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The effect of clusters on the development of the software industry in Dalian, China

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ABSTRACT

The trend toward globalization has not only facilitated the circulation of capital, technology, and talent, but has also provided industries in developing countries with an opportunity for rapid development. This study uses the system dynamics methodology to construct a dynamic development model to explain the phenomenon of clustering in the Dalian, China software industry. The results indicate that the rapid development of the Dalian software industry is the result of a growth effect generated primarily from the clustering of talent, technology, and capital and their mutual reinforcement. This study also discusses future bottlenecks to growth in the Dalian software industry that may result from limited environmental resources.

1. Introduction

Industrial development in any country is a complex, dynamic, and sustained process that is greatly affected by history, culture, politics, economy, society and the timing of development. The development is controlled by technology-related policies that are implemented in each country [1–3]. In addition, state guidance of industrial development can include talent incubation, capital accumulation, technical learning, and innovation [4–6]. Since all these factors are linked, the structure of industrial development is extremely complicated [7,8], and therefore developing policies regarding industrial development is comparatively complex [9].

In recent years, China has duplicated the industrial development patterns of Taiwan in order to pursue its own industry development, and China has exhibited astonishing development performance. For example, an industry cluster of semiconductor and electronic and electrical machinery manufacturers was formed using the Shanghai region as the hub, and distributing throughout the Yangtze River Delta and along the lower reaches of the Yangtze River. In another example, an automobile industry cluster centered around Jiangsu, Fujian, and Guangdong has developed gradually and now has the potential to develop into an international automobile manufacturing base in China [10–12]. Since 1978, the Chinese government has promoted a series of development projects to serve its domestic software industry, including the "Torch Program," "Ten National Software Industry Bases," "Six National Software Export Bases"; it also has approved eleven key software parks in Beijing, Shanghai, Dalian, Jinan, Xian, Nanjing, Changsha, Chengdu, Hangzhou, Guangzhou, and Zhuhai as national industrial bases for advancing overall software industry development [11].

Since the establishment of the Dalian Software Development Park in 1998, the output value of the software and information service industry there has developed rapidly, achieving a compound growth rate exceeding 50%. In addition, from 1998 to 2005 sales revenue has grown from US$25 million to US$1.28 billion. The 2005 report [13] on the development of the Dalian software and information service industry pointed out that the 2005 industry sales revenue increased by 43% compared to 2004, exceeding national average growth for that year. Simultaneously, Dalian City was officially named the first and only "Internationalized Software Industry Model City" in China. Taken

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together, this evidence demonstrates the key role played by Dalian in the development of the Chinese software industry. However, how Dalian was able to outperform its competitors in less than a decade deserves further discussion.

This study adopts the systems perspective to analyze software industry development in Dalian. In addition, we conducted an in-depth analysis of industry clustering from three perspectives: talent, technology, and capital. We used system dynamics (SD) causal loops to construct a dynamic model of the Dalian software industry development. Thereafter we adopted the sustainable cities development perspective for further consideration (within the restrictions of environmental conditions) of development bottlenecks that the Dalian software industry may encounter in the future, and the responses of the Dalian city government.

2. Industrial clusters and system dynamics methodology

The term "industry cluster" is defined as companies or organizations in a similar field and in the same geographic region. Companies in such clusters cooperate up and down the supply-chain while at the same time competing with each other [14]. Companies in an industry cluster gain a competitive advantage in their industry and foster enterprise innovations [15]. Numerous studies have found that industry clusters increase the competitiveness of relevant industries in both developed and developing countries. For instance, a narrow belt within the northeast and eastern parts of the Midwest dominated manufacturing in the U.S. until the mid-1950s, with 64% of manufacturing employment [16]. Brazil's shoemaking cluster in Sinos Valley held 5–12.3% of the total volume of the global shoe market from 1920 to 1990, respectively [17]. The Sialkot stainless steel clusters in Pakistan, together with Tuttlingen in Germany, dominate the global surgical instrument market [18]. The Japanese ceramic industry has clustered in the Seto area, which now controls the international market [19]. Switzerland's precision industry, which manufactures watches and clocks, is clustered in the Jura Arc [20]. Wind musical instruments have clustered in Elkhart, Indiana [16], while fashion goods have clustered in northeast-central Italy [21]. Many of Taiwan's world-leading industries, such as semiconductors, electronics, and TFT-LCED, have clustered in Hsinchu Science Park [1,7,22,23]. Michael Porter lists 30 clustered industries, such as the U.S. automobile industry cluster in Detroit, insurance in Hartford, and aircraft equipment and design in Seattle. Additionally, Portugal has several clusters oriented toward exports and entrepreneurship, ranging from ornamental stones in Evora to horticulture in Faro [14].

However, virtually all of the studies and research on these industry clusters has focused mainly on regional economic development, enterprise initiation, industry value chain, industrial networks, transaction cost, technology diffusion, geography and trade, technology forecasting, industry-education cooperation and technological innovation. Furthermore, most studies have focused on quantitative research while ignoring qualitative research [24,25]. Quantitative studies have clear methodology, are reproducible and falsifiable, but may have a narrow mathematical focus, and their findings are not always practically relevant. Accordingly, the problems of driving industrial development are increasingly vast, complex, and dynamic [26–30], while key variables involved in the infrastructure of software industry development frequently interact with each other [31]. Traditional quantified research does not effectively address these issues [32–35]. In contrast, qualitative studies do not identify the true from the false aspects of objective facts, but instead attempt to explain social phenomena. Consequently, the qualitative research may involve long-term observation and repeated speculation to establish in-depth interpretations for external phenomena [25].

Generally, the development of an industry requires extended accumulation of its own "energy," followed by a slow and gradual display of industry scale and performance [36]. Development not only is an extended process but also involves numerous factors, such as government policy (including infrastructure, counseling, and reward measures, etc.), industrial environment, market competition, R&D and innovation, talent incubation, and investment from domestic and foreign enterprises. Among these factors, talent incubation and key technology development require time to yield results. Additionally, along with the linked causal relationships that exist between variables, dynamic and complex phenomenon cannot be clearly explained using a single perspective or a single time point [32–35].

This study adopted elements of the system dynamics methodology to examine the primary reasons why the Dalian software industry developed so successfully. These elements are:

- In the process of industrial development, complex relationships exist between talent, technology, and capital. However, the analytical methods applied to conventional industries are unable to directly express the causal relationships existing among these variables. In contrast, SD causal loops are suitable for analyzing such complex structures. An analysis of the causal loops explains the impact on the system of linked causal relationships between variables and the external environment in the process of industrial development.
- As a long and time-consuming process, one of the key characteristics of industrial development is the change that follows a time path and shows a dynamic transitive status. Industrial development cannot use a single time point to understand industrial status; however, SD can use causal loops to construct a dynamic model in which talent, technology, and capital are considered from a dynamic perspective as a circulating flow. Observers thus can better explain the influence of the environment on dynamic behavior and systems, and analyze future system development trends.
- Industrial development is a long-term and evolutionary process. It is hampered by periodic and inevitable personnel changes in senior management that prevent policymakers from acquiring insight into the evolving status and problems during the period of industrial