Research on the Improvement of Independent Innovation Capability of Enterprises from the Path Dependence Perspective: Based on the Demonstration of the Strategic Emerging Industry in Zhejiang Province of China[1]

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***Abstract*--The enterprise competitiveness is one of the core issues in the development of the national and regional economy, and its centre is the independent innovation of enterprises. At present, the enterprises in Zhejiang province are faced with external environment which is extremely complex and turbulent. The traditional resource-based views and the core competence analysis are no longer applicable to the technology research which developed increasingly fast. The realistic technological innovation is the inevitable result of enterprise technological researches and development activities. At the same time, to a large extent, enterprises' technological innovation is a process of trial and error in market where a multitude of random factors, evident uncertainty and accumulation exist. Therefore, path dependence exists in the process of technological innovation. Through the analysis of the enterprise innovation process, the learning process and the technological knowledge accumulation, the behavior pattern of enterprises can be understood more accurately, the enterprise theory can be further improved, the research contents of economics can be enriched, and the guiding ideology for the research of Innovation Economics and Technological Economics can be obtained. In this paper, the path dependence of the technological innovation activities of the strategic emerging industries in Zhejiang province was quantitatively analyzed by using the theory of Evolutionary Economics, and the acting path was studied systematically.**

I. INTRODUCTION

Enterprise competitiveness is one of the core issues that affect the economic development of countries and regions, and what matters most to it is the technological innovation capability of enterprises. In the late 1930s, Schumpeter put forward the innovation theory and the concept of technological innovation for the first time, which symbolized the beginning of researches on the enterprise innovation ability by theorists. Since the 1950s, the technological innovation has been researched profoundly again due to the rapid advance of science and technology.

It is unrealistic for the mainstream economics to regard the process of technological innovation as a result of advance design and rational choice. The realistic technological innovation is the inevitable result of enterprise technological researches and development activities. At the same time, to a large extent, enterprises' technological innovation is a process of trial and error in market where a multitude of random factors, evident uncertainty and accumulation exist [10]. Therefore, path dependence exists in the process of technological innovation. Through the analysis of the enterprise innovation process, the learning process and the technological knowledge accumulation, the behavior pattern of enterprises can be understood more accurately, the enterprise theory can be further improved, the research contents of economics can be enriched, and the guiding ideology for the research of Innovation Economics and Technological Economics can be obtained.

In the technological innovation process of many enterprises, the lack of path dependence not only leads to the lack of innovation impetus, management ideas and talents, but also results in the insufficient resource investment and high innovation cost. Consequently, it is practically important to explore the path dependence which promotes the technological innovation capability of enterprises in our country. In this paper, the path dependence of the technological innovation activities of the strategic emerging industries in Zhejiang province was quantitatively analyzed by using the theory of Evolutionary Economics, and the acting path was studied systematically.

II. CONCEPTUAL MODELS AND THE RESEARCH APPROACHES WHICH INFLUENCE MECHANISM

A. Concept Model and Research Hypothesis

Path Dependence is derived from the Chaos Theory of natural sciences, which means that the ultimate result may be determined or locked by tiny and insignificant times. P. A. David [9], professor of the Stanford University, and W. Brain. Arthur [3][4] brought Path Dependence into technological innovation researches for the first time. They thought that in the dynamic economy of increasing returns, multiple equilibrium, rather than single equilibrium on which the traditional economic analysis based, exists in the technological evolution. The sensitive dependence of technological evolution on initial conditions influences and determines the technology development. However, once a certain technology (not the optimal one) is adopted due to accidental factors, the technological evolution, which is difficult to be replaced by other better competitive technologies, will be further strengthened to present the features of coherence and interdependence by the mechanism of increasing returns.

Then, in the literatures about technological history and technological economy, many scholars including Dosi, Mokyr and Rosenberg [8] pointed out that technological innovation is "path dependent". Stephen Redding [2] defined

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the path dependence of technological innovation as follows. The historical factor of technological development plays a major role in determining the future technological change (the major content is technological innovation). The historical factors include original market, technological management, system, rules, consumer expectations, etc. Under their influences, technological innovation is affected by the social, economic and cultural development, which further leads to the fact that the existing technological development, the path dependence of technological innovation, determines the successful innovation and the adoption of new technologies [1]. To some extent, these historical factors "agree with" the existing technologies and "oppose" the new ones. Arthur [5] and other scholars indicated that the adoption of increasing returns of existing technologies (causes positive feedback) would make the innovation locked in the existing non-optimal and low-efficient technologies, prevent the superior and replaceable technologies, and ultimately lead to low efficiency of technological innovation.

In this paper, based on the various research results and the characteristics of the strategic emerging industries in Zhejiang province, the causes of path dependence of technological innovation were analyzed as follows.

1. Industrial complementary constraints

This is the external path dependence of technological innovation. In the process of technological innovation, the production and promotion of any new technology are affected by the industrial environment of the enterprise. Only when a certain innovative technology becomes complementary with its upper or lower industry and adapts to the upper or lower technological environment, can the technological cooperation effect be produced and an effective network of technological innovation be formed. Ultimately, the whole industry chain can increase its returns, and the technology can occupy the market and become dominant.

2. Conversion cost constraints

Based on huge investment, low unit cost and low marginal cost form enterprises, the original technology becomes increasingly mature and popular. If it is replaced by a new technology, the original technology and knowledge will lose a part or all of the functions, and lead to the depreciation of a part or all of the technology and great loss of enterprises. In the process of technological innovation, due to the limitations of specific production process, the fixed equipments, manufacturing techniques and staff skills of the enterprise will become the sunk cost which is difficult to be recovered. The enterprise has to confront a huge amount of conversion cost when adopts new technology. Generally speaking, the enterprise can only partly alter its existing technology and make partial or marginal innovation according to the relative cost of innovation. This is the internal path dependence of the technological innovation process.

