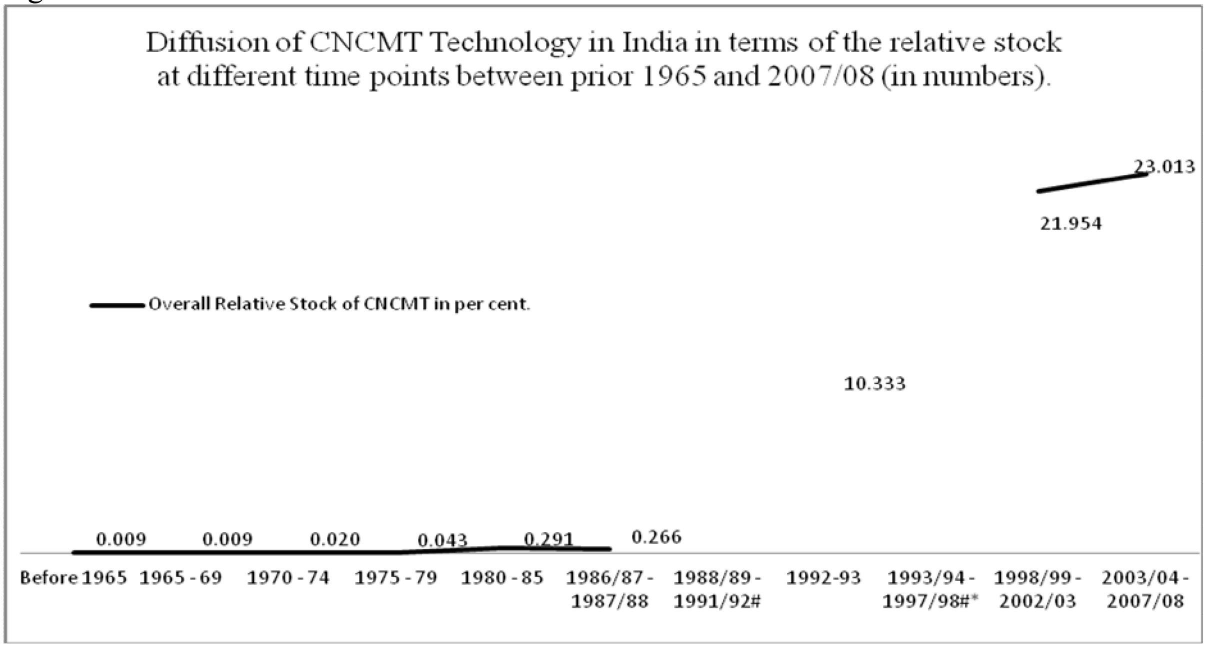
Figure 3 (c)



Source: Figure 3

In the case of domestic CNCMT technology too, until 1986/87, the diffusion rate was less than one per cent per annum, and it became 7.72 per cent in 1987/88 (Figure 5(a)). Since then it began to increase gradually. A spurt in diffusion noticed in 1991/92 (Figure 5) marks the beginning of the second liberal phase. Throughout the second liberal phase, from 1991/92 to 2007/08, the domestic diffusion of CNCMT technology, on an average, remained at 31.72 per cent per annum (Figure 5). Between 2000/01 and 2007/08, it was even higher at 51.06 per cent per annum (Figure 5(c)). Another important aspect noticed in the diffusion of CNCMT technology is that the rate of diffusion of domestic CNCMT technology consistently exceeded the rate of diffusion of the overall CNCMT technology in India from 1998/99 onwards (Figure 5 and Figure 5(c)). This can be attributed to the declining trend in the domestic production and net availability of the domestic conventional machine tools in the country; and a concomitant increase in the production and net availability of the domestic CNCMTs[12]. However, the increasing share of conventional machine tools in the total machine tool import is an important factor that brought down the overall diffusion rate[13].

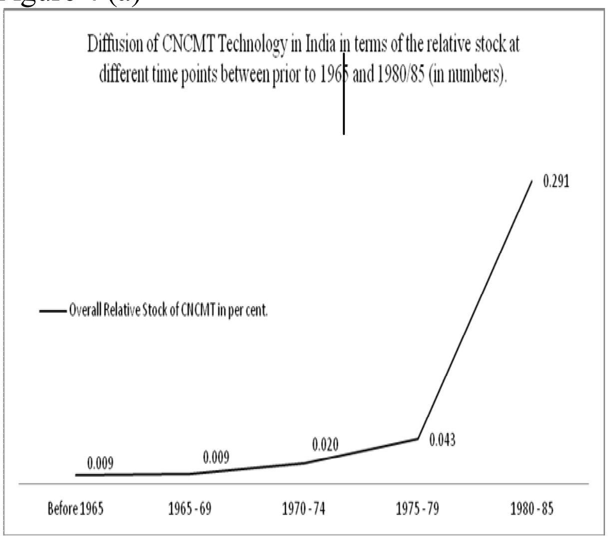
Figure 4



Source : Albin 1992 p.79 and own calculation from the IMTMA documents.

