System Dynamics Approach for Model of the Economic Impact of a Linkage Policy between China-Korea Industrial Park and the Free Trade Zone

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***Abstract*—This study firstly summarizes the linkage paths between China-Korea (Yantai) Industrial Park and the Free Trade Zone, and secondly applies the system dynamics (SD) approach to model the park's case enterprise for in the park to analyzing the changes in economic benefits before and after the implementation of the linkage policy. For a single policy, the results show that "tax subsidy in the FTZ" under the Trade & Investment path has the most significant positive effect, while "industrial park incentive subsidy" has a negative impact on the enterprise. For the combined policy, the combination of the "tax subsidy in the FTZ" Combined with "The strength of the industrial park on the return process supervision" under the linkage path in Trade & Investment is the most obvious.**

***Index Terms*—China-Korea industrial park, Free trade zone, Linkage policy, System dynamics.**

I. Introduction

Since the China-Korea Free Trade Agreement (FTA) came into effect in 2015, and the cooperation of between industries between in China and South Korea has become a hot topic in the political, industrial, and academic sectors of both countries [1]. In December 2017, after the approval of President Xi, the State Council issued the "Approval of the State Council on the Establishment of the China-Korea Industrial Park", making the decision to set up China-Korea Industrial Park in Yancheng City, Jiangsu Province; Yantai City, Shandong Province; and Huizhou City in, Guangdong Province [2]. On November 11, 2021, the APEC Business Leaders' Summit was held, and it was decided that the Regional Comprehensive Economic Partnership Agreement (RCEP) would came into effect on January 1, 2022, for ten countries, including China, Korea, and other countries. This was also expected, to create new opportunities for the construction of the China-Korea Industrial Park [3]-[4].

Considering the vertical depth of the park's cooperation with Korea and its geographical advantage [5], this study focuses on the China-Korea (Yantai) Industrial Park. Through intensive institutional innovation, the parks maximizes the advantages of linkage policies, attracting numerous a large number of multinational projects to move in [6]-[7]. In 2021, a total of 47 Korean-invested projects were introduced to the China-Korea (Yantai) Industrial Park, accounting for nearly half of the city's share. The total utilization of Korean capital in the park was more than $ 60 million dollars, an increase of 12 times. In addition, according to the China-Korea FTA, 90 percent of the tariff items of products and 85 percent of the trade volume for the two countries are gradually being realized. Korea C & M Co., Ltd. led the joint construction of a new energy automotive electronics production base with an investment of up to $ 20 million. This project is the first Korean-funded Fortune 500 projects introduced since the park's establishment of the park [8].

This paper analyzes the current situation of linkage development between the China and -Korea (Yantai) Industrial Park and the FTZ, summarizes the specific path of their linkage, and constructs a simulation model of the park's enterprise based on the system dynamics theory. By building a circular network framework model, the coordinated operation of the production, distribution, and delivery of the enterprise's products in the park is realized. A representative enterprise in the park, Atomy, was selected as the case model for analysis. In addition, in order to verify the validity of the model, this study measured the changes in corporate earnings before and after linkage by adjusting the variable parameters of the variables. Finally, the development of a China-Korea (Yantai) industrial park linkage to the FTZ in terms of trade and& investment, industrial innovation linkage, and port transportation is proposed to provide strong support for high-speed regional economic development [9].

The rest of this paper is organized as follows. Section 2 reviews relevant research. Section 3 proposes the specific path of linkage development between the China and Korea (Yantai) Industrial Park and the FTA. Section 4 establishes the SD model of an enterprise in an industrial park from overseas production, cross-border transportation, warehousing, distribution, delivery, and multiple other links. Section 5 presents the sensitivity analysis and model testing based on the modeling. Focus was placed on adjusting the parameters of various linkage policies between industrial parks and FTZ to promote the development of enterprises in Sino-foreign cooperative industrial parks. In Section 6, the model is summarized, and suggestions are made to promote a deeper interface between China and the Korea (Yantai) Industrial Park and the FTZ.

