Clustering Evolution of Taiwan IC Industry in China

BI-HUEI TSAI

Department of Management Science,
National Chiao Tung University,
1001 Ta-Hsuch Road, Hsinchu 300, Taiwan
e-mail: Joy@mail.nctu.edu.tw

Abstract: - This paper for the first time quantitatively analyzes the clustering behaviors by using the foreign direct investment (FDI) data of Taiwan IC industries. According to the relationship between the FDI and the industrial clustering phenomenon, we first formulate a dynamic FDI growth model for the estimation of total FDI amount. Consequently, we can tangibly elucidate the clustering behaviour of IC industry from Taiwan to China. Furthermore, the effects of the innovation, imitation and the potential investment factors on the IC industrial clustering are systematically compared among the IC design, IC manufacturing as well as IC packaging and testing industries. The results indicate the significant internal influence of intra-industry communications on Taiwan's FDI evolution into China. This suggests that Taiwan IC firms tend to successively imitate the previously experienced FDI firms to engage in FDI in China. Particularly, the internal impact is the strongest for IC manufacturing firms, revealing its greatest clustering extent. In addition, Taiwan IC industry's FDI amount in China is cumulatively predicted increasing in our model and the finding once again supports the clustering tendency of IC industries. However, the predicted FDI amount for IC manufacturing industry is not as accurate as the other two industries because Taiwan had strictly prohibited IC manufacturing industry from undertaking FDI into China before the third quarter of 2003. The prediction ability of our dynamic growth model for IC manufacturing firms is dramatically improved as the strict restriction period is removed from our sample analysis.

Key-Words: - diffusion theory, foreign direct investment, IC, dynamic growth model, clustering.

1 Introduction

This paper seeks to quantitatively analyze the clustering behaviours by using the foreign direct investment (FDI) data of Taiwan IC industries, since prior researches have not effectively shed light on the quantification of the clustering evolutions. The "clustering" mentioned here is defined as an interaction of relative groups in proximal geographical location [1-3]. Clustering theory proposes that firms can easily collaborate with the available materials and basic equipment or obtain related resources in neighboring areas [4], so the integration of neighboring research institutions, universities, corporations and government substantially advances enterprise competitiveness [5]. Von Hippel [6] illustrates that direct contact with customers and suppliers in neighboring areas can be a source of new ideas and innovation as well. Industries more reliant on scientific knowledge tend to benefit more from knowledge clustering [7].

In addition, Tsai [8] as well as Chen, Wu and Lin [9] emphasize that most of Taiwan and U.S. IC firms are located in Hsinchu Science-based Industrial Park (HSIP) and Silicon Valley, respectively, since industrial clustering speeds up knowledge interflows within the clustered enterprises, government, academies and institutions in practice. The intimate relationships between the employees, suppliers and customers in the industrial clusters enable firms to accelerate their knowledge interchanges through clustering. From a strategic perspective, an enterprise's motivation to invest in industrial clustering is practically efficiency and effectiveness. As a result, the firm's behaviour of clustering has thus become an issue of, not only academic, but also practical relevance. Research on industrial clusters has attracted much attention from scholars in the field of business and economics in recent years.

Prior literature in business fields mostly apply qualitative research to map the industrial clusters [10-12], to identify the spatial concentrations of related firms as industrial clusters [13], or to compare the difference in such characteristics as knowledge sharing and innovation achievements between the industrial clusters and other areas [8, 14]. However, few studies have well quantified clustering phenomena. It is not easy to empirically measure the orientation or extent of industrial clustering. Fortunately, the data available in Taiwan IC industries provide an access to overcome this problem and to discuss the two essential issues which has not been effectively investigated in previous articles. First, the unique foreign direct investment (FDI) data setting available in Taiwan provides us opportunities to quantify the clustering issues. Under Taiwanese regulations, the amount of FDI in China is required to be reported to the authorities. Foreign direct investment (FDI) of Taiwanese firms in China is defined as the capital flow from a foreign country (here, Taiwan) to a host country (China) to establish production facilities and conduct business activities. Industrial clusters are evolved in China once the previously-experienced FDI firms attract other firms to successively undertake FDI as well as construct business bases in China. Hence, the increasing presence of FDI inflows into China must be objectively quantitative indicators of the "clustering" trend. For the reason, this article for the first time adopts FDI flow into China to quantify the clustering formation process. Bass [15] dynamic diffusion model is employed to probe into the FDI capital flow, because the "diffusion (or growth)" concept has originally been applied in innovation fields [15-18] and has been extensively used to forecast the FDI capital flow [19]. Under diffusion theory, FDI flow could be defined as a process that transmits throughout a given social system by way of diverse communication channels. This means that FDI growth is the propagation of messages related to the FDI outcomes that lead to subsequent decision making, awaiting a change in the behaviour of the receiver. Particularly, this dynamic model can formulate the internal influence under this social system. The internal influence represents the effect on which previous FDI adopters (experienced firms) exercise on potential FDI adopters (successive firms) by persuading the latter to imitate the former in the FDI decision. If the incumbent enterprise's FDIs in China stimulate successive enterprise's FDIs, the increasing presence of FDI firms and FDI amount speed up the industrial clustering in China. In other words, the internal influence reliably represents the clustering tendency. Hence, the analysis of dynamic diffusion model can provide us insights concerning the clustering inclination in terms of not only the FDI patterns but also the internal influence. This investigation benefits the operation management, industrial development and political policies.

