# Knowledge Transfer between Users and Producers in the Accumulation of Technological Capability

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**Summary**

This study reveals that the user industry has a limited role in being a source of technological capability in the case of the machine tool industry in Korea where the user industry is relatively more advanced than other capital goods industries. This study examines the sources of technological capability in terms of migration of workforces and flow of product development knowledge. Although the capital goods sector is generally regarded as being the sector where user-producer interaction is important, the user industry is not the seed-bed of technological capability for machine development.

Users and producers interact in terms of expressing "needs", mainly in the form of specifications. As a result of receiving unique specifications from users, the producer learns to react by making specific customised special purpose machines. The user's specification could include information on the imported machine originally used.When confronted with technical problems in developing a new machine, the producer accesses foreign sources of knowledge. This study's finding reveals that users of special purpose machines have a significantly clearer role in providing specifications than do users of general purpose machine tools. Most intensive interactive learning between users and producers in the production process is found in special purpose machine tools. From the empirical findings, policy implications are discussed.

Keywords: East Asia, Korea, industrialization, innovation systems, capital goods

## 1. Introduction

The user industry in the capital goods sector has been regarded to be important for the accumulation of technological capability by producers. The existence of competent users is important for the competitiveness of producers (Porter, 1990). Thus, it can be conjectured that without the existence of sophisticated users to translate their needs into product requirements, there is insufficient pressure for producers to improve their technological capability (OECD, 1992, p. 262). Users not only provide demand that quality producers should meet, but also interact with producers in the innovation process. Lundvall (1985, 1988, and 1992) notes the importance of user-producer interaction in the innovation process. As a result of recognizing the importance of user producer linkages, there have been strategic and policy arguments directed towards promoting user-producer linkages. The existing literature on user-producer linkages is based upon the experiences of the advanced countries. Whether this is equally applicable to developing economies is not yet clear. Discussion on user-producer relationship in the "catching up" period has been poorly developed, as Rosenberg's (1976, p. 166) comments on the relationship show.

*From this perspective, some of my concerns about the prospects for poor countries, which rely on the importation of foreigncapital equipment are obvious. But if new techniques are regularly transferred from industrial countries, how will the learningprocess in the design and the production of capital goods take place? In the past, as I have argued, the appropriate skills were acquired through an intimate association between the user and the producer of capital goods. In the absence of these experiences, what substitute mechanisms or institutions can be established to provide the necessary skills?*

The purpose of this study is to analyse the extent to which users in Korea have contributed to the generation of technological capabilities in the Korean machine tools industry. Section 2 reviews the literature, and draws out propositions for testing the user's role as a provider of knowledge. Section 3 introduces a methodology of research that relies on interviews and a survey. Section 4 gives evidence contrary to the "trickle down effect" of product development knowledge from users to producers, and discusses the learning pattern of producers in utilizing external sources of knowledge. The concluding section discusses strategic and policy implications.

## 2. Literature Review

In advanced countries, increasing interest has focused on the micro- and mid-level dynamics of innovation in the studies of technical change. As mentioned above, a competent user industry that can express sophisticated demand for products has been emphasised as being important for the competitiveness of producers (Porter, 1990). The sophisticated demand tends to be concentrated among "lead users" (Morrison, Roberts and von Hippel 2000; von Hippel and Sonnack, 1999; Urban and von Hippel, 1988).Carlsson and Jacobsson (1992) and Carlsson (1996) discussed the automation equipment industry of Sweden. They emphasised the importance of "advanced users", another term for "lead users", for the strength of the producer industry. The existence of lead users in providing opportunities to developautomation equipment to solve their problems enables domestic producers to upgrade their technological competence. In addition, less advanced users, being unable to acquire products and services from distant foreign producers, also rely on domestic producers and therefore, provide them a market.

In the innovation process, understanding the qualitative demands of users is important for successful innovation. The SAPPHO Project (Rothwell *et al.*, 1974) emphasised the importance of understanding user needs. To meet user needs, close relationships with users is important. Håkansson (1989) revealed that the most frequent form of cooperation aimed at innovation is user-producer interaction. Håkansson (1989) argues that 80% of the cooperative activities aimed at innovation activities, which include cooperation between users and producers, are domestic. The concept of "user needs" requires further elaboration. User needs can go beyond the demand side.Users are not only passive agents expressing their needs, but also active participants in the innovation process through their innovation activities that are aimed at satisfying these needs. A study of the active role of users in innovation, by von Hippel (1978, p. 255), *Customer Active Paradigm,* argues that the users' needs, or requests, that are passed to producers, include apprehension of a need, determination of a solution type, development of product functional specifications, development of product design specifications and complete product design. Hippel's (1978) argument differs from those of Meadows (1969), Peplow (1960), Utterback (1971), Berger (1975) and Boyden (1976) in that in his view, user needs include information on design: design specifications and complete product design. In the case of the most active role of user innovation, user needs are expressed through the development of improved, sometimes radical, production equipment. Hippel also found that in the case of the semiconductor industry, 71% of the sixteen major process machinery innovations were made by users (von Hippel 1988, p. 22). This work shows that the users' role could include the supply side—providing knowledge on product development. To summarise the discussion of the user-producer relationship literature, there are two aspects to consider. One is the demand side; the user's role as a provider of qualitative demand. The other is the supply side; the user's role as a provider of knowledge. This paper is mainly concerned with the latter aspect, which is described as the "trickle down effect" of knowledge from users to producers.

The users' role as the provider of knowledge raises an important question in connection with the process of accumulation of technological capability in catching up countries. If users can play the role of the provider of knowledge to producers, users could also fulfil the role of supporting producers' learning processes on the supply side. In the newly industrializing countries (NICs), dynamic industrial growth has been concentrated in the capital goods user sectors, including electronics and textiles among others. These sectors have advanced user firms who were able to produce competitive products for the world market. These firms were leaders in assimilation and absorption of foreign production technology. Advanced user firms can be expected to have been a source of knowledge for the producer firms. Less advanced users that are forced to rely on domestic firms are important for local firms (see Carlsson and Jacobsson's observations about Swedish firms (1992)). Therefore, the role of users, which includes advanced users and less advanced users, needs to be explained within the catchingup country context. The existing literature on catching up countries highlights the importance of learning and access to foreign sources of knowledge (Lall, 1980, 1992 ; Kim, 1980; Dahlman and Westphal, 1981; Lee et al., 1988; World Bank, 1993), but does not goon to explain the pattern of interaction among users and producers. In order to understand the process of accumulation of technological capability in the capital goods sector, the role of users in the process of producers' accumulation of technological capability need to be investigated. The role of users is wide, ranging from provision of ideas, to product design, equipment for testing, financial support and collaborative research. This study is confined to those roles that are relevant to the flow of knowledge between users and producers. The first role relevant to the flow of knowledge is users' provision of technological capability support in the process of producers' innovation.