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II. Literature Review

Over the past 30 years, since the establishment of diplomatic relations between China and South Korea, the two countries have made important developments by expanding trade and deepening areas of economic and trade cooperation based on economic complementarity [10]. In the context of international and domestic cooperation between China and South Korea, the FTA, and the "One Belt, One Road" initiative, many scholars have analyzed and discussed the development status of the industrial linkage between China-Korea (Yantai) Industrial Park and FTZ [11]. Using macro-level analysis, scholars have proposed expanding the coverage of the China-Korea FTA, focusing on services and investment, increasing non-trade concerns about competition and the environment, and strengthening good governance norms [12]. Emphasis has been placed on upgrading the network platform, including rediscovering the advantages of the location, focusing on the parallel transfer of industries, and vigorously developing the "industrial chain economy" [13]. Cooperation in emerging industries, transportation, and logistics to promote economic and trade, humanistic exchanges, and policy docking needs to be strengthened [14], and a new cooperation model with which China and South Korea can participate in the international division of labor and collaboration, that is, third-party market cooperation, needs to be created [15].

Using micro-level analysis, Cattaneo selected data on the import and export trade between China and South Korea using a synthetic control method to conclude that the net trade effect from the China-Korea FTA policy is generally positive, and the bilateral import and export trade between China and South Korea shows a creation effect [16]. Taking the specific parks of Yancheng and Yantai as examples, scholars suggest that the China-Korea Industrial Park is in the construction and upgrading stages. There is an urgent need to take measures to promote the deep integration of "industry, talent and city," adhere to the seaward development strategy, and build a new highland for China-Korean cooperation [17]-[18]. In addition, based on the development needs of a specific China-Korea Industrial Park, the financial mechanism should be improved, and innovation should be strengthened to effectively meet the financial service needs of industrial park enterprises [19]. The training of professionals in Korea should be integrated into the industry to build a talent training system that serves the needs of a city's economic development [20]. Besides, it is necessary to expand from a single field of industrial cooperation to multi-disciplinary cooperation in trade and technology, beauty and health, culture and creativity, and tourism and sightseeing industries [12], [21].

From a methodological perspective, SD theory was first proposed by Professor Forrester in 1961 and introduced to China in the 1970s. Currently, this method is widely used in many fields, including natural sciences, social sciences, business planning, and dynamic decision-making [22]-[24]. In the early days, research related to system dynamics concerning industrial parks and cross-border trade combined customer expectation management ideas with service experience by adopting the system dynamics approach to design strategies [25]. A system dynamics approach was used to simulate the performance of cross-border e-commerce enterprises and to provide suggestions from the government's perspective [26]. Furthermore, there has been an increase in the level of reform and the development of the logistics industry, along with related studies, including those focusing on simulations of the combination of regional economies and logistics parks [27] and simulations of the impact of different policy combinations on free trade ports [28]-[29]. These have expanded the application of system dynamics in different fields from multiple perspectives. Recently, policy simulations of industrial ecosystems have become popular. A system dynamics approach was used to analyze the impact of governance mechanisms on value co-creation in the blockchain industry ecosystem [30]-[32].

In summary: (1) the linkage development of the China-Korea Industrial Park and FTZ has not been sufficiently researched; that is, previous studies did not fully consider the sharing of resources between the two, and they were only conducted for separate individuals. (2) Quantitative studies of Sino-foreign cooperative industrial parks are scarce. The impact of the CKIP on the efficiency of cross-border logistics and the increase in profits of enterprises in the region are largely lacking in terms of mathematical statistics and software tools. (3) Research on the linkage policy between industrial parks and FTZ mostly remains at the macro policy level, whereas the refinement and implementation of specific enterprises in specific parks have been neglected. From the perspective of linkage between China-Korea (Yantai) Industrial Park and FTZ, this study applies a system dynamics approach to model the case enterprises in the park and analyzes the changes in the economic benefits of the enterprises before and after the linkage policy implementation. Therefore, this paper not only broadens the perspective of the China-Korea Industrial Park and deepens the research content of the park's linkage development, but it also provides policy suggestions for the further development of resident enterprises and the linkage between the China and Korea (Yantai) Industrial Park and FTZ.