Second, this study compares the clustering extents of Taiwan integrated circuit (IC) firms since Taiwan holds the leading position in IC industry. The global market shares of Taiwan's foundry IC manufacturing, packaging and testing industry have been all the largest. Even the global market share of Taiwan's IC design industry also ranked number two in 2004. Especially, prior researches pointed out that the unique virtual integration structure in Taiwan IC industry was distinctly different from the integrated device manufacturer (IDM) structure of the IC industry in U.S., Japan and Korea [20, 21]. Under this virtual integration structure, all firms in different production stages, including upstream IC design, midstream IC manufacturing and downstream IC packaging and testing firms can provide us public financial statements for different production stages. The available FDI data of separate production stages in IC industry allow this study to focus on the FDI clustering characteristics difference among various production stages confined to IC production chains.

In regards to clustering characteristics difference among the IC industries, the process of each step in IC manufacturing related sector (IC manufacturing firms or IC packing and testing firms) is fixed with standardized raw materials, machinery and equipments, so such IC firms highly rely on the support from material and equipment suppliers. As long as Taiwan IC manufacturing firms construct factories in China, more and more suppliers would implement their channels in China. In this condition, such suppliers' channels enable successive IC manufacturing firms to free-ride suppliers' support much easier, which reinforce the profound "clustering" phenomenon. In contrast with those of IC manufacturing, packaging and testing firms, IC design products are designed differently according to the wide applications of final electronic products (such as CPU, chipset, mobile phone, power supply management and cartography). The production process is much less similar among IC design firms; therefore the free-riding of up-stream suppliers are much more difficult for IC design firms than IC manufacturing firms or packaging and testing firms, resulting in less FDI clustering inclination for IC design firms.

In addition, the techniques of IC packaging and testing firms are fairly low-end and mature comparing with IC design or IC manufacturing firms. As product life cycle theory [22] explains that new products are first introduced to a few developed countries and finally onto the developing countries, FDIs in China are driven as the production process is mature for IC packaging and testing firms. The lower Chinese labor costs are more likely to stimulate IC packaging and testing firms to engage in large amount of FDI in China, while firms' motivation of FDI flow is limited for IC design sector because of China's lack of technology-oriented employees. The potential size of industrial clustering in China is expected greater for IC packaging and testing enterprises than any other IC industries. From the aforementioned arguments, the clustering extents are expected to differ owing to the industrial features. Hence, this research seeks to compare the potential FDI size and internal influence among various industries to deeply realize the clustering evolutions.

As it is elaborately described above, the purposes of this paper can be summarized in threefold. First, the dynamic diffusion theory is applied to interpret Taiwan IC industry's clustering in China. Second, this article compares the clustering extents through the internal influence and potential FDI size along each production stage in IC industry. Finally, the prediction performance of our dynamic growth model is examined to ascertain its accuracy. The contributions of this research are to objectively quantify the clustering phenomena by using FDI capital flow into China from Taiwanese IC firms, which has never been discussed in prior research. It is a new application of dynamic growth perspective to highlight the clustering extents among various industries. The results invoke our insights concerning the industrial clustering features, thus benefiting enterprises' strategies in foreign investment and operational management.

This paper is organized as follows. In Section 2, we propose the dynamic growth model for FDI flow. In Section 3 we define the solution method, and in Section 4, we discuss the study on FDI flow from Taiwan to China. Finally, we draw conclusions and suggest future possibilities of similar studies.