The other role is users being a source of product development knowledge, a nurturer of the internal workforce that accumulates knowledge to produce machines from their experience while solving problems in the production process. In Japan, the textile industry was the seedbed for the technological capability to produce textile machinery (Sugiura, 1994), and the automobile industry was the seedbed for the technological capability to produce machine tools in Japan (Lee Kong-Rae, 1993). Both of these literature types discuss cases of making machines from the experience of solving problems for their production processes.A study by Rosenberg (1976, p. 19-22) illustrates cases of machine user companies (e.g. firearms companies; clock and watch companies) that accumulated thecapability to produce machine tools and set up machine tool companies through a process of vertical disintegration. All of the entry by users in the literature could be termed as entry into production through learning by using.

The discussion of the literature (Rosenberg, 1976; Lee Kong-Rae, 1993; Sugiura, 1994) implies the migration of workforce from user entry to production. The workforce accumulated its skills to repair or to produce machines, and from its experience in solving problems in a user factory, moved to a machine producing division of the same company, or moved to a separate spin-off machine producing company. This migration of the workforce is either due to internal recruitment (migration between the divisions) or external recruitment (migration to an external spin-off company). Recruitment is implemented by machine producers: (1) user firms that became producers as a result of diversification into machine production and (2) the spin-off machine producers. Therefore, this recruitment by producer firms can be regarded as a channel for knowledge sourcing (Lam, 2002).

In this study, the focus of knowledge flow is the knowledge relevant to product innovation. Product innovation of firms in the catching-up country context does not entail devising world frontier products, but developing a new product that is new to the firm by imitating an imported product or as an improvement to an existing product of the firm. Product innovation at the firm level, in terms of a product that is new to a firm, can be measured by the product design change or product model change. Product development of a machine, which is an engineering process rather than scientific R&D, mainly consists of design work. Design work is presumed to be central to the innovation process in studies of technical change (Bernal, 1971; Rosenberg, 1982; OECD, 1992, p. 26).Therefore, the knowledge of product development mainly consists of design work.The users' contribution to theprocess of developing a product is mainly "from the conceptualisation of products to be developed to actually developing completed prototypes" (von Hippel, 1976, 1977, 1982, 1988; Wheelwright and Clark, 1992). Various propositions can be found in the existing literature for investigating the trickle down effect of product development knowledge. The trickle down effect can vary in accordance with the type of machine. As Hippel (1978) discussed, the users of special purpose machine tools, being richly exposed to specific condition of users, are likely to have strong knowledge of special purpose machine tools being "overtly aware of user needs", and even have experience in making special purpose machines: (1) in order to solve unique problems of their factories, which other machine producers could not solve (Lee Kong-Rae, 1993) and (2) toobtain the economic rents of protecting their process equipment innovations from self developed machines (von Hippel, 1988). Users of general purpose machine tools, whose working conditions are similar to those of other user firms, are likely to have weak knowledge of general purpose machine tools. This study focuses on the following propositions.

Main proposition: the user industry leads the dynamic accumulation of technological capability of producers by the "trickling down" of product development knowledge.

Proposition 1. Users are a source of product development knowledge, being a nurturer of the internal workforce that accumulates knowledge to produce machines, which enable users to become producer firms

Proposition 2-1. Users are a source of product development knowledge, providing technological capability support to producers.

Proposition 2-2. Users of special purpose machines provide more active technological capability support to producers than do those of general purpose machines.

This study aims to test these propositions in relation to the Korean machine tool industry.

## 3. Methodology

In examining the above propositions, this study faces the following problems. Proposition 1 involves whether users have been a source of knowledge by being a pool for recruitment for producer firms. Users are a source of product development knowledge since they are a nurturer of the internal workforce having accumulated knowledge that enables users to become producerfirms. This was tested by investigating the migration of the workforce from users to producers. Migration of the workforce from one organisation to another can be regarded as the flow of knowledge (Lam, 2002).

This study examines the migration of the workforce from users to producers from three standpoints: (1) the migration of theworkforce either from a division using machine tools in an automobile manufacturer to a division producing machine tools in thesame firm or the migration of the workforce from an automobile manufacturer to a spin-off firm that is the result of a maker's entry into machine tool production; (2) migration of the workforce either from a division using machine tools in a non-automobile maker-user firm to a division producing machine tools in the same firm or the migration of the workforce from the non-automobile manufacturer -user firm to a spin-off firm that is the result of the firm's entry into machine tool production; and (3) the migration of key engineers from users to producers.

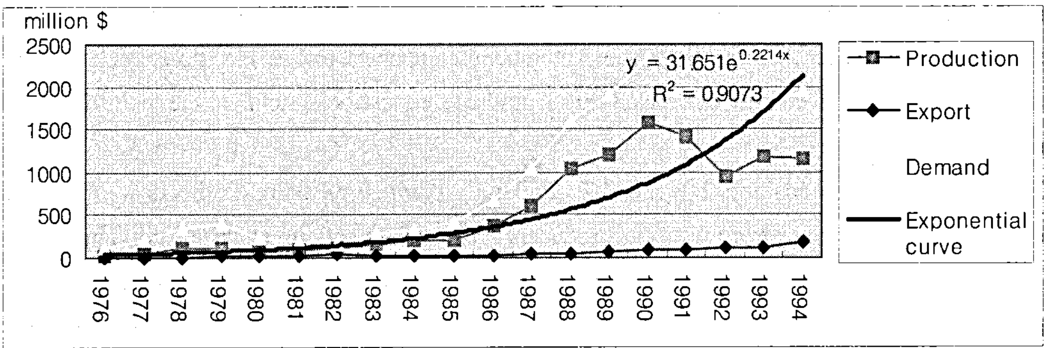
This study originally planned to examine whether the knowledge accumulated within the user entry firms had been sufficient to allow them to produce machines based on their usage experience. Such an examination would have identified users as a source of knowledge. However, in interviews, it was impossible to discover what proportion of the workforce had this ability at the timeof entry of the firm into production. Therefore, the question that was asked enquired about that proportion of the workforce having experience in use and repair in order to estimate the number of workers that accumulated the capability to produce machinesfrom their experience. In order to help those respondents who had difficulty in estimating the proportion, they were asked to respond within a certain range. The categories were internal recruitment with experience of use, internal recruitment without experience of use, other machine tool makers, and new recruitment of graduates or school drop outs. The ranges that were given were0-20%, 20-40%, 40-60%, 60-80%, and 80-100%.

