TECHNOLOGY GAP APPROACH TO A DYNAMIC CHANGE IN WORLD MACHINE TOOL MARKETS : A PANEL DATA ANALYSIS

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Abstract

This paper applies the technology-gap trade theory to explaining radical changes in the competitive positions of countries in world machine tool markets over the last three decades. It develops the notion that the innovation gaps in machine tools among countries led to the inter-country differences in the competitive performance in the sector as well as in its user sectors. Since competitive advantage largely depends on a capability to improve, create and apply technology to market competition, a higher innovative performance in one country than another is closely related to a higher export performance. A higher innovative performance in machine tools is also associated with a higher competitive performance of the large areas of its user sectors, due to sectoral interdependences and externalities generated by machine tool innovations. The results of empirical investigation through a panel data analysis show that the international gaps in machine tool innovations appeared to have a positive significant relationship with the differences in the export performance of both the machine tool sector and its user sector across countries.

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(Key Words)

Technology gaps, machine tools, competitive advantage, innovativeness, competitive performance, dynamic fixed effect model, panel data analysis, user sectors, cross-country analysis.

1. INTRODUCTION

Until the early 1970s, the world machine tool industry could be regarded as a mature industry with highly stable position of each country. But from the beginning of the 1970s, the industry has become one of the most dynamic sectors in terms of market competition and technical innovation. A marked shift has taken place in the competitive positions of leading countries over the last three decades. The most pronounced feature relates to the US and Japan. There was a remarkable decline in the competitive position of the US, while Japan showed a spectacular performance in both innovation and exports with steady and rapid growth of its market share.

Why such a change has happened in world machine tool markets? Why some countries have become more competitive and others less competitive in machine tools? There is a long history of efforts to answer these economic questions in the form of international trade theories. These explanations are often conflicting, and there is still no generally accepted one. Conventional theories have related cheap and abundant labour to the competitive positions of so-called successful countries. They are, however, not adequate for explaining the recent changes in world machine tool markets.

The technology gap approach, developed by a number of innovation studies, has brought a new insight into why there has been a marked change in the market shares of leading countries. Technology is centered at the heart of the approach in explaining competitive advantage among countries. It has emphasized that innovation creates technology gaps across countries and is a fundamental source of competitive advantage among countries.

This paper attempts to apply the technology gap approach to explaining a dynamic change in world machine tool markets. It proposes the notion that the international gaps in machine tool innovations are a significant cause of the inter-country variations in the export performance of not only machine tools but also of their user sectors. It carries out a cross-country analysis by applying a dynamic fixed effect model with a panel data composed of 20 countries and 18 years.

2. TECHNOLOGY GAPS AND COMPETITIVE ADVANTAGE

There has been growing sentiment that traditional trade theories are not sufficient to explain what determines competitive advantage. This is particularly true in those sectors involving sophisticated technology and highly skilled employees. The inadequacies of traditional theories to elucidate competitive advantage have, therefore, called forth a new perspective. The need for a new paradigm has brought a new line of analysis in which technology is centerd at the heart of theories.

Several theories regarding the role of technology have been developed, which are generally referred to as 'new-trade theories'. They have started from relaxing the fundamental assumptions of the neo-classical theories and produced a plenty of quite interesting conclusions with respect to technology.[1] Their central contention is that differential rates of technical changes between countries dominate the determination of comparative advantage.[2]

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1) Among the necessary assumptions are, for example, the absence of economies of scale, the presence of perfect competition(nationally and internationally), full employment of resources, identity of production functions(and therefore also technical knowledge) and patterns of tastes in all countries concerned and the absence of tariffs and other barriers to trade(Sewart 1978).

2) For instance, Jones(1970), Graham(1979), Krugman(1986), Hughes(1986), Fagerberg(1988), and Greenhalgh(1990).

There has been another group of contributions which has been called as 'tech nology gap theories'.[3] Their main theme is that the success of countries in innovation is a crucial part of their competitive advantage as well as the evolution of their industries. They assume that technology changes continuously and unevenly creating gaps in technological capability across countries.[4]

These theories are general explanations, irrespective of sector-specific nature. There, however, must be a sectoral specificity of the importance of the technological gaps in justifying competitive advantage. In some sectors, wage gaps rather than technology gaps may affect a relatively high competitive advantage. In other sectors, technology gaps might be reflected in a high level of competitive advantage. According to Bell and Pavitt (1992), relative factor prices account reasonably well for competitive advantage in supplier-dominated sectors like textiles and agriculture. But at the other extreme in specialised-supplier sectors, competitive advantage tends to be dominated by technological superiority.