2 Basic Assumption and Model Formulation

There are two origins of diffusion theory, one coming from the British and German-Austrian schools of growth in anthropology while the other from the S-shaped growth curve proposed by a French sociologist Trade (1903). According to the dynamic theory, a growth function N capturing the capital flow's dynamic pattern, given the fact that the pattern is time-dependent, we can denote a growth function of $N(t)$. The growth function is usually modelled as the solution of a differential equation $dN/dt = f(N, t)$ where the function f determines the shape of the curve of dynamic growth [17].

To explain the dynamics of FDI behaviour, we come up with a FDI growth model based upon the theory of dynamic growth with the following assumptions.

Assumption 1: *There are only two countries in the system. Also, only the FDI capital outflow from the parent country to the host country is considered.* We limit our discussion to a two-country, multi-period and one-way-capital-flow model.

Assumption 2: *There is a FDI capital outflow restriction in the side of parent country. Also, the capital of FDI outflow, M*(t)*, remains constant over the time period*. In other words, we assume that the size of the amount of capital is finite and known or estimable when the FDI market was opened.

Assumption 3: *There is no restriction on the capital inflow of FDI in the side of host country.*

Assumption 4: *The process of FDI capital outflow from the parent country is independent of all other kinds of capital flow.* In other words, we assume that the FDI flow is growing in isolation in the system.

Assumption 5: *The increment of capital outflow from the parent country at any given point of time is directly proportional to the amount of remaining potential at that time*. Mathematically, this can be represented as:

$$N(t+\Delta t) - N(t) = gN(t)\Delta t\,, \qquad (1)$$

where $N(t)$ is the cumulative amount of capital at time t, Δt is the increment of time and $g(t)$ is the growth rate. Dividing by Δt on both sides, we have

$$\frac{N(t+\Delta t) - N(t)}{\Delta t} = gN(t)\,. \qquad (2)$$

Taking $\Delta t \to 0$ in Eq. (2), we have

$$\lim_{\Delta t \to 0} \frac{N(t+\Delta t) - N(t)}{\Delta t} = \lim_{\Delta t \to 0} gN(t)\,, \qquad (3)$$

thus,

$$\frac{dN(t)}{dt} = gN(t)\,. \qquad (4)$$

The Eq. (4) can be further modified by considering the effect of the upper bound of the cumulative amount of capital on $N(t)$,

$$\frac{dN(t)}{dt} = g(t)(M - N(t))\,, \qquad (5)$$

where M is the potential size of FDI capital amount. The difference between M and N indicates the remaining amount of potential capital at time t.

Assumption 6: *The growth rate of the capital outflow depends on time through a linear function of* $N(t)$. The growth rate, depending on the internal and external influences, is given by,

$$g(t) = (a + bN(t)), \qquad (6)$$

where the parameters a and b together represent the degree of intensity of the resource for the external and internal influences, respectively. The external influence, a, is determined by two components: i) the intrinsic tendency of the individual firm to deal with FDI, and ii) the external Chinese promotions or advertisings which encourages foreign corporations to deal with FDIs in China. In other words, the external influence a affects the innovative behaviour of FDI, especially in the first step of the FDI process. On the other hand, the internal influence, b, represents the impact on the FDI involvement through the contact with previous experienced FDI firms, namely, the imitating behaviour of FDI flow. Such internal influence as interpersonal communication (interpersonal communication, interaction among members of a social system) is more suited to influencing behaviours when the FDI process has already started; more interestingly, this imitating behaviour helps explain the acceleration of the diffusion process as a logic process. If the incumbent enterprise's FDIs in China stimulate successive enterprise's FDIs, the increasing presence of FDI firms and FDI amount speed up the industrial clustering toward China. In other words, the internal influence reliably represents the clustering tendency. This paper can employ the internal influence, b, to denote the clustering extents. These two coefficients, a and b, can be used to compare the differential internal and external influence among various stages along the IC production value chains. Substituting Eq. (6) into Eq. (5), using the above assumptions, we find that the dynamic change rate of the capital amounts is proportional to the current amount. Thus, the dynamics of FDI flow is expressed as:

$$\frac{dN(t)}{dt} = (a + bN(t))(M - N(t)). \qquad (7)$$

We notice that the amount of capital at time t can be calculated by

$$n(t) = \frac{dN(t)}{dt}. \qquad (8)$$

The difference $M - N(t)$ could be referred to as the remaining potential size of FDI capital flow into China.