III. Linkage Paths

This section summarizes recent specific paths of linkage development between the (Yantai) Industrial Park and the FTZ.

(1) Trade and Investment: The Yantai FTZ is linked to the China-Korea (Yantai) Industrial Park, and the pace of investment has accelerated. In September 2021, many projects, such as new energy automotive electronics projects and automotive steering wheel assembly, were completed and landed. According to statistics, in the first half of 2021, 14 Korea-invested projects were settled in the FTZ, which was equal to the total number of projects in the previous year. In addition, since 2020, Yantai FTZ has focused on promoting joint construction and pioneering "investment facilitation across the office." As of the second half of 2021, the China-Korea (Yantai) Industrial Park has introduced 113 Korean-funded projects, including two Fortune 500 direct investments, utilizing $76.3 million in Korean capital. To sum up, the specific policies in the model include "Foreign Exchange Facilitation Settlement in Free Trade Zone," "tax

subsidies in the FTZ," "Lending offers for industrial parks" and "The strength of the industrial park in the return process supervision" [33]-[34].

(2) Industrial Innovation Linkage: The Yantai FTZ will further promote the expansion of the China-Korea Economic and Cultural Exchange Center. Under this influence, the China-Korea (Yantai) Industrial Park will focus on promoting cross-border e-commerce, industrial design, environmental protection, and other new business enterprises. Relying on the China-Korea Economic and Cultural Exchange Center provided by the FTZ, the Park conducted China-Korea cultural industry seminars and continued to import Korean animation and e-sports elements through innovative communication channels and activity forms, deepening the consensus on cooperation between the two countries in the cultural field [35]-[36]. The specific path policies were "Industrial Park Incentive Subsidy" and "Favorable rent for bonded warehouse in FTZ."

(3) Port Transportation: Since the completion of Yantai Port, the mutual recognition of AEO cooperation between China and Korea Customs and the development of a "two-step declaration" business between the park and FTZ have simplified the audit procedures, compressed the cost, and significantly improved the level of trade facilitation. According to statistics, in the two months since the above policy was in effect, Yantai issued 632 certificates of origin for the FTA between China and Korea, with a total investment of USD 16.12 million and a total tariff reduction of USD 810,000 for enterprises. Furthermore, on April 27, 2021, the State FTZ approved the Yantai FTZ to upgrade the Yantai Bonded Port Zone into a comprehensive bonded zone. On this basis, the Yantai FTZ laid out an efficient transportation network of "zone-gate-port-railway" to help the park's goods leave the port quickly. In 2021, the cargo throughput of Yantai Port will reach 337 million tons, an increase of 9.2% annually. The port operating revenue reached 11.99 billion yuan, an increase of 34.56% per year [27], [33]. "Industrial park to accelerate the lifting of goods from the port" and the growth rate of the FTZ overlay industrial park's "two steps to declare" were the specific policies of Port Transportation.

IV. Model Construction

System Dynamics (SD) can reflect the function of complex system structures and interactive relationships between dynamic actions, conduct dynamic simulation tests of complex systems, and investigate the changeable behavior and trends of complex systems affected by different strategy factors [37]-[39]. According to the SD principle, the construction of an SD model includes conceptualization, modeling, and simulation [40]. The system of product trade for the park's enterprises under the influence of the linkage policy between the China and Korea (Yantai) Industrial Park and the FTZ was analyzed first, and the system boundary was defined. Second, system flow charts were drawn based on the causal feedback analysis, and quantitative relationships were built based on the system analysis. Third, the model can be optimized by drawing the result chart, adjusting the values of the main policy parameters, and repeatedly simulating the experience. This process is elaborated in Section 5.