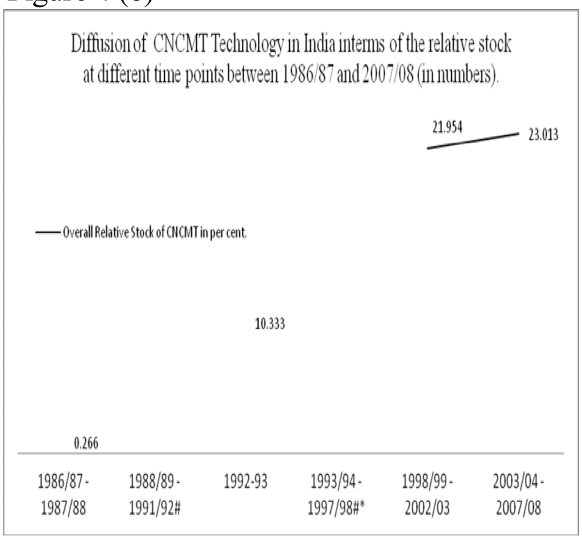
Notes: Overall diffusion curve has a discontinuity from 1988/89* to 1991/92* and from 1993/94* to 1997/98* due to the non availability of information from the IMTMA on the import of conventional machine tools for both period and CNC machine tool for the latter period. For more visual clarity, Figure 4 is further split into two as Figure 4(a) and Figure 4(b).

Figure 4 (a)



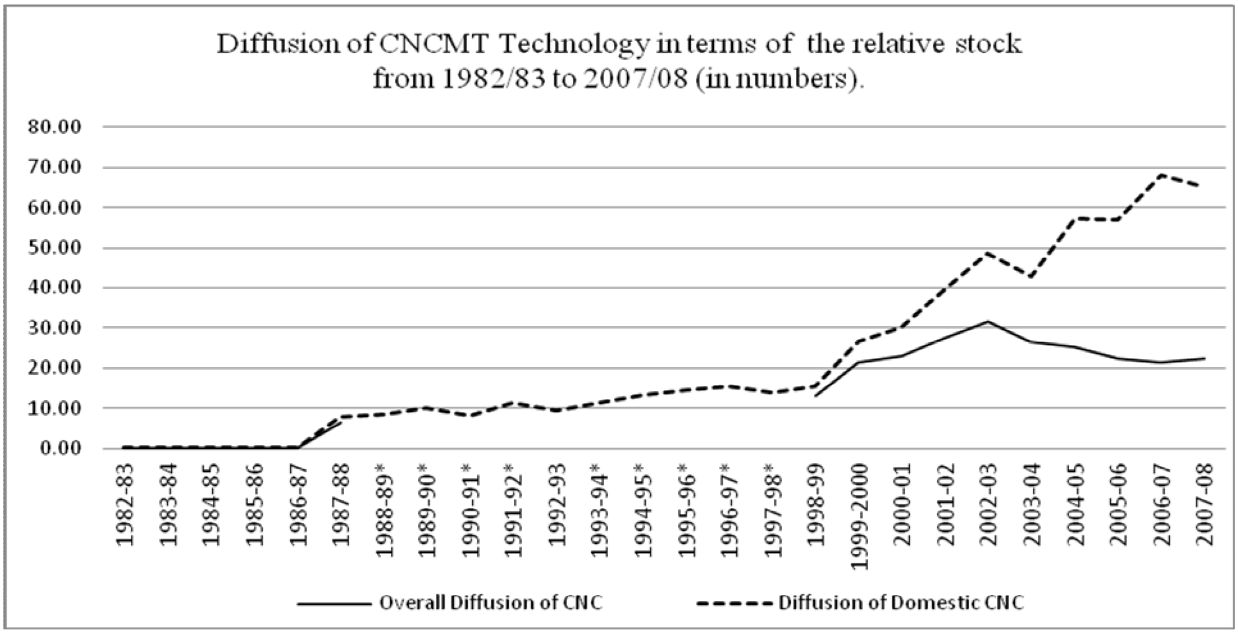
Source: Figure 4

Figure 4 (b)



Source: Figure 4

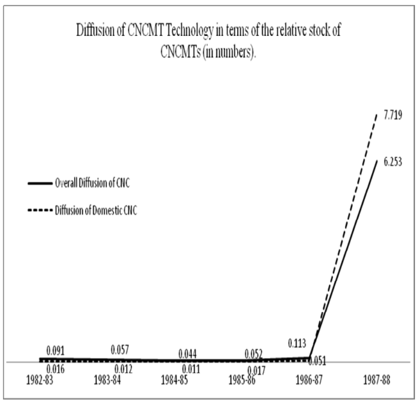
Figure 5



Source : Own calculation from the IMTMA documents.