3 Solution Methods

3.1 Analytical Solution and Statistical Computation

The growth rate in Eq. (6) can be rewritten as:

$$g(t) = (p + q\frac{N(t)}{M}). \qquad (9)$$

We can now express the developed model as:

$$n(t) = (p + q\frac{N(t)}{M})(M - N(t)). \qquad (10)$$

If M is constant, the analytical solution of Eq. (10) can be obtained by using the Bernulli equation,

$$N(t) = \frac{1 - e^{-(p+q)t}}{1 + \frac{q}{p}e^{-(p+q)t}}. \qquad (11)$$

3.2 Regression Analysis

From the equation (10), the basic model is $n(t) = pM + (q - p)N(t) - qN^2(t)$. In estimating the parameters p, q, and M from discrete time series data, we use the following analogue: $S_t = \alpha + \beta Y_{t-1} + \gamma Y_{t-1}^2 + e_t$. In this equation, S_t represents the FDI amount during the interval (*t-1*, *t*), Y_{t-1} represents the cumulative FDI amount through period *t-1* , and e_i is the error term. Since α estimates pM, β estimates $q - p$, and γ estimates $-p/M$: $-Mc = q$, $a/M = p$. The coefficient of external and internal influence is estimated by ordinary least squares (OLS) [1]. Finally, the prediction ability is inevitably examined in our research since previous literatures emphasize the accuracy of forecasting models [23-25].

4 Application of the FDI Model from Taiwan to China

4.1 Sample and Data

The sample used in our study includes 64 integrated circuit (IC) public firms of Taiwan: 46 IC design firms, 5 IC manufacturing firms, 13 IC packaging and testing firms. The investigated time period is from 1999 to 2007 and the sample data is measured in New Taiwan (NT) dollars (thousands). This article constructs the dynamic FDI forecasting model ranging from the period when our sample firms began to implement FDI in China, to the fourth quarter in 2007. The beginning periods are the first quarter in 1999 for both IC design and IC packaging and testing industries, while the second quarter in 2001 for IC manufacturing industries. The actual FDI amount is defined as the net FDI amount to China, namely, the FDI amount remitting to China minus the amount returning to Taiwan. The data of actual and permitted amount of FDI to China are collected from Taiwan Economic Journal (TEJ) database.

Table 1 shows the permitted and actual amount of FDI flow from Taiwan to China. Under "Regulations Governing the Approval of Investment or Technical Cooperation in Mainland China", Taiwanese firms should apply to the Investment Commission, Ministry of Economic Affair (MOEA) in Taiwan for their FDIs in China. After the Investment Commission reviews the FDI application documents, the commission determines whether these applications would be approved as well as the maximum quota for each applicant's FDI amount in China. The FDI investment amount of the Taiwanese firms that obtain the FDI approvals are confined by the maximum investment quota permitted by the Investment Commission. The cumulative maximum quotas are defined as the permitted amount in Table 1. From Table 1, it is obviously observed that IC foundry manufacturing firms are strictly prohibited from FDI in China before 2001. The FDI restrictions of IC manufacturing firms are most strict among IC industries.

Table 1. The permitted and actual FDI flow from Taiwan to China (The Unit is NT Dollars (thousands)).

	IC packing and testing		IC manufacturing		IC design	
Year	Permitted	Actual	Permitted	Actual	Permitted	Actual
1999	29,127	29,127	-	-	49,743	37,143
2000	36,001	36,001	-	-	181,882	85,959
2001	1,242,539	444,984	69,040	48,930	1,456,728	894,648
2002	2,465,567	1,688,093	69,040	48,650	2,786,212	1,601,342
2003	3,598,655	2,579,665	1,959,992	1,948,701	3,428,795	2,489,698
2004	6,527,870	5,612,450	11,911,286	9,256,593	4,199,260	3,293,861
2005	11,126,242	9,570,344	12,416,510	12,411,582	5,316,912	4,385,577
2006	15,590,467	12,667,510	24,364,115	12,462,065	6,305,167	5,240,580
2007	18,272,096	16,643,989	24,911,874	15,388,032	8,330,090	6,144,467

4.2 Empirical Results

4.2.1. Results of Dynamic Bass Diffusion Model

Table 2 and Table 3 exhibit the descriptive statistics of variables in this study and the results of the regression, respectively. Both coefficients β and γ appear significant in all the three regressions for the three industries. The total FDI amount, internal and external influence factors are further calculated and listed in Table 4. The coefficients of internal influence q are calculated 0.1252, 0.2496, and 0.6281 for IC design, IC packaging and testing, and IC manufacturing industries, respectively. The positive effect of internal communication exists in all the three types of industries.