The machine tool sector on which this paper have a focus is likely to be a clear case in which persistent technological gaps across countries have determined international competitive advantage. The present positions of developed countries in world machine tool markets are likely to be a reflection of the cumulative results of past technical competence throughout their history. Whereas the weak positions of most developing countries may be a result of the limited and uneven accumulation of their technological capabilities.

There have been high rates of technical change over the recent three decades with the introduction of computer-controlled devices in the machine tool sector. Numerical control(NC) has been developed and applied for improving the func-

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3) For instance, Posner(1961), Stewart(1978), Soete(1978, 1980 and 1981), Rothwell(1981), and Dosi Pavitt ad Soete(1990).

4) For instance, Dosi, et al.(1990) postulated that the competitive advantage of each economy is determined by the technological gap of that economy.

tion of conventional machine tools. As the cost of control technology fell, conventional machine tools were automated and advanced by adopting NC devices. As a result, the lathe evolved into the machining centre, and the milling machine into the turning centre, and the industrial robot emerged (Tidd, 1991). Such machines have been linked to form flexible manufacturing cells and systems.

These developments have offered very real economic advantages to the user, and have required the input of high level scientific knowledge and engineering skills. Subsequent technical change has been rapid and continuous in the sector. Under these conditions, non-price factors, i.e. product performance, sales service, user education, delivery, rather than price factors are the major determinants of competitive advantage. Amongst non-price factors, performance-related factors such as superiority, reliability, efficiency, advanced design, etc. are the most important in determining competitive advantage(Rothwell, 1981).

The performance of machine tools is a result of technical development. It can be improved and updated through innovation. The innovation of machine tools is therefore the key element of their international competitive advantage. Machine tool innovations are also associated with the competitive advantage of their user sectors. The link between machine tool innovations and the competitive advantage of their user sectors can be explained in terms of sectoral interdependences and externalities generated by machine tools.[5]

Such externalities and benefits which the innovations of machine tools produce can be exploited by their user sectors and become an important source of their competitive advantage. Especially, externalities refer to flows of information and technical linkages or technical interdependencies between the machine tool sector and

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5) A number of innovation studies has noted this point. Fransman(1986) noted that the machine tool sector produces 'pecuniary externalities in the form of machinery that has been adapted, modified and improved to take into account local conditions, as well as non-pecuniary externalities in the form of manpower which has been trained to bring about such changes in machinery'

its user sectors. These interdependencies are a fundamental link between sectoral competitive advantage and the competitiveness of an economy as a whole(Dosi, et al. 1990).[6]

Consequently, it is theoretically concluded that a higher innovative performance in machine tools in one country than in another is one of important determinants of a higher competitive performance of machine tools as well as with their user sectors. Put in another way, there is a significant relationship between the cross-country gaps in machine tool innovations and the cross-country variances in the export performance in machine tools and their user sectors. This relationship incorporating the conventional determinant, unit labor costs, can be specified as follows:

$$MS_{mj} = f(PS_{mj}, LC_{mj}) \quad (1)$$

$$MS_{cj} = f(PS_{mj}, PS_{cj}, LC_{cj}) \quad (2)$$

where MS_{mj} is an indicator of country j's export performance in machine tools; PS_{mj} is country j's innovative performance in machine tools; PS_{cj} is country j's innovative performance in automobiles; MS_{cj} is country j's export performance in automobiles and LC_{mj} is country j's unit labor cost of its machinery sector; and LC_{cj} is country j's unit labor cost of its automobile sector.

3. CROSS-COUNTRY GAPS IN MACHINE TOOL INNOVATIONS

The machine tool industry has become one of the most dynamic sectors in technical innovation. The threats and opportunities presented by new technology

6) In connection with the vulnerable condition of developing economies with respect to such externalities and economic benefits, Rosenberg(1976) noted that the user sectors of machine tools in the labour-abundant developing economies possess 'a strong inducement to perpetuate labour-intensive techniques' and their economic activites tend to be preoccupied with 'wort-spreading arrangements'. Under this situation they contribute little to the development of the capital goods sector.

in the form of numerical control and competitive pressures that emerged in the 1970s have been strong stimuli to shaping the innovation dynamics of the industry. Driven by the dynamics, a marked shift has taken place in the innovative performance of countries. This section briefly looks at these changes with the percentage shares of US machine tool patents accounted for by nationals of various countries.[7]

The most striking change relates to Japan and the US. The Japanese level of US patenting remained until the 1960s among the lowest of the countries considered. It was only in the 1970s that her share started to grow. In the 1980s, Japan had overtaken the position of Germany, and became the largest foreign country patenting in the US. in 1988. This reflects the changing mix of Japanese technical activities from the assimilative to the innovative (Pavitt and Patel, 1988). Contrary to Japan, the local patent share of the US has consistently declined since 1963.[8] This implies that the technical strength of the US has deteriorated, presumably making her competitive position vulnerable to other countries.