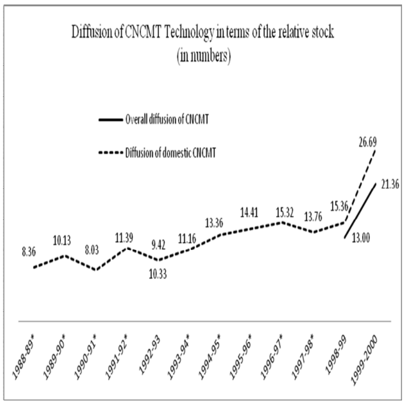
Notes: Overall diffusion curve has a discontinuity from 1988/89* to 1991/92* and from 1993/94* to 1997/98* due to the non availability of information from the IMTMA on the import of conventional machine tools for both period and CNC machine tool for the latter period. For more visual clarity, Figure 5 is further split into three as Figure 5(a), Figure 5(b) and Figure 5(c).

Figure 5 (a)



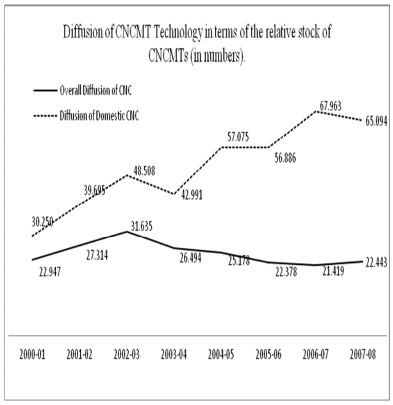
Source: Figure 5

Figure 5 (b)



Source: Figure 5

Figure 5 (c)



Source: Figure 5

Table 3 Diffusion of CNCMT technology in India in terms of the relative stock (in numbers).

Period	Net Availability of the CNCMT in Number (Q + M) - X	Net Availability of the Total Machine Tool (Q + M) - X	Overall Diffusion of CNCMT technology in terms of the relative stock of CNCMTs
(1)	**(2)**	**(3)**	**(2) ÷ (3) x 100 (4)**
Before 1965	26	288081	0.009
1965 – 69	17	180660	0.009
1970 – 74	47	234251	0.020
1975 – 79	130	302126	0.043
1980 – 85	960	329603	0.291
1986/87 - 1987/88	527	197920	0.266
1988/89 - 1991/92#	2731	19189#	-
1992-93	689	6668	10.333
1993/94 - 1997/98#*	4351*	35006#	-
1998/99 - 2002/03	7657	34877	21.954
2003/04 - 2007/08	29013	126070	23.013

Source: As same as in Figure 4.
Note: Q = output at home, M = import and X = export. Net availability of total machine tool given in column 3 does not contain the import of conventional machine tools for the periods from 1988/89 to 1991/92# and from 1993/94 to 1997/98#*.

Net availability of the CNCMT given in column 2 does not contain the import of CNCMT for the periods from 1993/94 to 1997/98#* as it was not available from the IMTMA. Until 1980-85 the data on calendar year is availed from the Survey of Machine Tools in India, 1986. Since 1986/87, on financial year, the data is availed from the IMTMA documents. The class intervals of Table 2 and Table 3 do not remain the same as they are determined by the availability of the data. These discrepancies, however, do not affect the overall result.

Having measured the extent of diffusion of CNCMT technology in quantitative terms, we move on to measure the same but as per the Ray's method in value terms in the following section.