Moreover, the relationship of $p < q$ is always held for all the three industries. This suggests that the effect of internal influence is larger than external influence. Thus, the imitating effect of Taiwanese IC firms dominates the dynamics of FDI flow in China, unveiling that the internal influence through communications or interactions among intra-industry firms is the key factor of FDI flow to China. Because of the economical high-risk and uncertainty in China, most Taiwanese eschew investing in China under the premise that no previous experienced firms had undertaken FDIs in China. After they share the FDI experiences from the incumbent FDI enterprises in China, they would evaluate the risk tolerance to involve in FDI in China. The IC industrial clusters are gradually established by means of this interactive communications among FDI members.

Table 2. Descriptive statistics of variables in our research (The Unit is NT Dollars (thousands)).

	Design	Manufacturing	Packaging and Testing
Mean	175,556.20	569,927.11	462,333.03
Median	123,514.00	6,776.00	192,322.00
Maximum	635,028.00	4,394,854.00	2,468,413.00
Minimum	-591.00	-1,833.00	0
Standard Deviation	175,501.61	1,145,966.45	633045.28

Table 3. The results of the regression (**: p□ 0.05; *: p□ 0.1).

Industry	Variable	Coefficient	t-Statistics
Design	α	41,703.07	0.843
N=35	β	0.1199	2.5533**
	γ	-1.6×10^{-8}	-1.9118*
Manufacturing	α	236,109.49	0.7446
N=26	β	0.6106	2.8959**
	γ	$1.59\text{E}\times10^{-8}$	-2.9278**
Packaging and	α	12826.47	0.1012
Testing	β	0.2489	4.1892**
N=35	γ	-1.36546×10^{-8}	-3.3527**

Table 4. The estimation results of total FDI amount, the internal and external influence factors.

	Design	Manufacturing	Packaging and Testing
M	7,973,318.00	13,488,100.86	18,278,986.67
P	0.0052	0.0175	0.0007
Q	0.1252	0.6281	0.2496

Particularly, the coefficient of internal influence *q* is the largest for IC manufacturing firms, which supports the most profound clustering effect for IC manufacturing industries among the three IC industries. As long as Taiwan IC manufacturing firms cluster together and construct factories in China, their suppliers could implement their channels in China. Thus, such suppliers' channels enable successive IC manufacturing firms to free-ride suppliers' support much easier, resulting in the strong motivation of successive firms to engage in FDIs.

In addition, the potential FDI amounts are totally estimated 7,973,318, 13,488,100, and 18,278,986 New Taiwan (NT) dollars (thousands) for IC design, IC manufacturing, and IC packaging and testing industries, respectively. Since the production process is mature and relatively low-end for IC packing and testing sector, the lower Chinese labor costs stimulate IC packaging and testing firms to engage in large amount of FDI in China. The empirical results are consistent with product life cycle theory [26] which emphasizes FDIs in emerging areas as the production process of a specific product is mature. Taiwanese IC packaging and testing firms are inclined to transfer their production into China where the labor wages are much lower than those in Taiwan.

4.2.2. Goodness of fit analysis

The actual FDI amount and predicted FDI amount by the growth model for the three IC industries are depicted from Figure 1 to Figure 3. Both the predicted and the actual net amount of cumulative FDI are increasing. The increasing presence of the FDI flow into China once again corresponds to the industrial clustering effect of Taiwanese IC enterprises. Besides, the finding controverts the claim that Taiwan government closes its country gate to international intercourse or prohibits its enterprises from foreign investment. Three different sizes of the amount of FDI are calculated by using the analytical method (Eq. (12)) for the three industries. According to Bass estimate procedures [1], the goodness of fit results are shown in Table 5. Table 5 shows that the evaluation of the goodness of fit, *R* square, is over 97% for IC design, packaging and testing industries. It manifests that we always obtain a set of parameters *p* and *q* to finely fit the real collected FDI data. However, the *R* square is only 41.43% for the IC manufacturing firms.