The UK shows similar trends to the US. The UK share moved from being the second largest country patenting in the US. in 1963 to the behind Italy in 1988. The decline in the British share indicates that the UK has lagged behind those of other developed countries as far as innovativeness is concerned.[9] Germany also appears to have a slightly downward trend in spite of a radical

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7) The statistics of US patents granted to foreign nationals give an indication of the ranking of countries in respect to their innovative performance. They are regarded as an accurate reflection of changing antional shares of innovative activities. See Pavitt(1985, 1988a) and Dosi, et al.(1990) for the shortcomings and the robustness of the variable 'patenting in the United States' as proxy for the relative innovative capability of a country.

8) The similar trends were also derived from the examination of industry-financed R&D for the United States(Pavitt, 1980; Pavitt and Patel, 1988; Dosi, et al. 1990)

9) A number of attempts have been made to identify factors affecting the downward trends of the British innovative performance(e.g., Rothwell, 1979; Parkinson, 1981; Pavitt, 1980a, 1980b, 1982, 1988b)

restructuring effort (Guerrieri 1992).

Table 1 The distribution of US machine tool patents among countries

Country	'62-'72(%)	'73-'82(%)	'83-'92(%)	'62-'92(%)	Remarks
USA	75.16	60.41	49.47	62.32	- -
Non-US Total	100.00	100.00	100.00	100.00	
Germany	29.50	27.71	25.60	27.24	- -
Japan	10.27	20.49	35.39	24.40	+ +
UK	17.75	10.29	5.63	10.10	- -
Switzerland	5.77	5.06	4.39	4.94	- -
France	9.35	7.67	6.25	7.47	- -
Sweden	5.52	4.67	2.99	4.94	- -
Canada	5.90	4.79	3.88	4.67	- -
Italy	2.84	3.34	4.01	3.50	+ +
Austria	2.16	2.09	1.77	1.97	- -
Netherlands	2.19	1.83	1.55	1.80	- -
Australia	0.94	1.30	0.93	0.40	-
Belgium	0.85	0.86	0.53	0.71	-
Taiwan	0.00	0.22	1.64	0.77	+ +
Israel	0.15	0.23	0.30	0.24	+ +
Denmark	0.36	0.44	0.33	0.37	-
Finland	0.27	0.51	0.82	0.58	+ +
Spain	0.15	0.22	0.23	0.21	+ +
Mexico	0.12	0.20	0.08	0.13	-
Brazil	0.13	0.09	0.14	0.12	+
S.Korea	0.01	0.03	0.16	0.08	+ +
India	0.04	0.02	0.00	0.02	- -
Others	5.73	7.94	1.68	5.34	
S.D.	7.15	7.08	8.76	7.44	

Notes : The remarks indicate as follows : + : the share increased from the 1973-1982 period to the 1983-1992 period ; + + : the share tends to increase over the entire period ; - : the share decreased from the 1973-1982 period to the 1983-1992 period ; and - - : the share tends to decrease over the entire period.

Source : The US Patent and Trademark Office, Technology Assessment and Forecast Program Report, 1993.

While remarkable changes have taken place in the innovative positions of the major countries, the international gaps of innovations seems to have been widened. As shown in the Table 1, the results of cross-country comparisons show that it spreads unevenly across countries. The ten largest patenting countries have accounted for more than a 90 percent share on average. The international gaps in innovative performance, which can be measured by the standard deviation among countries, were slightly narrowed in the 1973-1982 period, but greatly widened in the 1983-1992 period. These trends indicate that innovation gaps recently tend to diverge among countries.

The innovative performance of these countries can be classified into three groups according to the changing patterns of US patent shares. First-group countries are those increasing their shares over the entire period : Japan, Italy, Israel. Finland, Spain among the developed countries ; Taiwan and South Korea among the developing countries. Japan has showed a high level of US patent shares. Other countries are at a relatively low level, but reveal consistent increases. They seem to have well responded to the changes in their technological strength.