A. Conceptualization

Based on the principle of SD combined with park visits, this study selected a representative Korean-funded enterprise, Atomy, as the model object. Atomy is a global product distribution company founded in 2009. In February 2017, it moved into the East Zone of the park as the "largest e-commerce platform in Shandong Province." In addition, Atomy promoted the program of the Industrial Park linked with the FTZ in May 2020, and the company met the selection criteria for the study. 2021 sales of Atomy were $1.84 billion, and its product was imported from Korea to China, which is a typical cross-border e-commerce enterprise. Therefore, this study considers the trade activity process of Atomy's product as an information feedback system and divides it into several subsystems according to the supply chain [41]. In this study, the Atomy trade system was divided into four subsystems: production sourcing, cross-border logistics, bonded warehousing, e-commerce marketing, and services.

TABLE I
Atomic System Conceptualization

Production Sourcing	Cost of goods
	Cross-border e-commerce operating costs
	Product liability insurance costs
	Average consumer demand
	Cross-border purchase volume
	Purchase inventory
	Safety stock
	Number of shipments from suppliers in Korea
Cross-border Logistics	International logistics volume
	Cross-border logistics cost
	Cross-border logistics efficiency
Bonded Warehousing	Bonded storage efficiency
	Storage cost
E-commerce Marketing and Service	Promotion cost
	Pricing level
	Product sales volume
	Sales profit
	Atomy's reproduction inputs
	Performance growth
	Brand impact
	Consumer repurchase rate
	Cross-border e-commerce integrated service level
	New sales profits

B. Modelization

Causal Loop Model

In the SD model, there are positive(+) and negative(-) feedback effects between various variables, which can avoid single-way simulation and manual intervention. Therefore, the simulation results are more scientific and objective. The

chart below shows the causal feedback chain of the enterprise's system, where we only analyzed several main causal feedback loops (Fig. 1) [38]. The basic idea of this model is that there is a positive feedback relationship between cross-border purchase volume and enterprise reproduction. If the purchase volume increases, the quantity of procurement inventory improves and ensures a sufficient supply of products. More product sales will increase enterprises' profits and drive their sustainable development, and the reproduction input will eventually promote further growth in purchase volume (Fig.1). That is, loop R1 indicates that an increase in cross-border purchase volume has a positive impact on enterprise reproduction (Fig. 2).

R2 (Fig. 3) reflects the cost of operating a cross-border e-commerce business and the reproduction input mechanism for apartments. According to price theory combined with the theory of supply and demand, the modeling of cross-border e-commerce operating costs flows into two paths that constrain the amount of reproduction inputs of Atomy from pricing levels and average consumer demand, respectively. Thus, R2 loop has two branches, namely, the negative feedback loops R2-1 and R2-2 (Fig. 3).