3. Cognitive limitations

It is necessary for innovation to promote and reform the complex technology and organizational system operation, including test, error and learning. Obviously, it is costly to convert the original learning path to another. Likewise, it is impossible for enterprises to easily convert the main learning path to another by hiring individuals with required ability. The requisite skills are mostly specific, interdependent, and cooperative, rather than individual. In groups, it is extremely important to accumulate recessive technology and organizational knowledge. The singleness of learning path determines the cognitive limitations of enterprises, and then forms the dependence of enterprises' technological innovation on the previous path.

4. Technological constraints

The existing technology is the resource of enterprises' core competence. Although enterprises have fallen into the rigidity trap of core competence, due to the lack of timely perception or confrontation of the potential difficulties, enterprises still put a large number of technological innovation resources into original technology to keep the vitality. At the meantime, the "brilliant" product innovation and process innovation are still constantly formed with the continuous expansion of product demands. This temporary prosperity paralyzes the managers and gets the enterprises bogged down in the rigidity trap.

In this paper, the path dependence of technological innovation was reduced to the following typical characteristics.

a. Uncertainty. "The sensitive dependence on initial conditions" of technological development is determined by external accidental events. In the various original technological competitions, it is uncertain to choose the technology in advance [7].

b. Path "lock-in". A certain technology will be continuously reinforced and perfected when dominates the market. Meanwhile, the original multi-selectivity and uncertainty will disappear with the "lock-in" of developing direction. The lock-in includes level lock-in which leads to the invariability of enterprises' technological innovation, and development lock-in which leads to the evolution of enterprises' technological innovation along the fixed path.

c. Non-optimality. The "locked" technology may not the optimal one in competitive technology [6]. Although path dependence means that the dominant technology will constantly be strengthened, consolidated and improved to become the leading. Due to the "rigidity" of path, it is difficult for the better technology to break the blockage of the original technology and the monopoly on market. It means that the industrial structure will be "locked" in the low-efficient condition which is determined by the suboptimum or non-optimum technology.

Path dependence, a system with positive feedback mechanism, will evolve along a certain path when adopted by the system under the influence of external accidental events.

It is difficult for path dependence to be replaced by other potential or even better system and be locked in the invalid path. As a result, the above three characteristics are also the three successive stages of technological path dependence.

Through the above analysis, it can be seen that the industrial complementary constraints, conversion cost constraints, cognitive constraints and technological constraints of the strategic emerging enterprises lead to the path dependence of enterprises on technological innovation. The latter influences the technological innovation capability from the aspects of uncertainty, path lock-in and non-optimality of technology. On this basis, the conceptual model was established in this paper as Figure 2-1.

Figure 2-1 shows that the conceptual model includes eight variables, in which the reasons of the four path dependence are independent variables, including internal and external factors, in which the internal factors include conversion cost constraints, cognitive limitations and technological constraints, the external factors refer to industrial complementary constraints. the Technological innovation capability is dependent variable, which involves the measure dimensions such as ability of technological innovation input, ability of technological innovation management, R&D ability, marketing ability and manufacturing ability according to the process of technological innovation. The three characteristic dimensions of path dependence--variables Uncertainty, path lock-in and non-optimality--are intermediate variables.

According to the conceptual model of the influence of path dependence on technological innovation capability, the research hypothesis was put forward in this paper as the following table.

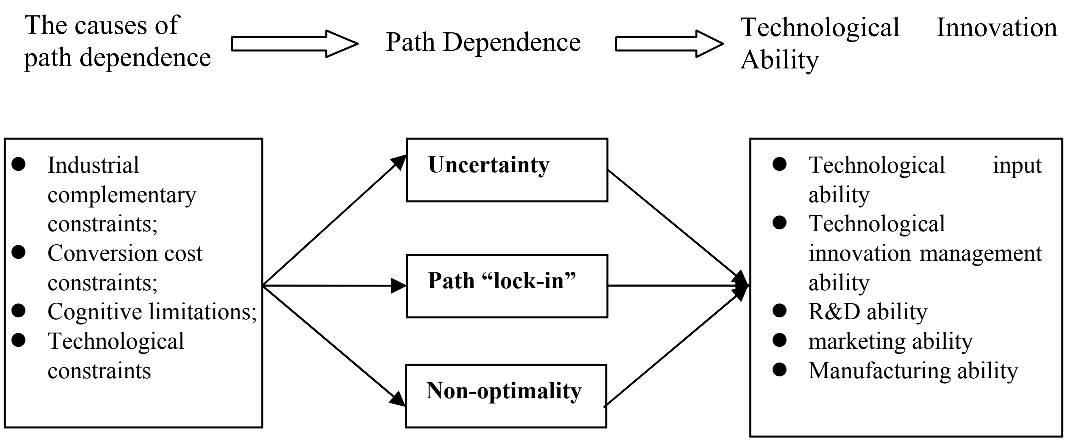

Figure 2-1 The conceptual model of the influence of path dependence on technological innovation ability