The survey question relating to the job or training of the top engineer just before moving into an interviewed company included the following categories: machine tool maker, machine tool component maker, automobile maker, automobile component maker, electrical and component maker, machine and component maker, post graduate education, public research institute and others.

To investigate proposition 2-1 and 2-2, this study planned to examine the flow of product development knowledge from users to producers through interactions between individual firms. This also proved to be difficult to measure because the knowledge isstored in people. To examine the flow of knowledge, a survey was carried out and supplemented by interviews with producers on the flow of the following knowledge relevant to a user firm's technological capability support for producers: knowledge embodied in prototypes, blue-prints and patents, and knowledge measured in terms of the help received from the employees of user firms in the form of technical assistance.

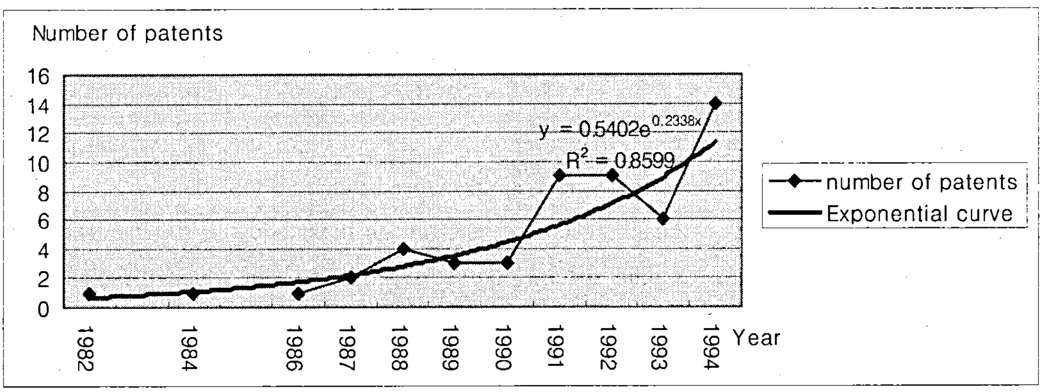
This empirical investigation focused on both types of machine tools: general purpose machine tools and special purpose machine tools. General purpose machine tools are produced for users in generic machining work environment. These machines are sold in large numbers and the majority of machine tools produced in Korea are general purpose machine tools. Special purpose machine tools are produced for a niche market composed of users whose working environments are unique and where general purpose machine tools would not be of use. The special purpose machine tool falls into two categories. One is a specialised machine tool that is "special" by virtue of adding components or changing components in the main body of a general purpose machine tool. The other is an original special purpose machine tool in which the main body has been specially designed. Special purpose machine tools are customized products. Therefore, interaction between users and producers was expected to be different. A question was included about technological capability support (provision of patents, blue prints, and dispatch of technological personnel) from users to producers in both types of machine tools ranked on a five-point scale from very important (score 5) to least important (score 1). The survey questionnaire also included a question about users as the source of ideas and technological information for developing new products. Interviewees were asked about both types of machine tools in relation to whetherthere had been provision of patents, blue prints, and secondment of technological personnel from users in the product development process.

This study concerns the machine tool industry in Korea. The machine tool industry was selected as being an industry that ispresumed to have been close to user industries driving industrial growth. The machine tool is crucially important for improvingproductivity in the machining processes in the export sector of Korea.



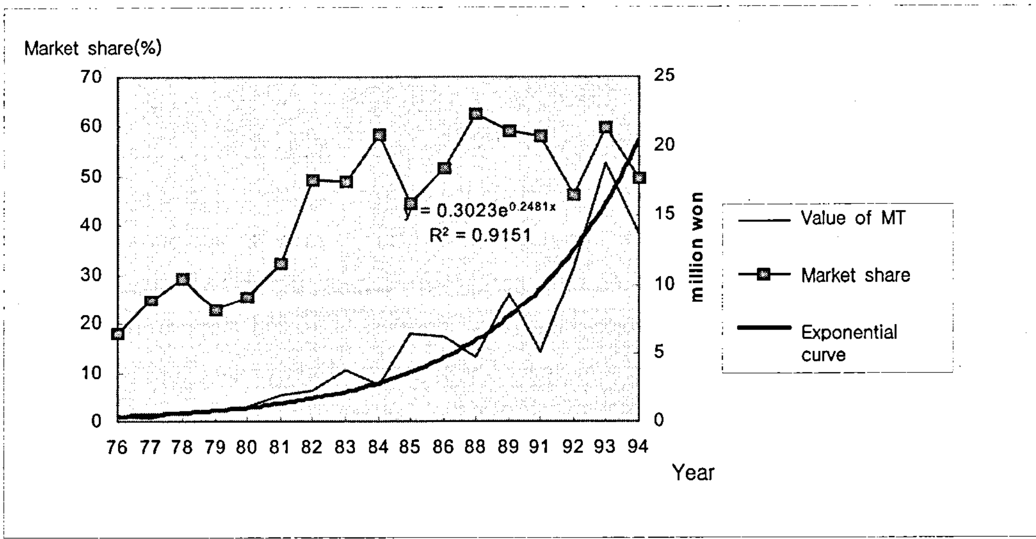

Notes: 1) Current price, 2) Output is based on shipment statistic, 3) Output calculated using exchange rates from National Statistical Office (1990; 1994).
Source: KOMMA (1985; 1993; 1996).

**Figure 1 :** Production, Export and Demand of Domestic Machine Tools




Notes: 1) Number of patents in 1983 =0, number of patents in 1985=0; 2) Number of patents in the pre 1982 =4.
Source: US Patent Office (1996, 97).

**Figure 2 :** Patent Grants for Metal Working Machinery, Elements, and Mechanisms by Korean Companies and Private Applicants in the USA




Notes: 1) Shipment based; 2) Value of machine tools, constant price at 1990 3) * Domestic market share of domestic producers (output-export)/(output + import-export).
Source: KOMMA (1985, 1996).