Second-group countries are those that have a tendency to continuously lose their shares : the US, Germany, the UK, Switzerland, France, Sweden, Belgium, Canada, Austria, Netherlands and India. The level of innovative performance has been relatively high in these countries except for India, but consistently declining. Their technical strength may have deteriorated over the entire period. The last-group countries are those that showed upward trends in the 1973-1982 period but downward tendencies in the 1983-1992 period : Australia, Belgium, Denmark and Mexico. They seemed to have recently faced difficulties in maintaining their technical positions.

These groupings are limited only to the area of machine tools. A country whose innovative activities are weak in machine tools can be strong in other sectors. Nonetheless, the technological strength of the machine tool sector is likely to be closely related to national innovative capability, due to the close linkages between machine tools and a vast area of their user sectors. These patterns are unlikely to be changed or reversed in a short period of time due to the cumulative, irreversible and uncertain nature of technological activities.

4. A DYNAMIC FIXED EFFECT MODEL

To what extent are such innovation gaps among countries associated with their competitive positions? Do the changes in the innovative performances of countries in machine tools have a significant link with the competitive performances in their user sectors? These questions can be tackled empirically with the aid of cross-country time-series data on some performance measures in the machine tool industry and its user sector. To test these questions, the functional forms specified in equations (1) and (2) can be transformed into an estimable econometric model as follows:

$$MS_{mjt} = (\alpha_j + MS_{mj,t-1}\ \alpha_{1j} + PS_{mjt}\ \alpha_{2j} + LC_{mjt}\ \alpha_{3j} + u_{mjt} \quad (3)$$

$$MS_{cjt} = (\beta_j + PS_{cjt}\ \beta_{1j} + PS_{cj,t-1}\ \beta_{2j} + PS_{mjt}\ \beta_{3j} + PS_{mj,t-1}\ \beta_{4j} + LC_{cjt}\ \beta_{5j} + u_{cjt} \quad (4)$$

$$j = 1,\ 2,\ 3,\ 4,\cdots\cdots\cdots,\ N \text{ and } t = 1\ 2,\ 3,\ 4,\cdots\cdots\cdots T$$

where MS_{mjt}, MS_{cjt}, PS_{mjt}, PS_{cjt} and LC_{mjt} and LC_{cjt} represent the same variables as stated in equations (1) and (2), but a time dimension is incorporated; $MS_{mj,t-1}$ and $MS_{cj,t-1}$ are lagged dependent variables for MS_{mjt}, and MS_{cjt}; α_j denotes a constant term for jth country which is equal to $\alpha + \mu_j$ in which α is the mean intercept, and μ_j is the difference from this mean for jth country; β_j, β_{1j}, β_{2j}, β_{3j} indicate the elasticities of the competitive performance(MS_{mjt}, MS_{cjt}), the past competitive performance ($MS_{mj,t-1}$, $MS_{cj,t-1}$), innovative performance (PS_{mjt}, PS_{cjt}) and unit labor costs (LC_{mjt}, LC_{cjt}) and u_{jt} denotes a stochastic error component.

The specification of equation (3) incorporates dynamic effects in that the lagged dependent variable plays a role of an explanatory variable. As an estimation method, we applied a dynamic fixed effect model in the panel data analysis. The rationale behind using a dynamic fixed effect model to test empirically the technology gap explanation are worth mentioning. Firstly, as well acknowledged, technological change is cumulative and innovation at present is affected by innovation in the past. This cumulative nature can be incorporated and captured in the lagged term.[10] .

Secondly, the panel data analysis enables he distinction of county-specific effects from time-specific effects. The country-specificity has special implications in this paper since technological change varies from country to country. Equation (4) specifies that export performance of the automobile industry is affected by innovative performances both in its own industry and in the machine tool industry, and by labor cost as well.

5. PANEL DATA AND ESTIMATION

5.1. Data and Variables

The relationship outlined above was empirically examined on cross-country and time-series data, namely a panel data covering the 20 countries and 21 years for the machine tool industry and 18 countries with 18 years for the automobile industry. The two most commonly used models for a panel data are fixed effect and random effect models. Since data are highly exhaustive, in other words, data cover almost all major countries exporting machine tools and passenger cars to the US, we adopted the fixed effect model.[11]

When a dynamic model is estimated with a panel data, the usual least square

10) It can be shown that successive manipulation of the dynamic term will give an equation with all terms of independent variables at each point of time and an initial term of dependent variable. This will imply in equation(3) that innovative performance, and unit labor cost, at all periods will affect the competitive performance at present.