5.3 Diffusion of CNCMT as per the Ray's method

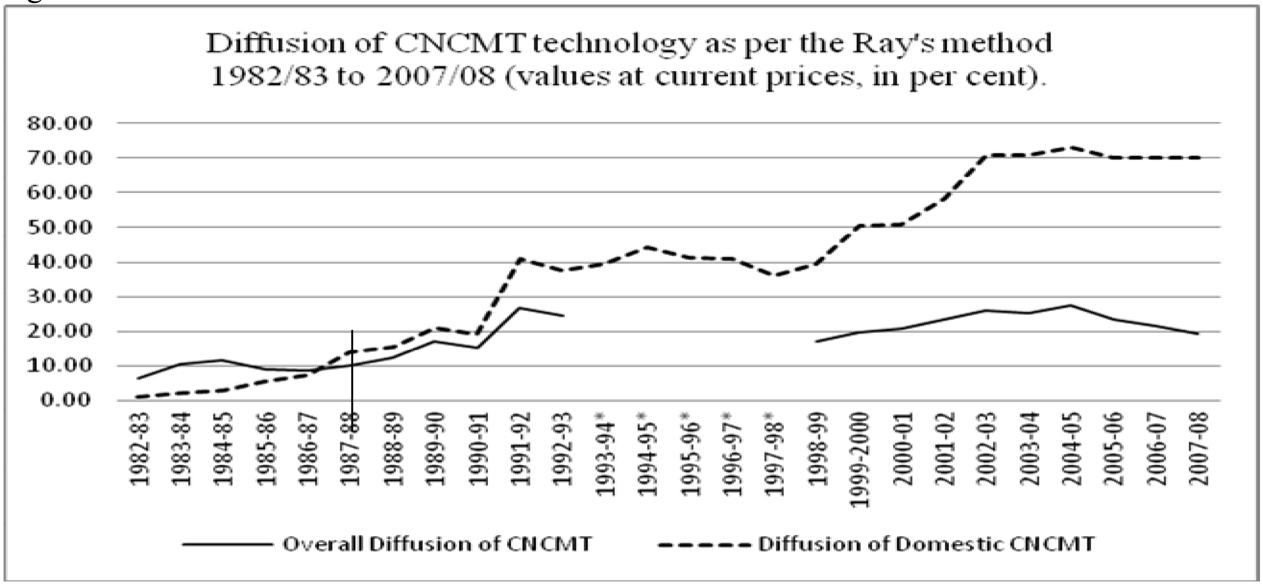
Ray's method of measuring the diffusion of CNCMT technology is almost similar to the relative stock method of the UNCTAD. Nevertheless the only difference in Ray's method is that it deals with the money values of the machine tools and not with the number of machine tools. Unlike in the previous methods, we could begin the analysis of the diffusion of CNCMT technology, as per the Ray's method, only from the year 1982/83 as information pertaining to the CNCMTs in terms of money values is available from that year onwards.

Unlike in the previous methods, while measuring the diffusion of CNCMT in monetary terms there is a good possibility of overcoming the problem of underestimation. For instance, CNCMTs are highly priced compared to the conventional machine tools. And also by nature a single CNC machining centre has the capacity of performing many conventional machines and hence their requirements tend to be less in quantity when compared with the conventional machines. For this reason, if expressed in value terms, the presence of CNC machines would have a better representation while computing the diffusion of it.

The overall trend of the diffusion of CNCMT technology obtained as per the Ray's method also depicts the same trend as it was in the previous methods; and we do not find any major differences in the diffusion pattern or trend while employing different methods (see Figure 3, Figure 5 and Figure 6). Diffusion curve of CNCMT technology obtained by Ray's method also portrays the abbreviated 'S-curve' as the rate of diffusion of CNCMT technology was low in the initial period - until the year 1986/87 as the overall diffusion is measured to be at the rate of 9.1 per cent per annum. During the protected regime, *that is,* until 1984/85, also the overall diffusion rate remained low at 9.4 per cent per annum. Since then, as the economy opened up, the overall diffusion rate of CNCMT technology began to increase. For instance, on an average, it remained at 17.68 per cent per annum between 1987/88 and 1992/93 (Figure 6(b)). Within this period, a spurt in the diffusion is also noticed in 1991/92 (Figure 6) which marks the beginning of the second phase of the liberalization process. Throughout the second liberal phase from 1991/92 to 2007/08 the overall diffusion rate of CNCMT technology remained at around 22.9 per cent per annum (Figure 6). However, from 2000/01 to 2007/08, the overall diffusion rate became even greater than ever before as it became 23.4 per cent per annum (Figure 6(c)). It coincides with the high growth phase of the economy and manufacturing sector in general and capital goods sector in particular. The increasing trend in the rate of diffusion of CNCMT technology observed in India suggests the high level of acceptance and preference for the CNCMTs among the user industries which includes the small scale industries also (Rajakumar, 2011a).