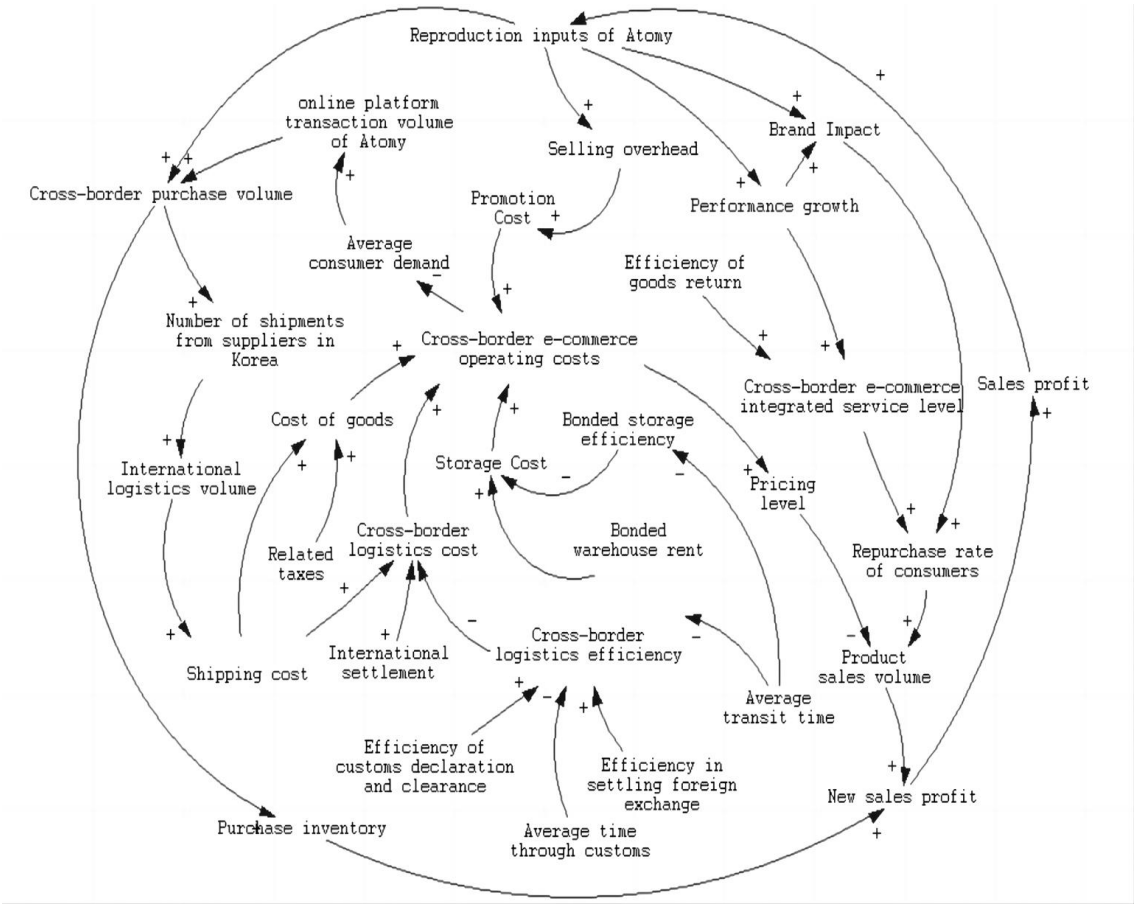
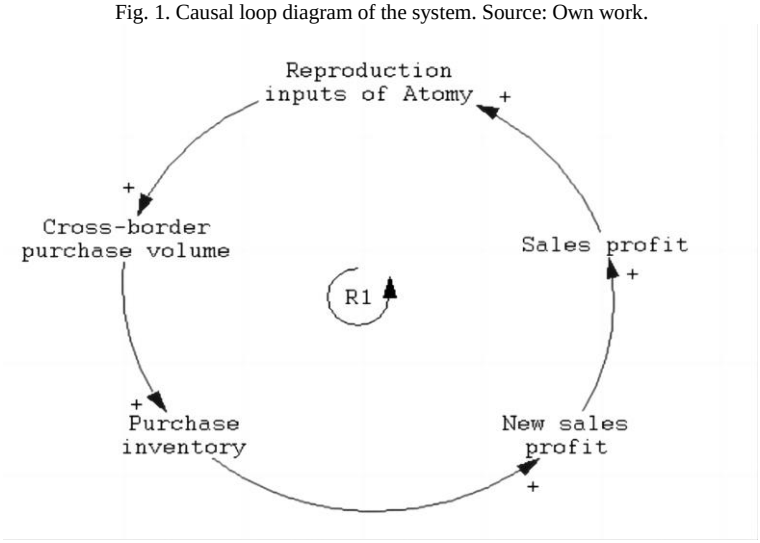
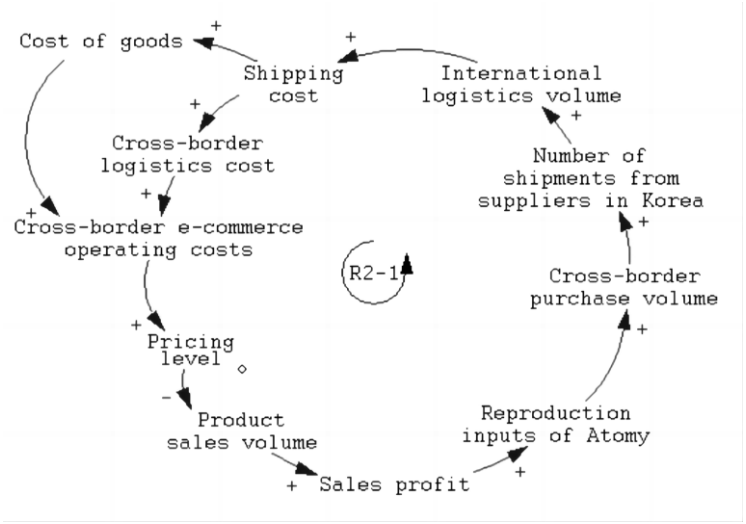