TABLE 2-1 HYPOTHESIS OF THE PAPER

Hypothetical Number	Hypothetical Content
H1	There is evident positive influence of “industrial complementary constraints” on “uncertainty of technological innovation”
H2	There is evident positive influence of “industrial complementary constraints” on “path lock-in of technological innovation”
H3	There is evident positive influence of “industrial complementary constraints” on “non-optimality of technological innovation”
H4	There is evident positive influence of “conversion cost constraints” on “uncertainty of technological innovation”
H5	There is evident positive influence of “conversion cost constraints” on “path lock-in of technological innovation”
H6	There is evident positive influence of “conversion cost constraints” on “non-optimality of technological innovation”
H7	There is evident positive influence of “cognitive limitations” on “uncertainty of technological innovation”
H8	There is evident positive influence of “cognitive limitations” on “path lock-in of technological innovation”
H9	There is evident positive influence of “cognitive limitations” on “non-optimality of technological innovation”
H10	There is evident positive influence of “technological constraints” on “uncertainty of technological innovation”
H11	There is evident positive influence of “technological constraints” on “path lock-in of technological innovation”
H12	There is evident positive influence of “technological constraints” on “non-optimality of technological innovation”
H13	There is evident negative influence of “uncertainty of technological innovation” on “technological innovation capability”
H14	There is evident negative influence of “technological path lock-in” on “technological innovation capability”
H15	There is evident negative influence of “uncertainty of technological innovation” on “technological innovation capability”

B. Questionnaire Design and Data Collection

This research, at enterprise level, cannot collect data from statistical yearbooks and statistical bulletins. Therefore, questionnaire was used to collect data in this paper. The questionnaire consists of two parts. The first part is the basic information of the respondents. The second part is the measurement tables about the variables such as the reasons of enterprise path dependence, characteristic dimension and technological innovation capability. On the measurement of variables, the method of subjective perception was adopted in this research. In the process of measuring, the Likert 7 Level Scale was used to respectively grade the conform degree of each item and actual state. The number 1, 2, 3, 4, 5, 6 and 7 respectively represents “totally disagree”, “quite disagree”, “a bit disagree” “uncertain” “a bit agree” “quite agree” and “totally agree”.

In the collection of the research data, 146 pieces of questionnaire were issued to 68 strategic emerging enterprises of Zhejiang province. The valid questionnaires are 112 pieces, and the effective rate is 76.7%. The technical department heads, the IT department directors, or the senior managers are selected to be the respondents, because the middle and senior managers, with sufficient knowledge, abundant management experience and familiarity with the enterprise, can accurately and comprehensively answer the questions about the enterprise, and greatly enhance the authenticity of the survey data.

C. Analysis Techniques and Research Instruments

In the statistic analysis of the recovered questionnaire data, Factor Analysis was used to verify the involved key factors, and test their reliability and validity in the conceptual model. In order to further investigate the sample data and the scientific nature of each scale, Structural Equation Model (SEM) was established by using structural equation instruments to comprehensively analyze the acting path of each factor in the model and inspect the goodness of fit. SPSS13.0 and AMOS7.0 were adopted in the statistic analysis in this paper.

D. Data Analysis

1. Validity Analysis

Validity, a multifaceted concept, can be classified into three categories, including Content Validity, Criterion Related Validity and Construction Validity. In this paper, Content Validity and Construction Validity were mainly inspected as required. Qualitative method is often adopted in the verification of Content Validity. Through a large number of literature researches and investigations and many times of consultation, investigation, analysis and treatment about path dependence, the questionnaire result reflects a favorable Content Validity. Based on the literatures and achievements of previous scholars, the question items about technological innovation capability possess great Content Validity.

Construction Validity is principally analyzed through Factor Analysis. Kaiser –Meyer-Olkin measure of Sampling Adequacy and Bartlett test of Sphericity should be made before Factor Analysis to judge whether the data is suitable. Table 2-1 is the Kaiser –Meyer-Olkin measure of Sampling Adequacy and Bartlett test of Sphericity of the questionnaire data.

TABLE 2-1 THE KAISER –MEYER-OLKIN MEASURE OF SAMPLING ADEQUACY AND BARTLETT TEST OF SPHERICITY

Latent Variable		**Kaiser –Meyer-Olkin measure of Sampling Adequacy**	**Bartlett test of Sphericity**		
			Approx. Chi-Square	**df**	**Sig.**
The causes of path dependence	Industrial complementary constraints	0.866	95.621	3	.000
	Conversion cost constraints	0.754	134.381	9	.000
	Cognitive limitations	0.793	85.52	3	.000
	Technological constraints	0.763	146.382	10	.000
Characteristics of Path Dependence	Uncertainty	0.789	76.436	3	.000
	Path “lock-in”	0.835	56.62	2	.000
	Non-optimality	0.822	78.551	3	.000
Technological innovation capability	Technological input ability	0.786	83.596	3	.000
	Technological innovation management ability	0.761	47.548	2	.000
	R&D ability	0.842	71.677	3	.000
	Marketing ability	0.796	22.457	2	.000
	Manufacturing ability	0.877	82.231	3	.000

It can be seen from the above table that the KMO Value of each dimension of path dependence and technological innovation capability keeps between 0.7 and 0.9, which is suitable for Factor Analysis. The probability P Value of the Batlett test of Sphericity of each dimension is 0.000. In this way, the rejection of the null hypothesis means there is significant difference between correlation coefficient matrix and unit matrix, which also proves that each dimension of path dependence and technological innovation capability is suitable for Factor Analysis.

2. Confirmatory Factor Analysis

a. The Factor Analysis of path dependence's causal latent variable

The Confirmatory Factor Analysis of the four subjective and objective causal variables of path dependence produces the result which is shown as Table 2-3. The corresponding normalized factor loading of the measurement index L3 of technological constraints is 0.38, which is smaller than 0.6, should be deleted. The normalized factor loadings of other measurement variables are all larger than 0.6. The C. R. Value is larger than the reference value 1.96, which indicates that each loading factor has statistical significance at the level of $p<0.05$.

The fitting effect of each subsidiary scale is shown as Table 2-4. The fitting indexes of the four latent variables are approximate to the ideal value, which indicates that the fitting effect of the measurement model has met the requirement. Therefore, the explanation ability of measurement index to latent variable is relatively strong, and there is considerable Convergent Validity among the data.

b The Factor Analysis of the latent variable of characteristic dimension of path dependence

Table 2-5 shows the result of the Confirmatory Factor Analysis made by the characteristic dimension variable of path dependence. The data in the table shows that the normalized factor loadings of the observational variables are all larger than 0.6, and the C. R. Values are larger than the reference value 1.96, which indicates that each loading factor has statistical significance at the level of $p<0.05$.