In the case of the diffusion of domestic CNCMT technology, even though it followed the same pattern of the overall diffusion of CNCMT technology, there were differences in its magnitude. For instance, since the year 1987/88 the magnitude of the domestic CNCMT technological diffusion began to exceed the overall diffusion of the CNCMT technology. Between 1987/88 and 1992/93 the rate of diffusion of domestic CNCMT was 24.64 per cent per annum (Figure 6) and it became 66.86 per cent per annum during 2000/01 to 2007/08 (Figure 6(c)). Throughout the second liberal phase, the domestic CNCMT technology was able to maintain its diffusion at the rate of 53.29 per cent per annum (Figure 6). This is more than double the rate of the overall diffusion of CNCMT. As already observed, this can be attributed to the declining trend in domestic production and net availability of the domestic conventional machine tools in the country and a simultaneous increasing trend in the production and net availability of the domestic CNCMTs. The greater and increasing share of conventional machine tools in the total machine tools imported is also an important factor that kept the overall diffusion rate at a lower level. It is for these reasons that the gap between the overall diffusion curve and domestic diffusion curve began to widen since 1991/92 (Figure 6)[14]. The diffusion gap became even greater during the high growth phase. Evidences also suggest that the high growth phase of the economy since 2000/01 provided a great impetus to the diffusion of CNCMT technology in India.

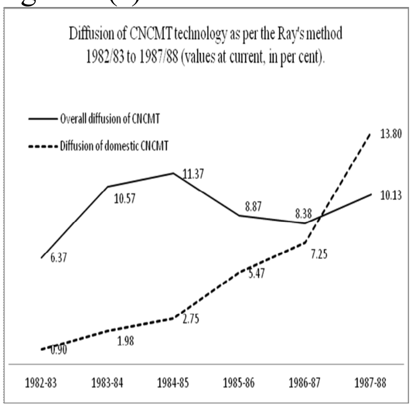
Figure 6



Source: Own calculation from the IMTMA documents.

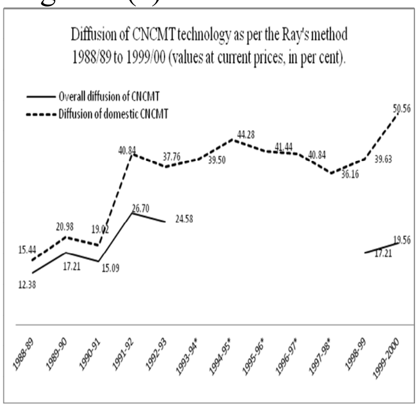
Notes: Discontinuity in the overall diffusion curve from 1993/94* to 1997/98* is due to the non availability of information from the IMTMA on the import of CNC machine tool. For more visual clarity, Figure 6 is further split into three as Figure 6(a), Figure 6(b) and Figure 6(c).

Figure 6 (a)



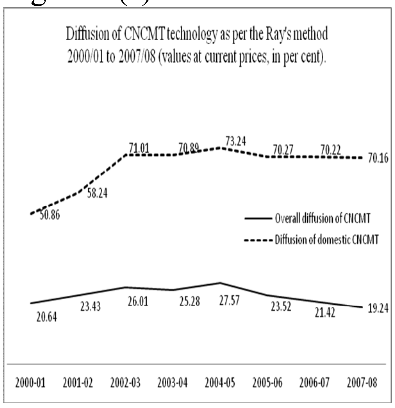
Source: Figure 6

Figure 6 (b)



Source: Figure 6

Figure 6 (c)



Source: Figure 6

In short, irrespective of different methods employed to measure the rate of diffusion of CNCMT technology in India, the general diffusion trend remained the same and it reflected the standard abbreviated 'S-curve' - from which we understand that the diffusion of CNCMT technology in India so far has not yet reached its third stage (*that is,* the state of maturity) but it is in the second stage of fast spreading since 1987/88. In term of the relative stock and Ray's method, the rate of diffusion of domestic CNCMT technology began to exceed the overall CNCMT technology in India since 1987/88. The gap between the domestic and overall diffusion of CNCMT technology began to widen since 1991/92 and it further got widened during the high growth phase mainly due to the larger import and declining production of the conventional machine tool in India. Liberalization policy measures thus favoured the diffusion of CNCMT technology in India.

Having estimated the extent of the diffusion of the CNCMT technology in India, we move on to offer some possible explanation in the next section.

6 Some explanation for the rate of diffusion of CNCMT technology

In the initial stages, that is, until 1986/87, the rate of diffusion of the CNCMT technology in the country was too low. This is mainly because CNCMT technology was used primarily in large industries and defence sector that too mostly confined to public sector. On an average, until the beginning of the 1990s, HMT alone accounted for 35 per cent of the diffusion of CNCMT technology of the country per annum (Albin, 1992 p.89). Manufacturing of CNCMTs in India on a large scale began only from 1984/85 – the year that also marks the end of the protected regime. Even though India produced CNCMTs even prior to 1984/85 they were limited in number. Mostly they were produced and consumed by the HMT alone. The magnitude of diffusion of CNCMTs technology through imports also remained very low as they were not popular among the medium and small scale industries. Interviews with officials of the HMT, CMTI and owners of some small scale industrial units in Chennai and Coimbatore revealed that the protected regime favoured a labour augmenting technology. Therefore technology with higher degree of precision, flexibility and automation such as CNCMTs that are also labour substituting in nature, and requiring high initial investments and formally educated skilled labour were not seen with great attraction and affordability by the medium and small scale enterprises. However, among the large industries even though the CNCMT technologies were affordable and popular, they had been used limitedly and were not encouraged for its wide spread applications. It is for these reasons the extent of diffusion of CNCMT technology in India remained too low not only during the protected regime but also during the initial stages of the liberalization period until 1986/87.