11) The appropriate estimation method for the dynamic fixed effect models depends upon whether μ_i is assumed to be fixed or random. If it is assumed to be fixed, the estimation of the models

methods do not lead to consistent estimates for the parameters. These inconsistencies are due to the asymptotic correlation between the lagged dependent variables and the disturbances. A traditional way to tackle this problem is to use an instrumental variavles estimation method.[12]

The data used for the analysis cover the 1973-1992 period, which can match all four variables for 20 countries. Our analysis did not use updated statistics due to the lack of recent data. But, it is not likely to matter because our aim is to provide a corroboration of the significance of the international gaps in machine tools innovation in shaping the cross-country variations in the competitive performance of both machine tools and their user sectors. All of these variables are calculated to be mixed indexes of relative performance values taking account of the size of the manufacturing sector of each country in terms of employment.

Six variables constructed by this procedure are as follows. The first two variables are each country's relative share of US patents in machine tools (PS_{mjt}) and in automobiles (PS_{cjt}). These variables are used as a proxy for the innovativeness of each country. The second variable is each country's relative share of machine tool exports to the US (MS_{mjt}). The third variable is each country's relative share of automobile exports to the US (MS_{cjt}), which stands for each country's competitive performance in the user sectors of machine tools. They are normalised by the number of employees in the manufacturing sector in order to control the size of each country. The last two variables are each

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with fixed effects is preferred. If it is assumed to be random, the use of random effects is demanded. The choice between the fixed effects and the random effects depends partially upon the relationship between the μ_j and independent variables. The Hausman test can be applied to test the relationships and to decide appropriate method to the analysis. The Hausman test does not preferably discriminate between these two models. Therefore we applied the fixed effect model based on the empirics of sample exhaustiveness.

12) For more detailed discussion, see Sevestre ad Trognon(1992). A brief outline of the instrumental variable method for the analysis of panel data is given in the appendix.

country's unit labour cost (LC_{mjt}, LC_{cjt}) in the machinery sector and in the automobile sector. These six variables are functionally defined as follows:

$$MS_{mjt} = MSM_{jt} / (N_{jt}{}^{*} (MSM_{jt}) \qquad (5)$$

$$MS_{cjt} = MSC_{jt} / (N_{jt}{}^{*} (MSC_{jt}) \qquad (6)$$

$$PS_{mjt} = PG_{mjt} / (N_{jt}{}^{*} (PG_{mjt}) \qquad (7)$$

$$PS_{cjt} = PG_{cjt} / (N_{jt}{}^{*} (PG_{cjt}) \qquad (8)$$

$$LC_{mjt} = W_{mjt} / e_{jt} \qquad (9)$$

$$LC_{cjt} = W_{cjt} / e_{jt} \qquad j = 1, 2, 3, 4, \cdots\cdots, N \qquad (10)$$

where MSM_{jt} is country j's export sales in machine tools to the US at a year t ; MSC_{jt} is country j's export sales in automobiles to the US at a year t ; PG_{mjt} denotes country j's patents granted from the US in machine tools at a year t ; PG_{cjt} denotes country j's patents granted from the US in automobiles at a year t ; N_{jt} indicates the number of employees in country j's manufacturing sector at a year t ; W_{cjt} is country j's labor wages in the automobile sector in local currency ; W_{mjt} is country j's labor wages in the machinery sector in local currency and ej is the exchange rates of country j to the US dollar at a time period of t.

5.2. Estimated Results

In the analysis, the dependent variable (MS_{mjt}) was regressed against three explanatory variables (PS_{mjt}, MS_{mjt-1}, LC_{mjt}). Since a lagged dependent variable is included as an explanatory variable, the usual OLS method will not give consistent estimates. Instead, an instrumental variable estimation method is adopted.[13] The estimates of the first two regression coefficients appeared to be positive and statistically significant at a 2 percent level in a two-tail test.

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13) A brief outline of the instrumental variable method for the analysis of panel data is given in appendix.

This implies that innovative performance and past export performance can be important elements of present export performance.

The estimate of regression coefficient of the labor variable (LC_{mjt}) turned out to be negative and statistically significant but the magnitude is very low compared with those of innovative and export performance variables. This indicates that the labor-cost advantage may not be relativeiy so important in achieving the export performance of machine tools.