TABLE 2-3 CONFIRMATORY FACTOR ANALYSIS OF THE CAUSAL VARIABLES OF PATH DEPENDENCE

Latent Variable		Non-standardized Factor Loading	Standard Error S.E.	Critical Ratio C.R.	Standardized Factor Loading	Observed significant level
Industrial complementary constraints	I1	1.000	---	---	0.846	---
	I2	1.091	0.086	12.524	0.957	***
	I3	0.782	0.082	9.346	0.652	***
Conversion cost constraints	C1	1.000	---	---	0.822	---
	C2	1.276	0.095	14.885	0.853	***
	C3	1.103	0.083	13.621	0.816	***
Cognitive limitations	L1	1.000	---	---	0.942	---
	L2	0.945	0.064	8.731	0.926	***
	L3	0.502	0.022	1.63	0.321	
Technological constraints	T1	1.000	---	---	0.897	---
	T2	0.892	0.076	11.195	0.770	***
	T3	0.874	0.073	10.972	0.765	***

TABLE 2-4 THE FITTING EFFECT OF THE CFA MODEL OF THE PATH DEPENDENCE'S CAUSAL LATENT VARIABLE

Latent Variable	X^2/df	RMSEA	NFI	CFI	GFI	TLI
Industrial complementary constraints	1.234	0.032	0.943	0.936	0.907	0.937
Conversion cost constraints	1.350	0.037	0.925	0.936	0.903	0.934
Cognitive limitations	1.357	0.021	0.957	0.955	0.917	0.956
Technological constraints	1.320	0.020	0.958	0.963	0.923	0.960

TABLE 2-5 CONFIRMATORY FACTOR ANALYSIS OF THE CHARACTERISTIC DIMENSION VARIABLE OF PATH DEPENDENCE

Latent Variable		Non-standardized Factor Loading	Standard Error S.E.	Critical Ratio C.R.	Standardized Factor Loading	Observed significant level
Uncertainty	U1	1.000	---	---	0.873	---
	U2	1.022	0.153	8.223	0.936	***
	U3	0.945	0.150	8.582	0.815	***
Path “lock-in”	P1	1.000	---	---	0.805	---
	P2	1.203	0.250	3.988	0.897	***
	P3	1.163	0.267	3.875	0.857	***
Non-optimality	N1	1.000	---	---	0.867	---
	N2	0.991	0.168	8.469	0.820	***
	N3	1.112	0.125	9.098	0.892	***

TABLE 2-6 THE FITTING EFFECT OF THE CFA MODEL OF THE CHARACTERISTIC DIMENSION VARIABLE OF PATH DEPENDENCE

Latent Variable	X^2/df	RMSEA	NFI	CFI	IFI	TLI
Uncertainty	1.450	0.029	0.962	0.945	0.917	0.937
Path “lock-in”	1.721	0.032	0.937	0.936	0.909	0.934
Non-optimality	1.682	0.035	0.918	0.930	0.903	0.925

The fitting effect of each subsidiary scale of path dependence characteristic is shown as Table 2-6. The fitting indexes of three latent variables are approximate to the ideal value, which indicates that the fitting effect of the measurement model has met the requirement. Therefore, the explanation ability of measurement index to latent variable is relatively strong, and there is considerable Convergent Validity among the data.

c. The Factor Analysis of latent variable of innovation ability

The scale of technological innovation capability is composed of five subsidiary scales include the input ability of technological innovation. The Confirmatory Factor Analysis of each subsidiary scale produces the result which is shown as Table 2-7. All the normalized factor loadings are all larger than 0.6, and the C. R. Values are larger than the reference value 1.96, which shows that each loading factor has statistical significance at the level of $p<0.05$.

The fitting effect of each subsidiary scale is shown as Table 2-8. The fitting index of each latent variable is approximate to the ideal value, which indicates that the fitting effect of the measurement model has met the requirement. Therefore, the explanation ability of measurement index to latent variable is relatively strong, and there is considerable Convergent Validity among the data.

TABLE 2-7 CONFIRMATORY FACTOR ANALYSIS OF THE CHARACTERISTIC DIMENSION VARIABLE OF PATH DEPENDENCE

Latent Variable		Measurement index	Non-standardized Factor Loading	Standard Error S.E.	Critical Ratio C.R.	Standardized Factor Loading	Observed significant level
Technological innovation capability	Technological input ability	IN1	1.000	---	---	0.871	---
		IN2	1.012	0.098	11.38	0.883	***
		IN3	1.013	0.097	11.56	0.890	***
		IN4	0.935	0.084	10.97	0.847	***
	Technological innovation management ability	IM1	1.000	---	---	0.911	---
		IM2	0.873	0.110	7.55	0.765	***
		IM3	0.932	0.107	8.67	0.851	***
		IM4	1.011	0.115	9.39	0.926	***
	R&D ability	RD1	1.000	---	---	0.782	---
		RD2	0.980	0.137	8.76	0.734	***
		RD3	0.820	0.135	7.28	0.721	***
		RD4	1.013	1.146	9.03	0.890	***
	Marketing ability	MR1	1.000	---	---	0.760	---
		MR2	1.085	0.153	7.17	0.783	***
		MR3	1.290	0.158	8.59	0.885	***
		MR4	1.100	0.146	8.20	0.821	***
	Manufacturing ability	MN1	1.000	---	---	0.830	---
		MN2	0.911	0.112	8.500	0.748	***
		MN3	0.825	0.096	9.369	0.725	***