Government policy of broad banding announced in July 1983 to facilitate the growth prospects of the capital goods sector in general and machine tool industry in particular began to facilitate the diffusion of CNCMT with a lag effect of four years. For instance, broad banding directly helped the machine tool manufacturers to diversify into related activities without prior permission from the government. This encouraged them to concentrate more on the manufacturing of CNCMTs. Over the years, many private machine tool manufacturers even stopped producing conventional machine tools and concentrated only on the production of CNCMTs[15]. This can be explicitly noticed since 1987/88 from a shift in the slope of the domestic diffusion curve of Figure 3(a), Figure 5(a) and Figure 6(a). Apart from this, through user industries, liberalization process subjected the machine tool industry into a technological transition path favouring and facilitating the diffusion of CNCMT technology in the country. For instance, as Rajakumar (2011a) observed, with the announcement of product de-reservation and de-licensing since the early 1990s, the small scale industries were exposed to competition from the medium and large size firms. This in turn forced the small scale industries in the manufacturing activities to enter into activities of capital intensive nature in order to survive competition. "Technological acquisition and up-gradation became the major enablers of growth and survival of micro and small enterprises (MSE)" (Rajakumar, 2011a, p.52). MSEs in the manufacturing activities, therefore, by acquiring the CNCMT technology had the assurance of technological advantage. The increase of investment ceiling limit on plant and machinery to Rs. 10 million for the small scale industries engaged in the manufacturing activities since September 01st, 2001[16] also encouraged small scale industries to go more in favour of the CNCMT technology than in the past. Since October 02nd, 2006, the ceiling limit is further increased to Rs.50 million[17]. Demand for CNCMT technology thus emanated from the small scale industries since the second liberal phase in general and after 2001 in particular facilitating the diffusion of CNCMT technology in India to a great extent.

This is also evident from shift in the slopes of the diffusion curves (both domestic and overall) in 2002/03 and 2006/07 (see, Figure 3(c), Figure 5(c) and Figure 6(c))[18].

The periodical announcement of the government expanding the OGL list pertaining to the capital goods and machine tools; reduction in the quantitative and tariff restriction on the machine tool imports particularly after 1995 have also enabled the diffusion of CNCMT technology in India in a big way. In addition, preference for labour augmenting technology of the protected regime gradually began to lose its relevance as competition, survival and growth became the prime concerns of firms during the liberal regime. This in turn made the user industries in general to demand CNCMT technology as it guaranteed them the better technology with flexibility and precision in manufacturing.

With the advent of the second phase of liberalization process in the country from 1991/92, many new industries have entered into the Indian market (Uchikawa, 2011b, p.45) which in turn increased the demand for more CNCMT technologies. For instance, modernization activities in the existing engineering and automobile units/firms; the new entry of many firms into the Indian automobile sector (Maruti Udyog Ltd., TVS, Hero Cycles, Escorts group, Daewoo, Ford, Opel, Honda, Hyundai to cite a few); and the mushrooming of many ancillary units in the small scale industries during the 1990s have contributed immensely to the diffusion of CNCMT technology. For instance, Uchikawa has observed that the "SMEs are the dynamic sector in the auto-component industry" (Uchikawa, 2011b, p.59). Throughout the second liberal phase, from 1991/92 to 2007/08, the manufacturing and capital goods sectors were also significantly growing at the rate of 6.1 and 7.7 per cent per annum (Albin, 2012 p.76). This in turn seems to have generated greater demand for CNCMT technology and explains the faster rate of diffusion of CNCMT technology in the country during this period.