Table 3 presents the estimates of the fixed effects by countries. 15 countries out of 20 countries turned out to have positive fixed effects, among which four countries (Japan, Israel, Switzerland, Singapore) are significant at a 2 percent level ; Italy is significant at a 5 percent level and the remaining four countries (the UK, Belgium, Sweden, Spain) are significant at a 10 percent level. France, Austria, Netherlands, Australia and Finland have negative fixed effects but they are statistically not significant except for Australia which is significant at a 10 percent level. One thing to note is that four countries having significantly high fixed effects: Japan, Israel, Switzerland, Singapore tend to have a strong innovative performance in machine tools

Table 2 Estimation Results of the Model (3) (Dependent Variable : MS_{mjt})

Explanatory Variable	Coefficients	t-values
$MS_{mj,t-1}$	0.532	31.126***
PS_{mjt}	0.118	14.814***
LC_{mjt}	-0.008	-10.626***
R^2	0.999	
n	420(20×21)	
F	55720***	

Notes : *** indicates significance at a 2 percent level ; ** indicates significance at a 5 percent level ; * indicates significance at a 10 percent level.

In order to analyze the effects of the innovative performance in machine tools on the export performance of their user sector, the automobile industry, the dependent variable (MS_{cjt}) was regressed against three independent variables (PS_{cjt}, PS_{mjt}, LC_{cjt}) and two lagged independent variables ($PS_{cj,t-1}$, $PS_{mj,t-1}$). Using the panel data composed of 18 countries and 19 years, we estimated the fixed effect model. The estimation results are not satisfactory in that the innovative performance in the automobile industry seems not to have significant influence on its export performance while the innovative performance in the machine tool industry has a statistically significant positive effect on the export performance of the automobile industry.

Table 3 Estimated Fixed Effects by Countries (Dependent Variable : MS_{cjt})

Countries	Coefficients	t-values	Countries	Coefficients	t-va lues
Germany	*0.582*	*1.287*	*Australia*	-0.636	-1.656*
Japan	1.314	3.395***	Belgium	0.534	1.701*
U.K	0.516	1.573*	Israel	1.788	4.247***
Swiss	2.786	4.940***	Denmark	0.111	0.331
France	-0.236	-0.733	Finland	-0.225	-0.697
Sweden	0.924	1.730*	Spain	0.454	1.566*
Canada	0.139	0.246	Mexico	0.045	0.162
Italy	0.654	2.050**	S. Korea	0.204	0.734
Austria	-0.312	-0.808	Hong Kong	0.020	0.070
Netherlands	-0.359	-1.006	Singapore	1.664	5.660***

Notes : *** indicates significance at a 2 percent level ; * indicates significance at a 5 percent level ; * indicates significance at a 10 percent level.

As an alternative model specification, we assumed error terms to be autoregressive of order one, and re-estimated the model. As shown in Table 4, the estimation results seem to be more reasonable in that the innovative performance in the car industry has the most significant positive effect on its export performance and that the innovativeness in the machine tool industry also has a significant positive effect but with smaller magnitude. In all cases, the labor cost variable does not show any significant impact on export performance.

Table 4 Estimation Results of the Model(4) (Dependent Variable : MS_{cit})

Explanatory Variable	Fixed effect model		Fixed effect model(AR1)	
	Coefficients	t-values	Coefficients	t-values
PS_{cit}	-0.382	-1.704*	0.185	0.799
$PS_{ci,t-1}$	0.313	1.438	1.183	5.672***
PS_{mit}	0.167	2.028**	0.391	4.799***
PS_{mit-1}	0.146	1.719*	0.427	5.236***
LC_{cit}	-0.004	-0.229	-0.017	-0.740
R^2	0.965		0.877	
n	342(18×19)		324(18×18)	
F	426.7		105.7	

Notes : (1) *** indicates significance at a 2 percent level ; * indicates significance at a 5 percent level ; * indicates significance at a 10 percent level.

Table 5 shows the estimates of the fixed effects by countries. Ten countries *out of 18 countries turned out to have a positive fixed effects,* among which nine countries are statistically significant. Germany, Japan and Sweden have been well known as countries having an innovative and competitive car industry. Canda, Mexico and South Korea have also built a relatively strong automobile industry by taking advantage of their proximity, openness and pricilege to the large US car market. They have shown a good fit for the relationship between the innovative performance of machine tools and the export performance of automobiles.

On the contrary, eight countries(the UK, Switzerland, France, Austria, Netherlands, Australia, Denmark and Finland) have negative fixed effects. Out of these countries, Switzerland shows the most statistically significant neative country effect. The UK, France, Italy, Denmark, Spain, Hong Kong and Singapore do not show any statistically significant country effects.