TABLE 2-8 FITTING EFFECTS OF CFA MODEL FOR TECHNOLOGICAL INNOVATION CAPABILITY

Latent Variable	X^2/df	RMSEA	NFI	CFI	IFI	TLI
Technological input ability	1.750	0.081	0.979	0.980	0.982	0.981
Technological innovation management ability	1.521	0.070	0.977	0.982	0.990	0.978
R&D ability	1.098	0.015	0.980	0.995	0.996	0.996
Marketing ability	1.930	0.089	0.920	0.970	0.972	0.973
Manufacturing ability	1.290	0.052	0.965	0.971	0.976	0.923

3. Reliability Analysis

Reliability, also known as dependability, refers to the consistency degree of the repeated measurements on the same object, that is, the degree of how the test score is not affected by the errors of measurement, which indicates the stability of the questionnaire result. Cronbach's alpha Coefficient, the most common reliability coefficient, mainly applies to the Multipoint-scaled Items. Therefore, in this research, SPSS13.0 was adopted to make Cronbach's alpha reliability test on the reliability data of the questionnaire about enterprise path dependence and the questionnaire about enterprises' technological innovation capability. The results are shown as Table 2-9, Table 2-10 and Table 2-11.

From Table 2-9, it can be seen that in the questionnaire of the reasons of enterprise path dependence, the Cronbach's alpha Coefficients of the four variables, industrial complementary constraints, conversion cost constraints, cognitive limitations and technological constraints, are all larger than 0.7, which indicates that the four subsidiary scales are considerably consistent and stable, and can be used to make further analysis.

The data of Table 2-10 shows that in the measurement of the path dependence uncertainty, path lock-in and non-optimality, the Cronbach's alpha Coefficients of the characteristic dimensions are larger than 0.7, which indicates that each subsidiary scale of the three characteristics is considerably consistent and stable, and can be used to make further analysis.

Based on Table 2-11, in the questionnaire of technological innovation capability, the Cronbach's alpha Coefficients of the subsidiary scales of technological input ability, technological innovation management ability, R&D ability and marketing ability are larger than 0.7, which indicates that each subsidiary scale of technological innovation capability is considerably consistent and stable, and can be used to make further analysis.

TABLE 2-9 RELIABILITY MEASUREMENT OF EACH SCALE OF THE CAUSAL VARIABLES OF PATH DEPENDENCE

Latent Variable		Number of Measurement index	Cronbach's alpha
Causes of path dependence	Industrial complementary constraints	3	0.965
	Conversion cost constraints	3	0.952
	Cognitive limitations	2	0.936
	Technological constraints	3	0.967

TABLE 2-10 RELIABILITY MEASUREMENT OF EACH SCALE OF THE CHARACTERISTIC DIMENSION VARIABLE OF PATH DEPENDENCE

Latent Variable		Number of Measurement index	Cronbach's alpha
Characteristics of Path Dependence	Uncertainty	3	0.925
	Path "lock-in"	3	0.887
	Non-optimality	3	0.926

TABLE 2-11 RELIABILITY MEASUREMENT OF EACH SCALE OF TECHNOLOGICAL INNOVATION CAPABILITY

Latent Variable		Number of Measurement index	Cronbach's alpha
Technological innovation capability Technological innovation capability	Technological input ability	4	0.935
	Technological innovation management ability	4	0.916
	R&D ability	4	0.893
	Marketing ability	4	0.915
	Manufacturing ability	3	0.886

III. MODEL VERIFICATION OF INFLUENCING MECHANISM

A. Specification and Fitting of the Model

After making Confirmatory Factor Analysis on each latent variable, the path diagram of initial SEM Model established by AMOS software is shown as Figure 3-1.

According to the theoretical hypothesis of the previous chapter, the four subjective and objective factors which include industrial complementary constraints, conversion cost constraints, cognitive limitations and technological constraints respectively bring about the influence of direct positive path on path dependence uncertainty, path lock-in and non-optimality. The three characteristic dimensions of path dependence respectively produce the influence of direct backward path on the technological innovation capability of enterprises. After estimating the initial SEM Model, the result of the parameter estimation and the model fitting are shown in Table 3-1.

From the results of Table 3-1, it can be seen that in the structural equation model, the C. R. Values of the four external reasons of path dependence and the path of the characteristic dimension are larger than 2.58, which shows that the path coefficient has statistical significance at the level of p=0.01. In the paths from path dependence characteristic to technological innovation capability, there is one path has no statistical significance, which means that the hypothesis 14, "path lock-in —> technological innovation capability" (C. R=0.702, p=0.402), has not been verified.

In this paper, the fitting index was calculated after making overall fitting of the model. The result is shown as Table 3-2. The fitting result shows that the X^2/df of the initial model fitting, 1.38 (smaller than 2), demonstrates the considerably favorable fitting effect. The RMSEA Value of the initial model is 0.059, which is in the acceptable range of 0.05-0.10. The values of NFI, IFI, TLI and CFI are 0.94, 0.98, 0.98 and 0.98, all larger than the reference value 0.90. Based on the above fitting effect, the fitting effect is relatively well, and the model is acceptable.