**Figure 3 :** The Value per Machine and Market Share of Domestic Machine Tools

The survey questionnaire was mailed to those firms belonging to the Korean Machine Tool Manufacturers Association (KOMMA 1994). Questionnaires were sent to key engineers in the development of new products after these individuals had been identified through telephone calls to the companies concerned. The response rate to the mailed out questionnaire was 38.1% (37 out of 97 firms). This sample covered the four largest firms, which produced 62.7 % of the metal cutting machine tools in 1993 (KOMMA 1995). Metal cutting machine tools account for 80% of machine tool production, according to 1992 statistics. Among small firms, thirty-three out of ninety-nine belonging to the machine tool trade association responded to the questionnaire - a response rate of 36.7%. All of the sample firms are assumed to be responsible for more than half of the total production of the machine tool industry. The "key engineer" is the engineer regarded as being central to the process of development of a new machine tool. This is usually the director of a development team, research laboratory, or someone holding a position whose main responsibility is the product development process. The interviews covered ten machine tool producers, five major producers and two automobile producers. The interviews were planned to cover major large producers (five out of six of the major producers) of machine tools, some small machine tool producers and major users.

The unit of analysis of technical change at the firm level is product model change. In understanding the knowledge flow between users and producers, the focus of analysis of technical change should be product innovation, as previously discussed. The results of product development activity are machine products that have a product model name label. The number of product models of a firm reflects the product development capability of a firm. There is one exception and that is when the unit of analysis is not product model change. In a special purpose machine tool, which is a minor type of machine tool, product models do not exist.Designs of special purpose machine tools vary in accordance with users' requests. In special purpose machine tools, the unit of analysis is design changes in special purpose machine tools.

The unit of analysis for firm organisation is the division of a firm relevant to machine tool production. Industry level data were collected from literature surveys and statistical directories. Literature and documentary information were used to supplement the information collected at the firm or industry level. The following section deals with the main findings.

## 4. Main Findings

### *4.1. Growth of the User and Machine Tool Industries*

The Korean machine tool industry's user industries include the key export sectors, examples being automobiles, electronics and shipbuilding. The Korean machine tool industry has been growing along with the key export sectors, which have been growing rapidly; thereby, driving industrial growth. Since the 1980s, these industries have occupied a place in the world market. Theautomobile industry accounted for 3.2% of the world market in 1995 (United Nations, 1995). Korean automobilemakers have been capable of producing original car models and engines since the 1980s. They have the capability to manage planning and establishment of production lines,[1] and have the capabilities to develop some production equipment.For example, Hyundai Automobiles developed its own transfer machine (for machining bearing caps) for the first time in 1983 (The Committee for Editing the 25 History of Hyundai Automobiles, 1992). It also developed various machine tools.[2] The automobile industry was ranked eleventh, with ninety-one patents out of the total of US patent granted by 1996 for motor vehicles and motor vehicle equipment.

1) Interview with a division director of Hyundai Automobiles, 7 Nov. 1994.
2) Interview with a middle manager of Hyundai Automobiles, 7 Nov. 1994.

Between 1976 and 1994, the domestic machine tool industry dynamically accumulated technological capability. During this period, accelerating growth of exports and production[3] along the logistic curve (see Figure 1)[4] and theaccumulation of technological capability in terms of patent grants[5] with a similar trend (Figure 2) were recorded. During this period the industry also demonstrated its ability to produce more expensive machines (Figures 3 and 4). Korean machine tool makers began to be capable of manufacturing original models. According to the survey in this study, 23% of the models from the firms surveyed are original models and 54% are either original models or modified foreign models. As a result of this rapid accumulation of technological capability, Korean machine tools have increased their position in the domestic market; from 18.1% in 1976 to 49.8% in 1994 (see Figure 3).[6] All of this remarkable achievement in market performance and accumulation of technological capability of both users and producers is a good reason why the machine tool industry should be selectedfor a case study investigating the users' role in the process of producers' accumulating technological capability.

### *4.2. Users as a Source of Knowledge, through Being a Pool of Recruitment*

This section examines whether users are a source of product development knowledge, being a nurturer of the internal workforce that accumulates knowledge to produce machines, which enables users to become producer firms (proposition 1).

#### *4.2.1. Workforce Migration of Automobile Affiliated User Entry Firms*

This study examines whether these automobile makers, assuming automobile makers are advanced user firms, provide machine tool producers with the workforce that accumulate the knowledge to develop machine tools from their experience of machines usage. In Korea, there are three large automobile makers, all of which have machine tool producers within their conglomerate group (*Chaebol*). These machine tool producers are among the five largest machine tool producers.

3) The production of Korean machine tools rose from 22 million dollars in 1976 to 1.147 billion dollars in 1994 (Lim, 1997: 31).

4) Usually the logistic curve is used to describe the general trend of the growth of any "population" (Johnston, 1984; de Solla Price, 1963).

5) According to US patent data, the number of patents granted for Korean applications in metal working machinery, elements, and mechanisms (SIC 35), which is relevant to machine tool technology, was 1 in 1982 and 2 in 1987. In 1994, it rose to 14 (US Department of Commerce, 1999).

6) Domestic market protection was relaxed in the period. For Korea, this relaxation allowed a gain in market share. For example, the nominal protection ratio, as the measure of market protection, decreased substantially between 1980-1990 (for further details see "Policy for promoting an industrial sector" in B in section 4.2.4 in Lim (1997))

These are represented as the A, B and C firms in Table 1.

**Table 1:** Considered Best Estimate of Sources of Recruitment in the Entry into Production of Machine Tools

| Firms | Year of entry into machine tool production | Internal recruits | | Other recruitment sources |
|---|---|---|---|---|
| | | Proportion of internal recruits | Experience of the internal recruits | |
| A | 1976 | 10% from a automobile maker | No previous experience of use or making machine tools | 90% new recruitment |
| B | 1991 | 5% from B automobile maker1[1] | Experience of use, making machine tools | 40% other machine tool producers, 45% new recruitment, 10% others |
| C | 1976 | 10% from other firms in the same Chaebol group[2] | No experience of making or using machine tools | 90% new recruitment |
| D | 1976 | 30% from internal recruits with machine use experience, 30% from internal recruits with no use experience.[3] | | 30%from new recruitment, 10% from other machine tool producers[3] |
| E | 1952 | no data available[4] | no data available[4] | no data available[4] |

Notes:
1) All five firms are regarded as being the five major producers of machine tools occupying the largest share of the machine tool market according to an interviewed executive of Korea Machine Tool Manufacturer's Association.
2) Firm B is an automobile maker and also a machine tool producer. Machine tool production is made in the machine tool division. When the machine tool division started producing machine tools, 5% of recruitment was made internally.
3) Firm C belongs to the *Chaebol* group, which has an automobile producing company. Firm C started producing machine tools before the *Chaebol* group entered into automobile production.
4) Range of proportion of internal recruits was asked during an interview because interviewee could not answer with an exact proportion. The number is the average of the range.
5) This firm started machine tool production in 1952.
6) Because of confidentiality, the firm's name was randomly given.
Source: Interviews in 1994.