Table 5 Estimated Fixed Effects by Countries (Dependent Variable: MS_{cij})

Countries	Coefficients	t-values	Countries	Coefficients	t-values
Germany	0.761	1.675*	Netherlands	-0.541	-1.799*
Japan	2.884	7.506***	Australia	-0.444	-1.297
UK	-0.039	-0.147	Denmark	-0.231	-0.866
Swiss	-1.550	-2.819**	Finland	-0.365	-1.419
France	-0.108	-0.401	Spain	0.071	0.350
Sweden	1.580	2.857**	Mexico	1.328	6.954***
Canada	17.424	27.430***	S. Korea	0.308	1.602*
Italy	0.125	0.505	Hong Kong	0.001	0.005
Austria	-0.827	-2.393**	Singapore	0.044	0.226

Notes: *** indicates significance at a 2 percent level; ** indicates significance at a 5 percent level; * indicates significance at a 10 percent level.

These regression results highlight the significance of the international gaps with regard to the cross-country differences in the export performance in machine tools as well as their user sectors. The results of our analyses are by and large consistent with some of the past empirical studies which have conducted intra-sectoral, inter-country analyses.[14] For example, the empirical study performed by Soete (1980) showed similar results in that the cross-country differences in the innovative performance are significantly associated with the export performance in most industrial sectors. He conducted a cross-section re-

14) For instance, Soete(1980), Dosi and Soete(1983), Fargerberg(1988) and Dosi, Pavitt and Soete (1990)

gression analysis based on US patent data and trade data for 22 OECD countries.

5.3. Complementary Explanation

We have found the statistical significance of the innovative performance of machine tools in explaining the cross-country gaps in the export performance of both machine tools and automobiles. It is now worth tracing the country-specific trends which characterize the competitive positions of major countries over time in order to further make sure of our statistical findings. This inquiry can be a complementary explanation for the previous empirical findings from the estimation of the dynamic fixed effect model. We look into some country cases: the US, the UK, Japan, Germany, France and Italy.

Table 6 Export market shares of major countries in machine tools in world markets

Year	World total ($million)	USA	Germany	Japan	UK	France	Italy
		Shares of major countries(%)					
1960	1,058	33.14	29.86	0.43	10.40	4.29	4.23
1965	1,423	23.31	30.68	3.16	12.44	5.69	6.66
1970	2,459	16.34	34.26	4.70	10.52	5.54	9.52
1975	6,240	14.97	35.57	7.25	7.74	6.28	8.11
1980	11,206	11.38	29.34	13.99	7.62	5.47	8.68
1985	9,814	9.60	23.33	24.09	5.17	3.22	8.56
1986	13,693	7.94	26.07	24.28	4.29	3.26	8.49
1987	15,129	8.13	27.26	21.81	4.84	3.09	8.93
1988	15,545	9.47	25.69	24.13	6.37	3.10	10.19

Note: Machine tools include SITC code no. 715 for the 1960-1977 period and 736 for the 1978-1988 period.

Source: United Nations, International Trade Statistics, several years.

Figure 1 and Table 6 illustrate the evolution of the market shares in the world exports of machine tools for six major countries over the last three decades. The most pronounced feature relates to the US, the UK and Japan. There was a marked decline in the US and the UK shares throughout the period. The US share continued to decrease from 33.1 percent in 1960 to 9.5 percent in 1988. As a result, the US slipped into the place behind Italy as exporter of machine tools in 1988 from the world's largest in 1960. Similarly, the UK share also continuously declined from 10.4 percent in 1960 to 6.4 percent in 1988. The trends of the US and the UK in their competitive position closely correspond to the trends in their innovative position which rapidly deteriorated over the same period.

In contrast to the US and the UK, the Japanese share showed a spectacular performance with steady and rapid growth of its share over the period. It was the lowest with less than one percent among these six countries in 1960, but became the second highest with 24.1 percent in 1988. The German share achieved its maximum at the end of the 1960s accounting for around 35 percent of world exports in machine tools. Its share showed a stable position throughout the 1970s, but has had a tendency to shrink since then. Germany won the highest share in the exports of machine tools to world markets, but captured far lower shares than did Japan in both the exports of machine tools to the US(MS_{mj}) and the exports of automobiles to the US (MS_{aj}).

France and Italy also appeared to have a similar pattern to Germany in that they had a relatively high share in the exports of machine tools to world markets, but low shares in both the exports of machine tools to the US(MS_{mj}) and the exports of automobiles to the US(MS_{aj}). The relative stagnation of the Italian share ended in the 1960s and steadily rose since then. The French share also revealed a stagnation at about 5 percent until the beginning of the 1980s, and tended to decline afterwards.