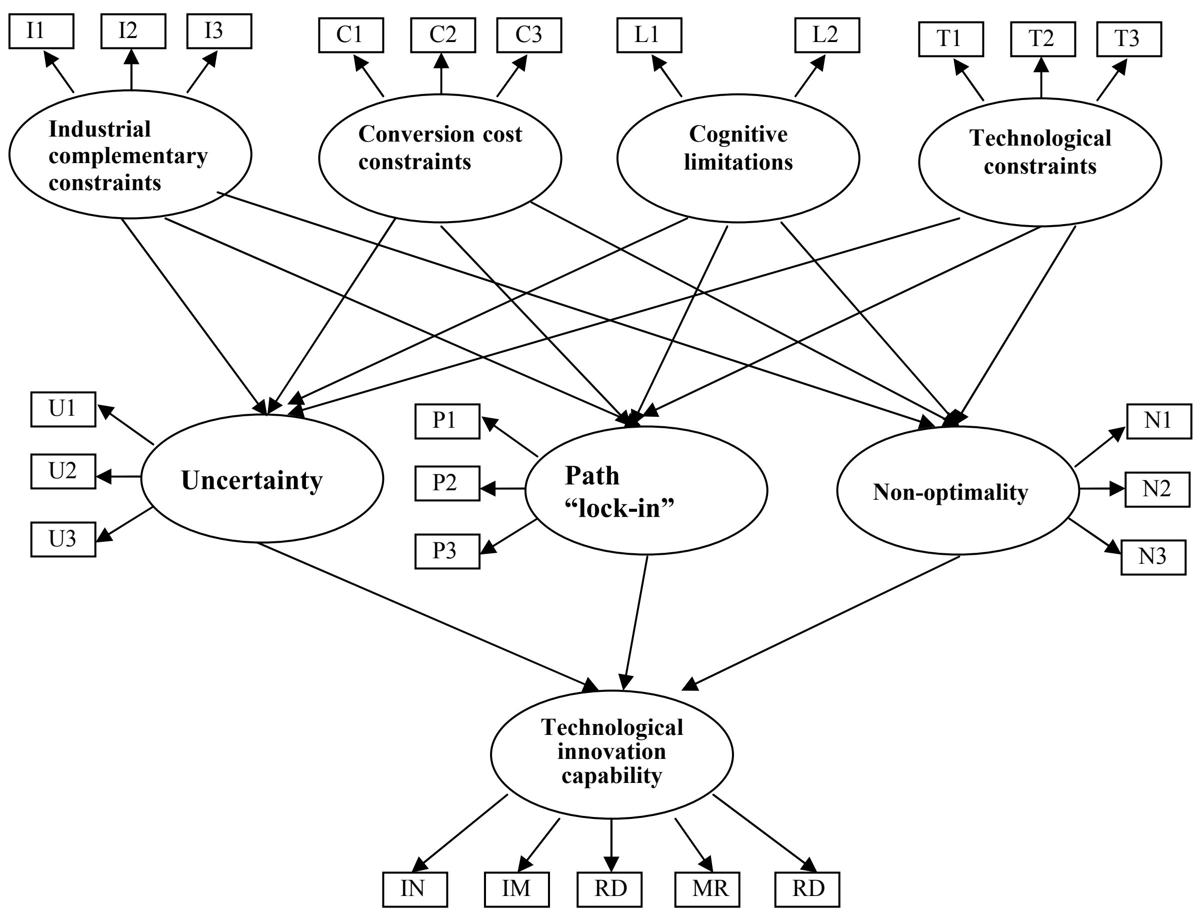

Figure 3-1 Initial SEM model

TABLE 3-1. THE PARAMETER ESTIMATION RESULT OF INITIAL SEM MODEL

The paths diagram of SEM Model	Non-standardized Factor Loading	S. E.	C. R.	P	Standardized Factor Loading
uncertainty <—industrial complementary constraints	0.761	0.067	8.62	***	0.750
path lock-in <—industrial complementary constraints	0.292	0.074	4.65	***	0.311
non-optimality <—industrial complementary constraints	0.494	0.056	5.47	***	0.512
uncertainty <—conversion cost constraints	0.215	0.049	6.35	***	0.231
path lock-in <—conversion cost constraints	0.507	0.051	7.21	***	0.553
non-optimality <— conversion cost constraints	0.415	0.068	4.66	***	0.420
uncertainty <— cognitive limitations	0.621	0.052	8.08	***	0.645
path lock-in <— cognitive limitations	0.270	0.059	3.88	***	0.290
non-optimality <— cognitive limitations	0.381	0.047	3.97	***	0.393
uncertainty <— technological constraints	0.202	0.050	5.97	***	0.210
path lock-in <—technological constraints	0.561	0.058	7.53	***	0.532
non-optimality <— technological constraints	0.640	0.047	5.90	***	10.628
technological innovation capability <—uncertainty	-0.246	0.045	9.85	***	-0.263
technological innovation capability <—path lock-in	-0.038	0.075	0.702	0.402	-0.051
technological innovation capability <—non-optimality	-0.335	0.038	10.65	***	-0.321

TABLE 3-2 FITTING EFFECTS OF INITIAL SEM MODEL

X^2/df	RMSEA	NFI	CFI	IFI	TLI
1.36	0.058	0.943	0.985	0.986	0.981

B. Model modified

The C. R. Value of the "path lock-in —> technological innovation capability" has failed to pass the verification, which shows that it is impossible to judge the existence of the direct and significant influence of path lock-in on technological innovation capability. Due to the relatively large P Value, this path is considered to be deleted. In the further analysis of the relation among the three stages of path dependence, it can be seen that when the technological innovation path is locked, enterprises' technological innovation will produce the initial state of "lock-in" and reject the new technology, and then the optimality of the initial technological innovation will be lost. Therefore, based on the equation model of the initial structure, "path lock-in —> non-optimality" was added in this research. After modifying the model, the SEM path is shown as Chart 3-2, and its estimation result of parameter is shown as Table 3-3.

It can be seen from Table 3-3 that the CR Value of the path coefficient of modified SEM Model is larger than 4, which manifests that all the path coefficients are significant at the level of p=0.001. Table 3-4 shows that the fitting index of modified model keeps in the acceptable range, which indicates the great fitting degree of the model.