Table 1 shows that in general these automobile affiliated firms did not rely on the workforce with knowledge accumulated from experience in the automobile makers by the time of entry. In two (A and C) of these three firms there was no internal workforce with experience of use and repair of machine tools. Firm B had 5 % of its internal recruits with experience of use and repairof machine tools. This shows that in the case of automobile affiliated entry firms, which are advanced user entry firms, the entry was not made on the basis of accumulated skills from using machines. These automobile affiliated entry firms, which are large firms, invested heavily in modern production equipment and technical licensing over during the 1970s and

80s. Entry firms' recruitment involved recruitment of that workforce that needed to be trained for "modern"machines through technical licensing and contacts with foreign sources of knowledge. Further discussions on this aspect aremade in the last part of this section. As shown in Table 1, it is difficult to argue that automobile affiliated machine tool makers emerged as a result of accumulated knowledge from experience of using machines. In other words, advanced users played a limited role as a source of knowledge, being a pool of recruitment.

### *4.2.2. Workforce Migration of Other User Entry Firms*

The possibility was recognized that there could be other user firms apart from automobile makers. Therefore, thisstudy analysed workforce migration of other user entry firms. Here, what is user entry firms refers to those firms from the industrial sector that do not produce machines, but entered into production of machine tools. This study looked at whether there were user entry firms (other than automobile makers) among the surveyed firms during the 1976 to 1994 period. There were nine userentry firms, which were 24% of the surveyed firms. This study examined whether user entry firms relied on an internal workforcewith knowledge of machine tools that was accumulated through usage experience when they entered into machine tool production. Among nine user entry firms, four are user firms that entered into machine tool production on the basis of usage experience. The range of the proportion of the workforce having usage experience was between 40% and 100% in these firms: 1 firm (40-60%), 2 firms (60-80%), and 1 firm (80-100%). These user firms were the ones engaging in the production of ship engine, tools, bearings andmoulding. These user firms included both large and small firms. This study could not identify the factor differentiating this group of firms from the other five user entry firms.

The other five user entry firms do not belong to the type "user firms on the basis of experience of use" (see Table 2), which includes: entry on the basis of poor experience (3 Firms) and entry on the basis of other machine tool makers (2 Firms). Therefore, it can be concluded that half of the user entry firms had an internal workforce with experience of use. None of the nine user entry firms surveyed belonged to the top five machine tool producers, and all of the entry firms were small volume producers of machine tools. This contrasts with the automobile affiliated user entry firms, which are large volume producers.

**Table 2:** Considered Best Estimate of the Source of Recruitment of User Entry Firms

| Type of entry (Number of Firms) | Source of recruitment for the highest range of the proportion (range of the proportion) | Other sources of recruitment | Range of proportion of internal workforce with experience of use |
|---|---|---|---|
| Entry on the basis of usage experience (4 Firms) | Internal workforce with experience of use (40-100%) | Other machine tool makers, internal workforce with no experience of use, recruitment of new graduates or school leavers | 40-100% |
| Entry on the basis of poor experience (3 Firms) | New graduates or school leavers (40-80%) or internal workforce with no experience of use (40-60%) | Other machine tool makers, internal workforce with experience of use, recruitment of new graduates or school leavers | 0-20% |
| Entry on the basis of other machine tool makers (2 Firms) | Other machine tool makers (40-60%) | Internal workforce with no experience of use, internal workforce with experience of use, recruitment of new graduates or school leavers | 0% |

Notes: 1. Sources of recruits were asked in the questionnaire at the interviews are as follows: other machine tool makers, new recruitment of graduates or school drop outs, internal recruitment with experience of use, internal recruitment without experience of use, other.

2. Because interviewees had difficulty in recollecting exact proportion of recruits, they were asked to give their best estimate. The range of the proportion on a scale of 5 was suggested, and the following choices were offered: 0-20%, 20-40%, 40-60, 60-80, 80-100%.

3. Range of proportion shows the widest range where all the estimated ranges of the source of entry firms are included according to the type of entry.

### *4.2.3. Migration of Key Engineers to All the Surveyed Firms*

The study examined the origins of the key engineers in charge of R&D or production in the producer firms. The results showed that in roughly half (48.6%) of the surveyed firms key engineers were originally from other machine tool producers included in the survey, while 5.4% came from machine tool users, such as automobile makers, automobile component makers, electronics product producers and electronics component makers. This shows that the user sector is not a seed bed for nurturing the key engineer for making machine tools.

### *4.2.4. Skills Accumulated from Experience of Use: Outdated*

The machines produced based on experience of use are low in quality, and could not compete with imported machinesin the period of speedy catching up. From the middle of the 1970s, machines that were needed were imported due to the export drive and the government's investment in the military. What domestic producers had to achieve was imitative production of these machines at a lower price. Large Domestic firms invested to produce such modern machines drawing upon various sources of knowledge that included technical licensing. Therefore, the machines that could be produced from the skills accumulated from experience of use were outdated machines. According to KOMMA (1991), an interviewee from the Korean railway arsenal said"Until twenty years ago, we could produce almost every machine by ourselves. We made lathes, but the development of technological capability of firms outside was so rapid that in-house made products lost competitiveness…" (KOMMA, 1991, p. 148).

In the past, a machine tool could be made by the workforce having usage experience. In 1946, a worker who accumulated skills to produce machines from his experience of use in the iron factory could make a machine after three years of development effort from his experience of use (KOMMA, 1991, p. 138-140). In the period of slowly catching up, machines produced out of usage experience could still be useful. In the fast catching up period of the 1970s and 1990s, up-to-date machines were produced by technical licensing, joint venture, and in collaboration with a producer of the numerical controller, which is an integrated computer for controlling a machining process. Skills that were necessary to produce "modern machines" were morethan reverse engineering. In order to produce up-to-date Numerical Control (NC) machine tools or mechanical machine tools, engineers had to access knowledge from other NC controller firms or licensors. Thus, the internally recruited workforce was of limited value to the user entry firms (See Table 3).