Similarly, the government's efforts since 2000/01 to improve and build new infrastructure facilities in the field of transport (road, railway, civil aviation and shipping) and telecommunication also seems to have triggered fresh demand for the CNCMTs which in turn resulted in the rapid rate of diffusion of the CNCMT technology in India since 2000/01. This period also coincides with the high growth phase of the economy in general; manufacturing and capital goods sectors in particular. They were experiencing the growth rate of 7.6, 12.8 and 14.5 per cent per annum respectively (Albin, 2012 p.76). These high rates of growth obviously would have a direct impact on the diffusion of CNCMT technology and it reflected in the overall and domestic rate of diffusion of CNCMT technology in the country (23 and 65 per cent per annum respectively) during 1999/00 to 2007/08. Unlike in the earlier period, the second phase of liberalization process also marks the beginning of the spread of CNCMT technology among the small scale industries engaged in the manufacturing activities particularly from 2000/01 onwards. For instance, as observed by Rajakumar (2011a), the MSEs were growing impressively that it outperformed the growth performance of the overall industrial sector in India between 2002/03 and 2007/08. As most of the small scale units were/are catering to the needs of the large and medium firms, who are increasingly becoming quality, cost and time conscious in competitive market environment; by using CNCMT technology, the small scale units are able to win the confidence of the large and medium firms from whom they get the contracts and job orders. It is this fact greatly helped in the diffusion of CNCMT technology among the small scale units which in turn fuelled the rapid rate of diffusion of the CNCMT technology in India. It is also understood from the field survey and recent literature (Rajakumar, 2011a and Uchikawa, 2011a & b) that, apart from many other factors, the growth of automobile industry along with the growth of small scale industries subcontracting to the automobile industry are the major factors behind the diffusion of CNCMT technology in India since the inception of liberal economic measures[19]. In all these, as already observed, diffusion of CNCMT technology into the MSME is capable of displacing labour from micro, small and medium industries that otherwise remain as the major sources of employment opportunities in India. This is because; the newly emerged CNC Machining Centres, for instance, have the technological capability of replacing many of the conventional machines[20] and hence the labour force attached to it. To this extent, it needs to be viewed as a failure in fulfilling the United Nation's Sustainable Development Goals (SDGs) of achieving inclusive development.

7 Summary

The objective of this paper is to understand and measure the extent of CNCMT technology in India; and to offer some possible explanation to it. The study is also particular about assessing the impact of liberalization on the diffusion of CNCMT technology in the country. Based on a survey of various methods used to measure the diffusion of CNCMT technology, three different methods are used in the present study. They are (a) Pillai and Subrahmanian's method of net addition of CNCMTs at different time points in quantity terms (b) the UNCTAD's method of the relative stock of CNCMTs at different time points in quantity terms and (c) Ray's method of the share of net availability of CNCMTs in the net availability of the total machine tools in the country in value terms. Unlike the second and third methods, the first method indicated only the direction of the diffusion of CNCMT technology better than the extent of diffusion per se. And it is learned that irrespective of the different methods employed, the general diffusion trend of CNCMT technology in India remained the same and it reflected the standard abbreviated 'S-curve' depicting a common slowness in the rate of diffusion at the initial stage until 1986/87; and a faster rate of diffusion since the year 1987/88. However, it has not reached the third and final maturity stage.

The rate of diffusion of CNCMT technology during the protected regime remained very low. Even with the imported CNCMTs the situation did not improve. Be it the overall or domestic diffusion, the net addition of CNCMT was less than 100 per annum until the mid 1980s. In terms of relative stock the rate of diffusion remained at less than one per cent per annum during the protected regime. The same was around nine per cent per annum in terms of Ray's method. This is mainly because, in the initial years, the CNCMT technology was popular mainly among the large industries and defence sector – in that the HMT, a public sector company, alone was accounting for 35 per cent of the diffusion. Faster rate of diffusion of CNCMT technology in India is realised only after the introduction of the economic liberalization measures in 1985/86 and 1991/92 as spurts in the rate of diffusion of CNCMT technology are noticed in 1987/88, 1991/92, 1999/00 and 2002/03 as per all the three methods for both the domestic and overall diffusion. This can be attributed to the government policies such as broad banding, expansion of the OGL list, periodical reduction of the tariff and quantitative restriction to import machine tools after 1995 and the increase of investment ceiling limit on plant and machinery for the small scale industries. Another important finding of the study is that the rate of diffusion of domestic CNCMT technology began to exceed the overall CNCMT technology in India since 1987/88. The gap between the domestic and overall diffusion of CNCMT technology began to widen since 1991/92 and it further got widened during the high growth phase mainly due to the larger import and declining domestic production of the conventional machine tool in India.

The modernization activities of the existing firms in the manufacturing sector and the entry of many new firms, particularly large firms in the automobile sector, along with the growth of small scale industries subcontracting to the automobile sector have facilitated the faster rate of diffusion of CNCMT technology in India particularly from the inception of the second liberal phase in 1991/92. Government's efforts to improve and build new infrastructure facilities since 2000/01 that coincided with the high growth phase of the economy; and the demand for CNCMTs by the small scale units to meet the need of the large and medium industries through subcontract and job orders also remained responsible for the rapid diffusion of the CNCMT technology in India between 2000/01 and 2007/08 but at the cost of employment opportunities in small and medium industries in particular.