The possible reason in our interpretation is about the strictly political limits of FDI in China for IC foundry manufacturing firms. Under Regulations Governing the Approval of Investment or Technical Cooperation in Mainland China, Taiwanese firms are required to implement FDI in China only when they obtain the governmental permissions. None of IC foundry manufacturing firms are permitted by Taiwanese government until the second quarter in 2001. Among the IC foundry manufacturing firms, Winbond Corporation is the only company which receives the government's permission to involve FDI in China prior to 2002. Its permitted maximum amount is NT$69,040, so Winbond Corporation initially invested 45,720 to China. Due to the strict restrictions, no other IC manufacturing firms engage in FDI before 2002.

Table 5. Goodness of fit for the growth models.

	Design	Manufacturing	Packaging and Testing
R^2 (%)	99.68	41.43	97.23
Adj-R^2 (%)	99.36	39.09	94.54

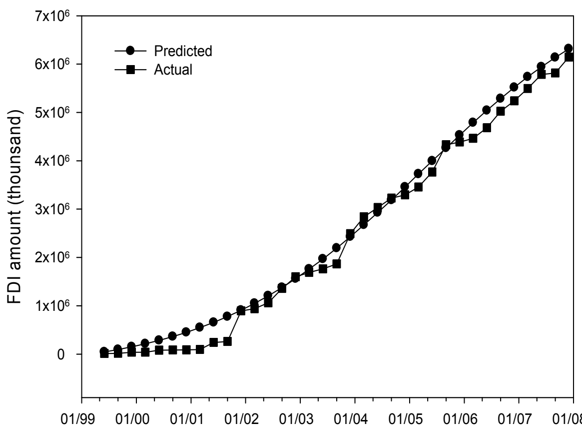

Figure 1. Actual FDI and predicted FDI by the growth model for IC design industry.

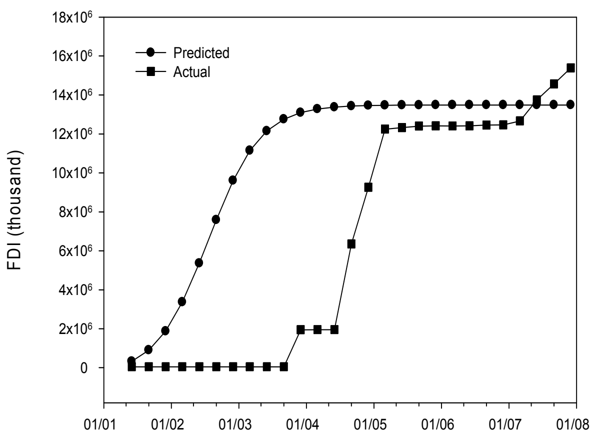

Figure 2. Actual FDI and predicted FDI by the growth model for IC manufacturing industry.

After the Taiwanese government drew up "Directions Governing the Review and Supervision of Investment in an IC Foundries in Mainland China" and revised "Regulations Governing the Approval of Investment or Technical Cooperation in Mainland China" in the third quarter of 2002, the government gradually relaxed the FDI restrictions to China for IC manufacturing firms, and totally five IC manufacturing firms began to engage in FDI in China. Thus, huge amount of capital flows were remitted to China after the government approved of the FDI applications for IC manufacturing firms. For example, Taiwan Semiconductor Manufacturing Company (TSMC) initiated remitting nearly 2,000 million to China in December of 2003 and in September of 2004 it remitted nearly 4,000 million for the second time.

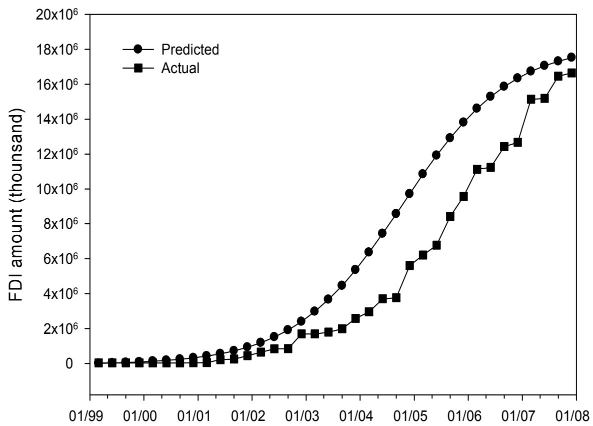

Figure 3. Actual FDI and predicted FDI by the growth model for IC packing and testing industry.