In conclusion, the extent of migration of workers from users to producers implies that users are a limited source of the technological knowledge necessary to develop a machine. User entry is presumed to have contributed to intensifying competition and, therefore, enhancing competitiveness (Lee, 1993). User entry can result in vertical disintegration of user firms. However, thisshould not be interpreted as a result of spill-over of knowledge, which has been accumulated from experience of use of machine tools in the user factory. The reason is that advanced user firms, such as automobile makers, do not enter into machine tool production because of their accumulated knowledge out of experience of use. Roughly half of the other user entry firms (excluding automobile makers) entered into machine tool production without any accumulated technological capability. The proportion of key engineers who nurtured their capability to develop machines from experience of use was minimal. The skills that existed to be nurtured in the user were outdated. Therefore, the proposition that these firms were a source of knowledge cannot be supported in the majority of producer firms.

This finding differs from the findings in the literature for advanced countries where users

**Table 3:** Skills and Possibility of Machine Making out of Use Experience

| Period | Korea in the 1940s and 50s | Korea in the latter 1970s and early 1990s | Advanced Countries from the 1850s to the 1950s |
|---|---|---|---|
| Type of machine tools | Outdated machine model, produced with craftsmanship, which used to be produced in advanced countries in the past-conventional (mechanical) machines | Up to date machine model for import substitution: NC machine tools and conventional machine tools with modern production system | Mechanical machines with craftsmanship based production |
| Characteristic of the period | Lagging behind period | Fast catching up Period | Period of leading industrial dynamism |
| Knowledge Base | Mechanical engineering | Mechanical engineering, Electro-mechanical engineering | Mechanical engineering |
| Method of learning to produce machines | Reverse engineering | Reverse engineering, technical licensing, joint venture, collaboration with NC controller maker (in the case of NC machines) | Reverse engineering, R&D |
| Possibility of making machines out of machine use experience as an individual | Engineercould learn to produce a machine using reverse engineering techniques. There is a case of an engineer who could make machines in 3 years using his usage experience (KOMMA, 1991) | In the case of NC machine tools, an engineer needs to collaborate with NC controller makers or learn to produce through technical licensing. In thecase of up-to-date machine tools, an engineer needs to learn through various sources of knowledge, including technical licensing (Lim, 1997). | Engineers could make a machine out of machine experience of use. Rosenberg (1976) |

enter into production based on their accumulated knowledge gained from experience in using machines (Rosenberg, 1976; Lee, 1993; Sugiura, 1994) (See Table 3).

### *4.3. Users as a Source of Knowledge through Providing Technological Capability Support*

The following section examines the role of the user as a source of product development knowledge, through providing technological capability support, which is relevant to proposition 2-1 and 2-2; providing prototypes, blue-prints and patents; and being called upon to provide staff level technical assistance. This section examines: (1) cases where advanced users helped producers in the process of developing a new product through the transfer of designs, prototypes, blue prints, patents or through staff seconded to give technical assistance; (2) survey results on whether users generally are regarded as being important to producers as providers of blue-prints, patents and staff seconded to give technical assistance; and (3) whether users of special purpose machines provide a more active technological capability support to producers than those of general purpose machines.Examination of cases of the flow of product development knowledge from users was carried out to see whether the most active form of the *customer active paradigm,* i.e. where users develop designs for production equipment and sometimes transfer them to producers, can be found in the Korean machine tool industry. This study finds that automobile makers, as advanced users, do not provide product development knowledge through the flow of prototypes, blue-prints or patents or technical assistance to producers in the process of product development.

First, interviews were conducted with four machine tool producers who are affiliates of the conglomerate (*Chaebol*) group and, therefore, who have close relationships with automobile makers in the same conglomerate group. Interviews were also conducted with engineers in the two majorautomobile makers. The interviews revealed that no instance of transfer of product development knowledge from a producer to a user was found in the machines designed for common groups of users - general purpose machine tools - in other words, general purpose machine tools, the dominant type of machines produced in Korea.In special purpose machine tools,[7] there is a flow of specifications, which includes drawings and rough descriptions of the machines to be developed, but the design process is carried out by producers, not by users. The details of specifications include technical specifications of existing imported machines. Further details are represented in Table 6. This finding reveals that even under the most favourable circumstance where users and producers have close relationships in the same conglomerate group, the transfer of completed product design is rare.

By means of a survey, this study looked at whether users generally are regarded as an important source of product development knowledge through the transfer of blue-prints, patents and technical assistance. Approximately a fifth (20.6%) of the surveyed producer firms responded that users are "important" or "very important" in general purpose machine tools. Just under a third (30%) of the firms in the special purpose machine tools area made the same response. These cases and the above survey results reveal that to the majority of producers, user firms are not important as a source of product development knowledge.

The study also examines whether users of special purpose machine tools were more likely to be a source of product development knowledge for producers than the users of general purpose machine tools. The rationale behind this is that if users are capable of producing equipment for their production process, they should be able to provide technological capability support to producers for the production of special purpose machine tools. The users of special purpose machine are more likely to have the technological capability needed because they are more likely to be aware of the problems of their own production and more likely to have experience

7) According to statistical data, less than 10% of machine tools produced in Korea are special purpose machinetools in which the main body is specially designed.

in trying to solve problems. This study examines whether there was a significant difference between users of special purpose machine tools and users of general purpose machine tools in the transfer of product development knowledge. An KRUSKAL-WALLIS ANOVA analysis of the survey responses of those producers producing special purpose machine tools and those producing general purpose machine tools was made. The survey questionnaire focused on whether producers regarded users as important or veryimportant in terms of provision of prototypes, blue-prints and patents, and through calling upon the staff for technical assistance. The result is a P value 0.18>0.1.[8] This result clearly shows that there is no evidence that the more specialised the machine the greater the flow of product development knowledge to producers. This is different from what was expected. This shows that users of machine tools do not have the technological capability to devise machine tools in order to solve problems of their own production process and, thereby, transferring their devised design to producers.

All the above results show that the flow of knowledge from users to producers through prototypes, blue-prints, patents and technical assistance is limited; in other words, proposition 2 is not supported because (1) automobile producers, as advanced users, do not provide product development knowledge, (2) the majority of producers do not regard users as a source of technological capability support in product development, and (3) special purpose machine tool users, who are expected to have accumulated higher technological capability for solving problems and more likely to transfer their knowledge of devising machines than general purpose machine tool users, do not provide significantly higher technological capability support in product development knowledge than do the general purpose machine tool users (proposition 2-2).