These country-specific trends of the shares in the world exports of both machine tools and automobiles are in line with that of the shares in the innovative

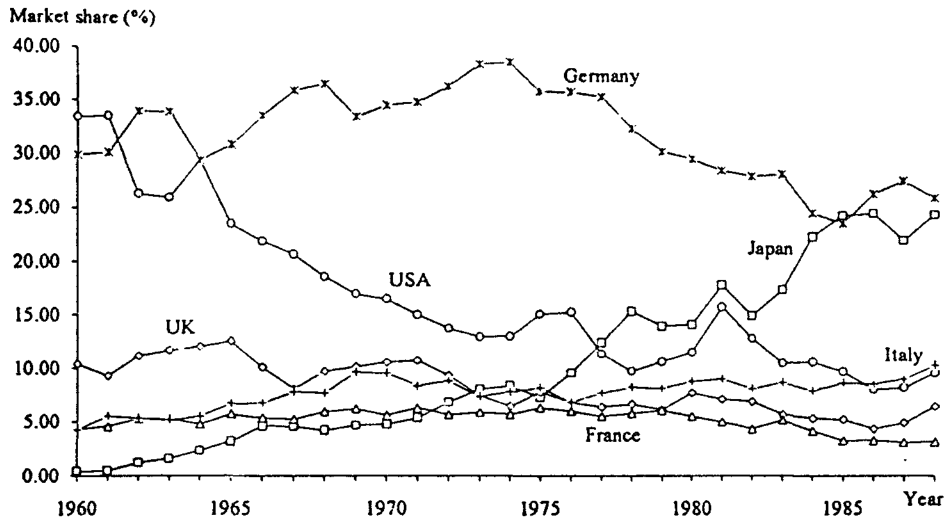

Figure 1 Trends of major countries in the export shares of the international markets in machine tools, 1970-1988

performance in machine tools. More generally, the country-specific trends of major countries with regard to competitive performance have a tendency to correspond with the country-specific trends in innovative performance.

This accordance was discerned by precise statistical analyses of a cross-country panel data in the previous section. The picture which emerges in Figure 1 is by and large consistent with what we observed from the international patterns of the innovative performance in machine tools: the strong competitive position of Germany and Japan, the middle position of Italy, the UK and France and the weak position of most developing countries.

6. CONCLUDING REMARKS

There have been great changes in the innovative performance of machine tools among countries. Some countries have consistently improved their innovative positions, while some other countries have shown opposite trends. The most striking example of the former relates to Japan. The contrary examples are the US and the UK whose innovative performance has continuously declined.

The international gaps in the innovation of machine tools have been relatively stable in spite of the remarkable changes in the positions of some countries. The gaps showed a tendency to diverge rather than converge in the last decade. A panel data analysis by applying a dynamic fixed effect model showed that such innovation gaps among countries significantly led to the inter-country differences in the export performance of machine tools as well as their user sectors.

The discussions and findings based on the technology gap approach yield useful implications to answer the questions put forwarded: Why a dynamic change has taken place in world machine tool markets?; Why some countries have become more competitive and others less competitive in the market? It is thereby concluded that the differences in the innovative performance among countries render cross-country technology gaps, and bring out a dynamic change in world machine tool markets.

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〈Appendix〉 Estimation of Dynamic Fixed Effects Model

When estimating panel data, least squares dummy variable method is usually adopted. It is usually assumed that the disturbances are i.i.d.. This assumption enables to apply ordinary least squares(OLS) method. When, however, the lagged dependent variable is included as an explanatory variable, it is shown that wstimation by OLS with finite samples is not consistent. In this case, instrumental variables estimation method gives a way to tackle this problem. Balestra and Nerlove(1966) have shown that it is possible to get consistent estimates in an autoregressive error components model, by using a kind of two-stage least squares estimator which uses current and lagged values of the independent variables as instrumental variables. Sevestre and Trognon(1992) applied Balestra-Nerlove method to the dynamic fixed effects model.

In this paper, Sevestre-Trognon method is adopted. The procedure is as follows: First, using current and lagged values of independent variables, the explanatory variables are transformed. Then the transformed data are stacked. These steps are done by GAUSS. Finally the stacked data set is used for applying ordinary estimation method of panel data analysis in LIMDEP(Aptech Systems, GAUSS, version 3.0 and Greene, W.H., LIMDEP, version 6.0).