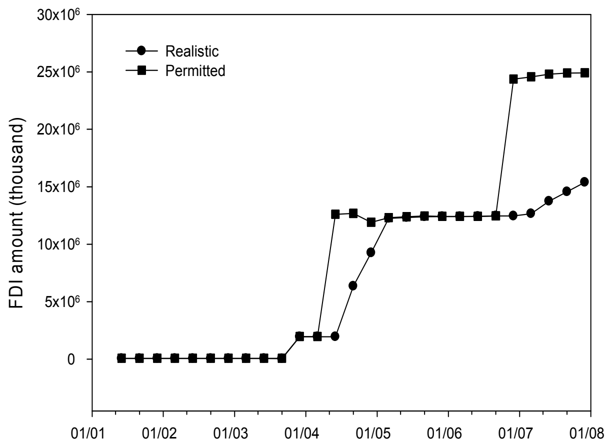

Figure 4. Permitted and realistic cumulative FDI amount for IC manufacturing industry.

Permitted and realistic cumulative FDI amount for the IC manufacturing industry are listed in Figure 4. It is clearly observed the FDI remittance is bound by the regulatory prohibitions. Once IC manufacturing firms receive the governmental permission, these companies would remit huge amount of capital flow in China. Hence, the remitting amount is fairly great for each time but the frequency of remitting is very low. As a result, the variation of actual FDI amount is so great that the actual FDI attribute reveals much deviation from the smoothness of the predicted FDI trend.

4.2.3 **Additional Test**

In previous section, we found that the forecasts of IC foundry manufacturing firms as well as IC packaging and testing firms were not as accurate as that of IC design firms, because the government restrained them from involving in FDIs in China. From Table 1, it is clearly observed that the actual FDI amount in China is close to the permitted FDI amount in China prior to 2000 and 2002 for IC manufacturing and IC packaging and testing industries, respectively. The regulatory FDI control prevents the FDI from flowing freely, which reduces the prediction capacity of our models.

In this section, we remove the sample periods of strict regulatory FDI limits for these two kinds of IC foundry industries, thus additionally constructing the forecasting models again with the period of FDI restriction relaxations as the sample period. For IC manufacturing firms, the sample period ranging from the third quarter of 2003 to the fourth quarter of 2007 is applied in the additional test. For IC packaging and testing firms, the sample period ranging from the fourth quarter of 2000 to the fourth quarter of 2007 is additionally investigated.

Table 6. Descriptive statistics of net FDI amount to China for the additional test (The Unit is NT Dollars (thousands)).

	Manufacturing	Package and Testing
Mean	854,890.67	572,926.28
Median	76,439.5	202,170
Maximum	4,394,854	2,468,413
Minimum	-1,833	4,766
Standard Deviation	1,323,077.9	660,120.34

Table 6 and Table 7 exhibit the descriptive statistics of variables in the additional tests and the results of the regression, respectively. The total FDI amount, internal and external influence factors are further calculated and listed in Table 8. The internal influence coefficient remains the largest for manufacturing firms and the smallest for IC design firms. This once again implies the greatest extent of clustering effect for IC manufacturing firms. The examination of the prediction ability for the additional test model based upon deregulation period is also shown in Table 8. The R^2 dramatically increases from 41.43% in Table 4 to 92.30% in Table 8 for IC manufacturing industry. On the other hand, The R^2 increases from 97.23% in Table 4 to 99.56% in Table 8 for IC packaging and testing industry. It can explicitly conclude that the model based upon the restriction relaxation period performs much better than that of original model for IC manufacturing industries.

Table 7. The regression results of the additional test (**: p□ 0.05; *: p□ 0.1).

Industry	Variable	Coefficient	t-Statistics
Manufacturing	α	1454239.499	1.6456
N=18	β	0.2459	0.7101
	γ	-2.55×10^{-8}	-1.0890
Packaging and	α	25,348.72	0.1417
Testing	β	0.2452	3.3465**
N=29	γ	-1.35×10^{-8}	-2.7849**

Table 8. The estimation results of total FDI amount, the internal influence, external influence factors and goodness of fit for the additional test.