These empirical results do not support the three propositions put forward. The study of the Korean machine industry by Ha (1997) gives indirect support to the finding on the machine tool industry. His study shows that the limited flow of knowledge from users to producers is not confined to the case of the machine tool industry. According to the survey result of 187 Korean machine producers in 1997, in answer to the question why producer firms need to collaborate with users, 9.8% of the machine makers said that they collaborate with users to gain information about experience of use. The exchange of workforce in order to acquire technology from users was confined to 6.7% of machine producers while 52.8% used exchange of personnel to acquire information onthe market and product. The survey results show that user-producer collaboration for an access to technological knowledge is rare. The dominant reason for user-producer collaboration is marketing with 52.2% of respondents said that they collaborated

8) 34 firms that produce general purpose machine tools. 30 firms that produce special purpose machine tools.

with users to acquire information on user needs of the product and 34.8% to remove uncertainty about the sales of products.

As the trickle down effect of product design knowledge is weak, domestic firms need to learn to make machines through accessing various external sources of knowledge. According to the survey results, the majority of machine tool maker firms, 54.3%, regarded technical licensing as the main source of technological capability support, and 17.1% of the firms responded that public research institutes were the main source, while 14.3% of them regarded foreign component makers as the main source and 14.3% foreign buyers. Table 4 shows various external sources of technical information. However, this does not mean that interactive learning is unimportant. Users are important in terms of their requirements. The survey result clearly shows that in the case of general purpose machine tools, 50% of producers regarded those requirements,[9] which are specifications from users, as being important compared to 66.7% in special purpose machine tools. To understand user needs, interactive learning with users isimportant. In particular, requirements of advanced users, e.g. internationally active firms, provide a stimulus to producers for developments. When advanced users order a higher quality machine than that routinely being produced,[10] domestic producers are challenged to develop such a machine. Producers could employ the requirements of their users as a guide to productdevelopment. Therefore, interactive learning with users is important for domestic producers to upgrade their technological capability.

### *4.4. Users and Learning Patterns of Domestic Firms*

Korean firms needed to learn to produce up-to-date machines through accessing external knowledge sources other than users because the technological capability support from users is limited. Given the poor trickle down effect from users, domestic firms need to learn to make machines through accessing various external sources of knowledge. A firm's learning patterns in the process of product development can be divided into two types. One is learning through

9) Requirements for general purpose machine tools are about customization of the machine tool for an individual user company.

10) For upgrading technological capabilities of producers, advanced users' role as a provider of requirements for higher quality machine is important. According to an interview with H automobile, when a new plant is established, orders for machines to be purchased are divided into three groups: first group to be imported (most advanced machines), second group to be ordered from domestic producers (least advanced machines), and third group to be analysed to decide whether to order from domestic producers or to import (middle range machines). This third group of machines are those that have not been made by domestic producers but domestic producers have the potential ability to make. When the third group machines is ordered from domestic producers, these domestic producers get the opportunity to meet the challenge to develop a higher quality machine andrequirements from the user are a guide for product development.

technical licensing orco-operation with public research institutes. This pattern is observed in general purpose machine tools, which are now mostly NC machine tools. This pattern is also observed in special purpose machine tools that are made through technical licensing.[11] The survey result reveals that 54.3% of the respondent firms regard technical licensing as a major source of knowledge and 17.1% the public research institute. In this case, user-producer interaction in the process of product development is limited because the producer's learning is focused on learning to develop a machine by imitating a foreign model.

**Table 4 :** Results of the Questionnaire-What Are the Two Main Sources of Technical Information in Developing a New Product?

(unit: %)

| Sources | Percentage of respondents |
|---|---|
| Reverse engineering | 24.3 |
| Exhibitions | 21.6 |
| Technological licensing | 21.6 |
| Journals and manuals | 18.9 |
| Informal exchange of Information | 5.4 |
| Public R&D capacities | 2.7 |
| Component maker | 0.0 |
| Trade association meetings | 0.0 |
| Foreign buyers | 0.0 |
| Other | 5.4 |
| Total | 100.0 |

The case of firm H highlights a firm's learning processes in relation to external sources of knowledge. Figure 4 reflects the accumulated technological capability of firm H. The firm utilized technical licensing when it entered into production of a new type of product or a new series of products, which consist of models of the same type of machine tools (see Table 5). For example, in NC lathes, it entered into a technical licensing agreement for the first model in 1978. After that, all subsequent NC lathes (two series, ten models) were developed using the firm's own capability. In machining centres, which consist of three series and ten models, the firm entered into technical licensing (four models) when it first started toproduce a vertical machining centre and a horizontal machining centre. These licensed models were the first models in the series. Subsequently, six other models in the same series as the licensed model were

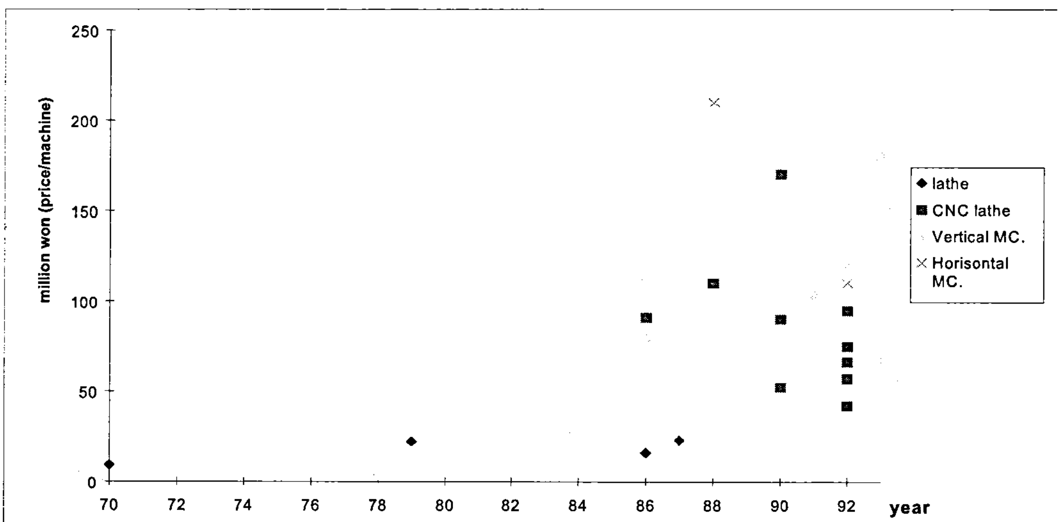
11) According to KOMMA(1993), technical licensing of special purpose machine is 2 out of 57 technical licencesbetween 1976-1993. These technical licences were agreed at the end of the period 1976-1993: One in 1989 and the other in 1991.

developed using the firm's own capability. Some of the subsequent models were the result of extending the size of the machine tool. According to one engineer whowas interviewed, these were not completely straightforward as additional technical knowledge was required to develop an extended machine tool. The firm develops machines based upon a user's needs gleaned through a market survey, analysis ofuser feedback, and trends in competing products that include imported machines. In designing general purpose machine tools, user-producer interaction is limited.