TABLE 3-3 THE PARAMETER ESTIMATION RESULT OF MODIFIED SEM MODEL

The paths diagram of SEM Model	Non-Standardized Factor Loading	S. E.	C. R.	P	Standardized Factor Loading
uncertainty <—industrial complementary constraints	0.739	0.062	8.60	***	10.742
path lock-in <—industrial complementary constraints	0.267	0.075	4.60	***	0.282
non-optimality <—industrial complementary constraints	0.468	0.057	5.23	***	0.473
uncertainty <—conversion cost constraints	0.215	0.048	6.35	***	0.231
path lock-in <—conversion cost constraints	0.502	0.051	7.18	***	20.550
non-optimality <— conversion cost constraints	0.378	0.069	4.45	***	0.400
uncertainty <— cognitive limitations	0.621	0.051	8.08	***	20.645
path lock-in <— cognitive limitations	0.265	0.059	3.83	***	0.287
non-optimality <— cognitive limitations	0.342	0.053	3.76	***	0.353
uncertainty <— technological constraints	0.202	0.050	5.97	***	0.210
path lock-in <—technological constraints	0.548	0.058	7.51	***	10.525
non-optimality <— technological constraints	0.606	0.047	5.71	***	10.592
non-optimality <— path lock-in	0.315		8.80	***	0.320
technological innovation capability <—uncertainty	-0.323	0.045	10.22	***	2-0.346
technological innovation capability <—non-optimality	-0.455	0.038	11.35	***	1-0.433

TABLE 3-4 FITTING EFFECTS OF MODIFIED SEM MODEL

X^2/df	RMSEA	NFI	CFI	IFI	TLI
1.31	0.052	0.945	0.985	0.986	0.983

IV. RESULT ANALYSIS

In this research, Confirmatory Factor Analysis and structural equation were used to comprehensively analyze the phenomenon of path dependence in the process of technological innovation. Through modifying the initial SEM Model, the effect analysis is shown as Table 4-1.

A. Direct Effect

1. There is direct relationship among the four reasons of path dependence and their characteristic dimensions, that is, the industrial complementary constraint exerts the most significant positive effect on the uncertainty of technology, and the cognitive constraint ranks second. It indicates that the initial stage of enterprises' technological innovation is influenced by the external industrial environment. On the one hand, when the relevant enterprises update their products, the original enterprise is likely to make self-innovation on technology to adapt to the technology of the relevant enterprises. There is no existing standard of enterprises' technological innovation for reference. Technological innovation involves product innovation and process innovation. Therefore, enterprises will face a multitude of uncertain technological innovation schemes. On the other hand, the different environment of technological innovation of different enterprises will lead to the increases of innovation uncertainty. Because of the cognitive constraints in enterprises, there is knowledge and information asymmetry between the technological innovation department and other relevant departments. It is quite difficult for them to reach consensus on technological innovation and promotion, which also considerably increases the variation of the enterprise innovation.

Technological constraint and cost constraint are the major positive influences on path lock-in. It is obvious that the internal factors of enterprises will begin to work when the technological innovation of enterprises enters into the second stage – path lock-into. Due to the mechanism of increasing returns of technology, the choice of the initial technology and the feature of self-reinforcement of technology will lead to the immobilization and modeling of the technological innovation. The conversion cost of technological innovation means the costly expenditure for denying and breaking through the existing path. The increasingly large asset and asset specificity will not only lead to strong path dependence effect, but also make the technological substitution, path breakthrough, conversion cost become costly, and ultimately result in difficult innovation.

TABLE 4-1 EFFECT ANALYSIS OF MODIFIED SEM

Effect	**Industrial complementary constraints**	**Conversion cost constraints**	**Cognitive limitations**	**Technological constraints**	**Uncertainty**	**Path "lock-in"**	**Non-optimality**
Direct effect							
Uncertainty	0.742	0.231	0.645	0.210	0.000	0.000	0.000
Path "lock-in"	0.282	0.550	0.287	0.525	0.000	0.000	0.000
Non-optimality	0.473	0.400	0.353	0.592	0.000	0.320	0.000
Technological innovation capability	0.000	0.000	0.000	0.000	-0.346	0.000	-0.433
Indirect effect							
Uncertainty	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Path "lock-in"	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Non-optimality	0.090	0.176	0.092	0.168	0.000	0.000	0.000
Technological innovation capability	-0.500	-0.269	-0.416	-0.402	0.000	-0.138	0.000
Total effect							
Uncertainty	0.742	0.231	0.645	0.210	0.000	0.000	0.000
Path "lock-in"	0.282	0.550	0.287	0.525	0.000	0.000	0.000
Non-optimality	0.563	0.576	0.445	0.693	0.000	0.320	0.000
Technological innovation capability	-0.500	-0.269	-0.416	-0.402	-0.346	-0.138	-0.433

Complementary constraints, technological constraints and cost constraints all bring about a great positive influence on the non-optimality of path lock-in. It is evident that the non-optimality of technology is jointly affected by the external factors of enterprises. Due to the external industrial environment, the original technology expands its monopolistic advantages, the internal cost constraint and the "rigidity" of the technology itself will be further strengthened when compared with the second stage, and the industrial structure will be "locked" in the low-efficient condition which is determined by the suboptimum or non-optimum technology.

2. The three characteristics of path dependence exert an influence on the technological innovation capability. The non-optimality of technology produces the most significant negative effect on the technological innovation capability of enterprises. The negative influence of the technology uncertainty on technological innovation capability of enterprises has passed the significance testing. However, the hypothesis that the path lock-in produces significant negative influence on technological innovation capability has been rejected. It indicates that for the strategic emerging industries of Zhejiang province, the influence of path dependence on technological innovation capability of enterprises cannot be ambiguously judged. In addition, the uncertainty of technological innovation will result in the weakness of the innovation ability.