	Manufacturing	Packaging and Testing
M	13,785,972.91	18,324,111.42
P	0.1055	0.0014
Q	0.3514	0.2466
R^2 (%)	92.30	99.56
Adj-R^2 (%)	91.82	99.55

Also, Figure 5 and Figure 6 exhibit that the predicted FDI amounts are much closer to the actual FDI amounts for models based on the restriction relaxation periods. The improvement of the prediction ability reflects the political influence in FDI, especially for IC manufacturing firms.

5. Conclusions

This paper has quantitatively analyzed the clustering behaviours by using the foreign direct investment (FDI) data of Taiwan IC industries. The results of the regression exhibit that the internal influence dominates the growth of FDI flow from Taiwan to China ranging from 1999 to 2007 for IC industries. This suggests that the internal influence through intra-industry communications or interactions is the key factor of FDI flow. Since IC industry FDI was permitted in 1999, the imitating behaviour has always taken a more prominent role than innovative behaviour. Because of the economical high risk and uncertainty in China, the information from host country (China) through advertising fails to stimulate the investment desire and motivation of investors from the parent country (Taiwan). As long as the Taiwanese enterprises make sure that the Chinese investment environments are safe enough to their required levels from the information captured from the pioneering, experienced firms, they will undertake FDI flow in China successively. Hence, the IC industrial clusters are gradually formed to China through the imitating FDI behaviour of Taiwanese IC firms.

Specifically, industrial characteristic differences in FDI have been empirically explored among various production stages of IC industry. This article has pointed out the most profound imitating inclination for IC manufacturing industry, which suggests its greatest FDI clustering inclination. More interestingly, the potential size of total FDI flow amount is the largest for IC packaging and testing firms, consistent with the product life cycle theory.

Finally, the dynamic diffusion model has predicted the FDI amount as increasing gradually. Once more and more IC corporations build up production sites in the specific location, the other IC firms are likely to cluster together constructing their factories to share the available materials, basic equipment and suppliers' resources. Our prediction exhibits that the prediction ability of our FDI growth model is superior for IC design, packaging and testing industries. Unfortunately, the predicted FDI of IC manufacturing industry is not as accurate as that of the other two industries because our sample periods cover the phase when the Taiwanese government strictly prevents IC manufacturing industry from FDI in China. After such period is deleted, the prediction ability increases substantially for IC manufacturing industry.

So far, we have investigated clustering evolutions based on dynamic Bass diffusion model. However, other applications on different countries, relaxations of the assumptions, the heterogeneous properties among investors, non-symmetric growth patterns, and the periodical nature, should be considered in further research.

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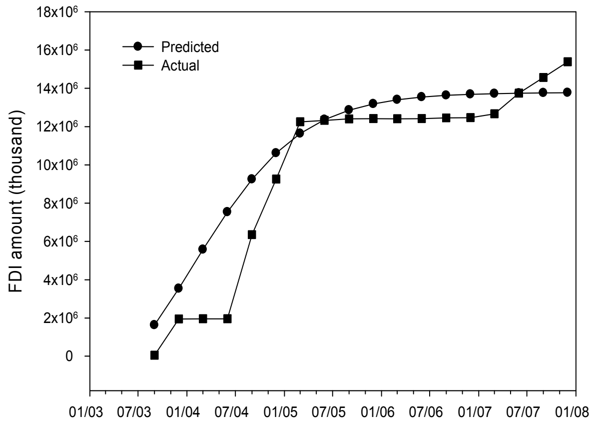

Figure 5. Actual FDI and predicted FDI by the growth model for IC manufacturing industry during the deregulation period.

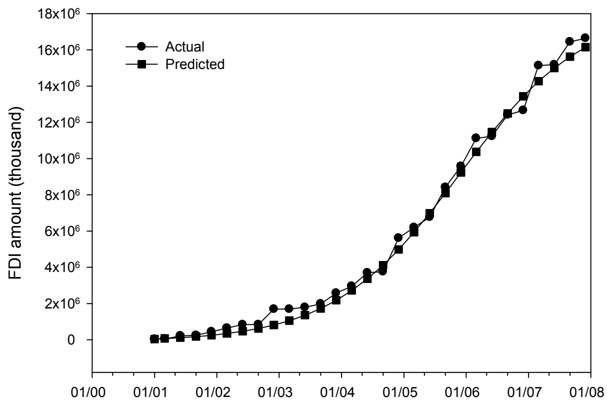

Figure 6. Actual FDI and predicted FDI by the growth model for IC packing and testing industry during the deregulation period.

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