**Table 5:** Number of Models Developed: Firm H

| Type of machine | Number of total models | Models developed from technological licensing | In-house R&D models |
|---|---|---|---|
| NC lathe | 11 models (2 series) | 1 model | 10 models |
| Machining centre | 10 models (3 series) | 4 models | 6 models |

Notes: These models do not represent the complete range of available models in this company. These models have been identified from interviews and from product lists as new models (KOMMA, 1994). There may have been other less successful models that disappeared from the product list of the company. If developed without technical licensing there would be no recorded material available on such models.
Source: Interview, 10 Nov. 1994.




Notes: 1) Technological capability in terms of the price per machine developed by firm H, 2) The price of products on the product list of (KOMMA 1994) at the time of interview on January 27, 1995, and 3) MC means machining centre.
Source: Interview on 27 January, 1995

**Figure 4 :** The Transition of Technological Capability of Firm H

The other type of learning is through interacting with users. Users give the specifications of a machine to be developed and the producer produces the machine. This learning is observed mainly in special purpose machine tools. In this case, user-producer interaction is intensive. According to the survey analysis, the contribution in providing specifications of users ordering special purpose machine tools differs significantly from that of users ordering general purpose machine tools. The user's role is much more important when providing specifications for special purpose machine tools.

The KRUSKAL-WALLIS ANOVA analysis result is a P value $0.07<0.1$.[12] The contents of specifications from automobile makers in both types of special purpose machine tools in the case of firm H, are presented in Table 6. In a special purpose machine tool, the specifications from the user include (1) modifications to an existing model of a general purpose machine tool, such as tool change, adding components, and other design changes for making the NC machine fitted to the automation line and (2) building an automated production line by linking more than two machines. In an originally special purpose machine tool, the most important information that the user passes on to the local producer is the technical specifications relating to imported machines, which have been used by the user firm, together with additional specifications to optimise performance as a result of experience of use. For example, in one case, to improve the level of maintenance, an automobile producer suggested a special purposemachine tool with a ceramic coating instead of the heat treatment of the imported machine according to an interviewee of firm H. In developing a special purpose machine tool, firm H might face problems. The machine tool producer can solve these problems by importing components[13] and automation related equipment or by gaining access to other external sources of knowledge. In this process, users introduce foreign producers of components, whom they have gotten to know through interaction with them, to domestic producers.

This interactive pattern is specific to the catching up country and could be the basis for further research. What is specific to the catching up country is that the specifications from the user are likely to be requests to make a machine by copying animported one. All of these learning patterns are involved in a firm's learning process. A firm's interactive learning with users is expected to be more important in the future because domestic user firms will need more customized machines to improve their productivity, and domestic producers must be able to meet the user demands on the basis of their accumulated technological capability and interaction.

12) Thirty-four firms producing general purpose machine tools. Thirty firms producing special purpose machine tools.
13) For example, in 1983, a special chuck was ordered from a Japanese company to make a special purpose machine tool. (Interview 27 March. 1995).

**Table 6:** Specifications and Related Information from Automobile Makers in Both Types of Special Purpose Machine Tools

| Type of special purpose machine tools | Customisation process | Specifications and related information from automobile makers |
|---|---|---|
| Specialised machine tool | Minor modification of machine design of a general purpose machine tool to meet user specifications: utilise main body of a general purpose machine tool | -Specifications on modification of existing machine design: tool change, adding components, other design changes for making the NC machine fitted to automated production line building an automated production line by linking more than two machines<br>-Automation related information: information on organising production process |
| Originally special purpose machine tool | Develop a machine in response to user specification: main body specially designed to meet user specification | -Specifications on substitution of imported machines: technical specifications of existing imported models and additional specifications to optimise performance from the experience of using it<br>-Introduction of foreign component makers |

Source : Interview on 27 January, 1995.

## 5. Conclusions

The purpose of this paper is to analyse the extent to which users in Korea contribute to the generation of technological capabilities for developing products in the machine tool industry through the knowledge "trickle down" effect. The finding is that there is a limited trickle down effect of technological knowledge from users. User entry is not driven by accumulated capability from experience of use: efficient usage of machines, repairing, modifying and inventing machines. Users provide limited assistance to producers in transferring their accumulated knowledge. This finding differs fromthe findings in the literature relating to advanced countries where the active roles of users as a provider of knowledge was discussed (von Hippel, 1978, 1988). The finding in the Korean machine tool industry may reflect the fact that users have not accumulated the technological capability to solve problems in the production process to the extent of inventing production equipment. In addition, the case of Korea may also reflect the fact that machines that could be produced out of experience during the catching up period of the 1970s-1990s are outdated. Korean producers have been moving into producing up-to-date machines, including NC machine tools through various sources of knowledge. Therefore, skills accumulated from experience of use are of limited value for producing up-to-dated machines.

With regard to interactive learning between users and producers, this study's finding reveals that users of special purpose machines have a significantly clearer role in providing specifications than users of general purpose machine tools, as can be expected from the stylized facts of existing literature of advanced countries. However, interactive learning through the flow of specifications is different from that in the advanced countries where (1) the user's role extends much further than provision of specifications, e.g. provision of prototypes of devised machines in the user factory and (2) specifications from users are for making creative machines to solve problems in the production process, which cannot be found in this study.

The policy implication is that because of the limited trickle down effect, user firms have a limited influence in leading the development of technological capability in the producers firms. Unless there are aggressive investments by producers who makeefforts to access sources of knowledge, further accumulation of technological capabilities by the machine tool producer is impossible. Therefore, a policy measure to stimulate aggressive investment in learning through access to various external sources ofknowledge is required. Another implication for policy is that stimulating co-operative R&D among machine users and producers does not result in productive outcomes. Users with only limited capability cannot contribute much to the R&D process. The best contribution users make is to provide specifications and comments about the machine to be developed. Policy measures to stimulate the trickle down of user knowledge are not expected to bear fruit until users have developed greater capabilities. This study's findings raise questions about the validity of policy measures needed to stimulate user entry into production. Newentrants would be desirable to increase competition in machine production (Lee, 1993). Considering that user entry is not necessarily entry on the basis of accumulated technological capability, it should not be treated differently from the entry of other firms.

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