Notes

1. 'Differences are also made between adoption and diffusion. Adoption means the incorporation of new technology into the individual firms or organization and focuses on the decision of an individual unit. But diffusion is an aggregate phenomenon centered on how innovations are transmitted across an economy over a period of time' Satheesh, (2009).
2. Entrepreneurial function involves deciding to go forward with the effort, organizing it and obtaining financial support. Investment is the act of risking funds for the venture. Development is the lengthy sequence of detail oriented technical activities, including trial and error testing, through which the original concept is modified and perfected until it is ready for commercial utilization. Scherer (1971), quoted in Parker (1978).
3. For Schumpeter even though technical change consists of invention, innovation and diffusion, he was also of the view that 'the application of new combinations by entrepreneurs is possible without invention while inventions as such need not necessarily lead to innovations and need not have any economic consequences. Innovation itself is the independent endogenous factor that causes economic life to go through a number of cycles'. However, 'his sharp distinction between innovations and inventions has triggered off several reactions, and both theoretical analysis and empirical research have been directed to the question whether innovations are really as independent of inventions as Schumpeter supposed' Heertje (1987).
4. In simple terms invention means the creation of new products and processes; innovation means the transfer of invention to commercial application; and diffusion means the spread of innovation into the economic environment Eatwell, et.al, (1987).
5. 'Final Report on the Indian Capital Goods Industry', at the http://dhi.nic.in/indian_machine_tools_industry.pdf (accessed on March 10, 2012).
6. Interactions with the officials of the IMTMA, CMTI and HMT were of much use in obtaining this information.
7. More details on this point is available in Edquist and Jacobsson (1988, p.130).
8. As the Survey of Machine Tools in India did not provide information on the value of machines, the IMTMA data was used to suit to the Ray' method of measurement of diffusion in value terms.
9. Survey of Machine Tools in India (1986).
10. Prior to the 1980s, on an average, the overall net addition of the CNCMTs were even less than 100 units per year.
11. We use the term diffusion gap to indicate the gap between the overall diffusion and domestic diffusion.
12. See Figure 5.3 and Table 5.11 in Albin (2012).

13. See Figure 5.4 and Figure 5.5 in Albin (2012).
14. A similar reason is also applicable for Figure 5.
15. LMW, Coimbatore and Premier, Pune are samples to cite in this context.
16. Government of India, Ministry of Small Scale Industries, 2003-04 Annual Report, p.1. Available at the http://msme.gov.in/ssi-ar-eng-2003-04.pdf (accessed on June 07, 2012).
17. Government of India, Ministry of Small Scale Industries, 2006-07 Annual Report, p.9. Available at the http://msme.gov.in/ssi-ar-eng-2006-07.pdf (accessed on June 07, 2012).
18. However, for the year 2006/07, the slope of the overall diffusion curve remained negative in terms of the relative stock (Figure 5(c)) and Ray's method (Figure 6(c)) and it is attributed to the increased conventional machine tool production at home and its import. See, Figures 5.1, 5.2, 5.3 and 5.4 in Albin (2012). And also the increased CNCMT export (Figure 5.5) in Albin (2012). A very minor fall in the slope of the domestic diffusion curve as per the Ray's method (Figure 6(c)) for the same year 2006/07 is attributed to the increased conventional machine tool production at home (Figures 5.1) and the increased CNCMT export (Figure 5.5).
19. Interviews with the owners of some small scale industrial units were of much use to arrive at this finding. Sample firms were identified from Ambatore and Gundy of Chennai; and Ganapathi, Kalapatti and Singanallur of Coimbatore, Tamil Nadu. Based on the convenient sampling method, the owners of 30 units in total were interviewed. It consisted of 15 units each from Chennai and Coimbatore. The small scale units interviewed are engaged either in the manufacturing of different parts of the automobile components or textile machineries. However, majority of them are found in the manufacturing of auto components. All of them have subcontracts and job orders. 20 of them (ten each in Chennai and Coimbatore) are operating for more than 20 years (that is, units that began its operation in 1990 or even before). Other 10 (five each in Chennai and Coimbatore) have begun their operation between 2001 and 2005. Except 5 units, all others began their activity only with conventional machines and equipped themselves with the CNC machines only after 2001mainly to meet their long term commitments to supply the spare parts and components. In 5 cases (one in Chennai and four in Coimbatore), whose inceptions were between 2001 and 2005, reported to have owned CNC machines since their inception and they also have conventional machines.
20. It is learnt from an interview with the officials in Ashok Leyland, Chennai that recently they could replace around 55 conventional machine tools with mere 10 CNC machine tools.

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