Once the selected technology produces benefit and dominates the market, it will be continuously strengthened and promoted by the enterprise. At the same time, the original choices of technologies will disappear. There are two sides of the influence of the technological "lock-in" on enterprises' technological innovation. On the one hand, the selected technology will be strengthened, consolidated and promoted constantly to realize virtuous cycle of self-enhancement, that is, development lock-in, which will promote the technological innovation capability of enterprises. On the other hand, after long times of development, the technological innovation of enterprises shows the rigidity of path. Even the appearance of preferable technology can not break the block and monopoly of the initial technology of cluster enterprises on market, which will restrain the technological innovation capability of enterprises. After modifying the original equation, the positive influence of path lock-in on technological non-optimality is added. The former exerts positive effect on the latter. Based on the above analysis, the self-improvement of technology has brought benefits to enterprises. With the development of new technologies and new innovation forms, the path lock-in has restrained the choice of better technology and path, which thus reduces the technological innovation capability of enterprises.

B. Indirect Effect

The internal and external factors such as industrial complementary constraints, conversion cost constraints, cognitive constraints and technological constraints lead to the path dependence of enterprises' technological innovation, and further bring about influences of indirect backward path on technological innovation capability. On the one hand, the various external environments, learning abilities, knowledge stocks and conventions of different enterprises lead to the diversified technological innovation, rather than simplified one. The differences among enterprises determine the differences of technological innovation and choices, further determine the discrepancy of the enterprise innovation abilities, and ultimately lead to the discrepancy of the economic benefits of enterprises. On the other hand, the process of enterprises' technological innovation is uncertain and unbalanced. The difference and unbalance among enterprises lead to the technological innovation and introduction of enterprises, and then produce new difference and unbalance which are the conditions of the next round of innovation and introduction of technology. The process of technological innovation and diffusion is emanative and unbalanced.

Based on the above analysis, the process of technological innovation has path dependence, and different enterprises have different innovation process and different path choice. Technological innovation is not only a complex adaptive learning process, but also a process of using existing knowledge stock and bounded rationality by enterprises. Due to the huge uncertainty of the technological innovation process, government and enterprise should jointly improve the economic policy and innovation system to encourage the technological innovation of enterprises.

V. DISCUSSION AND AREAS FOR FURTHER RESEARCH

A. Analysis & Discussion

The process of technological innovation has path dependence, and different enterprises have different innovation process and different path choice. Technological innovation is not only a complex adaptive learning process, but also a process of using existing knowledge stock and bounded rationality by enterprises. The above empirical analysis leads to the following beneficial insights:

1. Both comparative advantages and competitive advantages should be emphasized

Because of the lock-in effect generated by path dependence, technologies with potential comparative advantages will not necessarily form into competitive advantages during the market competition. Some of them will be eliminated. This tells that relationship between comparative advantages and competitive advantages should be reexamined. Focuses and stress only on comparative advantages are not enough. The formation of competitive advantages should also be emphasized to enhance advantages and avoid disadvantages (the result of comparative advantages formation) as well as to select the superior and eliminate the inferior (the result of competitive advantages formation). Thus, for the government departments, the development of local industries with comparative advantages should be emphasized as well as the upgrade of industrial structure. The high and new technology industries and strategic emerging industries should compete with those of developed countries and regions to form industrial competitive advantages and get rid of external path dependence on developed countries during the local economic development. Finally, the international competitiveness of the province or even the nation can be promoted.

2. The selection of initial path must focus on the technological innovative ability acquisition

Only under the situation of correct and reasonable initial selection, can the reinforcing effect of path dependence on technological innovative ability be displayed maximally. The initial path selection is highly asset-specific. If the initial path selection is not the optimal, then the latter optimized technological arrangements will not be realized because of the huge sunk costs. Under this situation, path dependence will not play the role of strengthening but weakening technological innovative ability on the contrary. Therefore, path selection and the existence of path dependence should be focused especially to obtain and promote the technological innovative ability of enterprises.

3. The existence of path dependence urges the acquisition of technological innovative ability to focus on influences of small events and random events

Technology evolution is not a pure technological substitution but a process of social gambling. This gambling is not one-off but repeated and forms a random and dynamic process. If a small event or random event becomes an influencing factor during technology evolution in the gambling, it may turn into a power reversing the technology or formulating evolution path through amplification effect. Therefore, a complete analysis should carry out on factors influencing technological innovative path during the innovation. Important events should be focused as well as the small event and random events possibly causing great influences on path.

4. Adjustments on previous strategies should be conducted when there are changes in business environment or enterprise competence

Core competence, enterprise culture and operator's behavior characteristics are the main influencing factors of the enterprise development while obviously presenting the features of path dependence. To transcend the path dependence and make the enterprise growth and development to escape from previous shadows, virtual organizations are needed for building strategic alliances. External strategic resources of the enterprise are used to support the internal development strategies, organize the knowledge innovation, develop the core competence, reform the enterprise culture, promote enterprise learning and perfect the management structure. Then the reasonability of operator's behaviors will be ensured and promoted institutionally.

B. Areas for Further Research

Although domestic researches on path dependence and technological innovative ability just kick off, this issue has gained increasing attention from scholars. Directions for further research have been proposed while integrating the deficiencies:

On the one hand, the number of collected samples is few as limited time and resources during the research. Random sampling can be adopted in future and representative enterprises should be selected for cooperation. Then a large amount of samples can be collected for further research on the influence of path dependence on innovative ability.

On the other hand, a path dependence scale based on China's situation should be developed. At present, most domestic researches on path dependence are qualitative. As path dependence is highly environmentally dependent, it is significantly meaningful to develop a path dependence scale based on China's situation with high credibility and efficiency. In addition, as the development of localized path dependence scale, more and more scholars will pay attention to the empirical researches on path dependence, which will promote the accuracy and universality of the study.

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