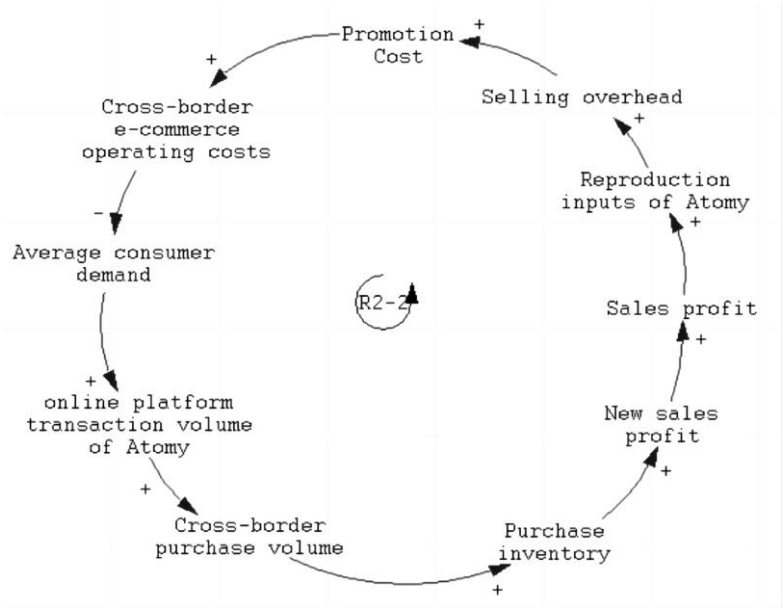
Fig. 1. Causal loop diagram of the system. Source: Own work.



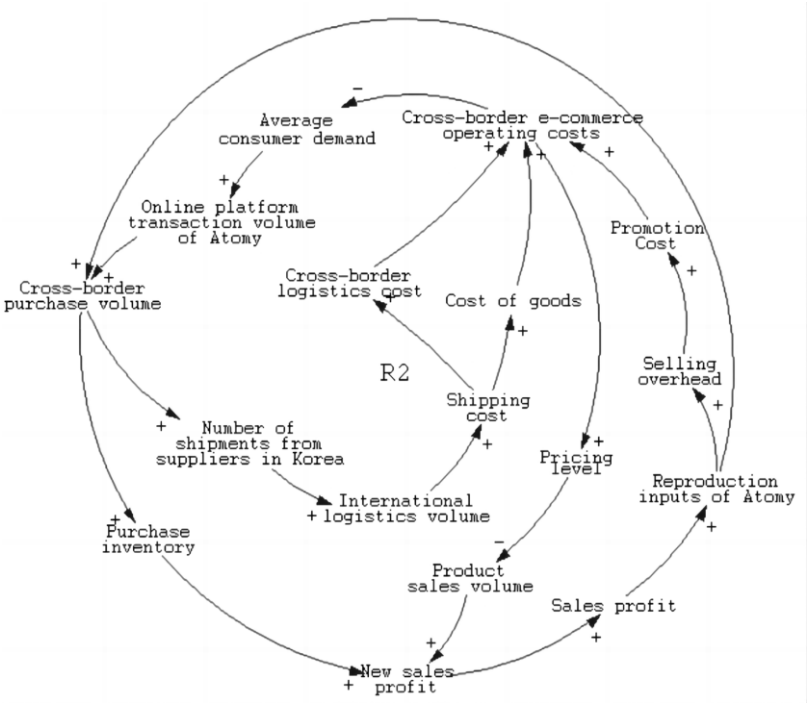
R1



R2-1



R2-2



R2

Fig. 2. Feedback loop for the main model source: Own work.

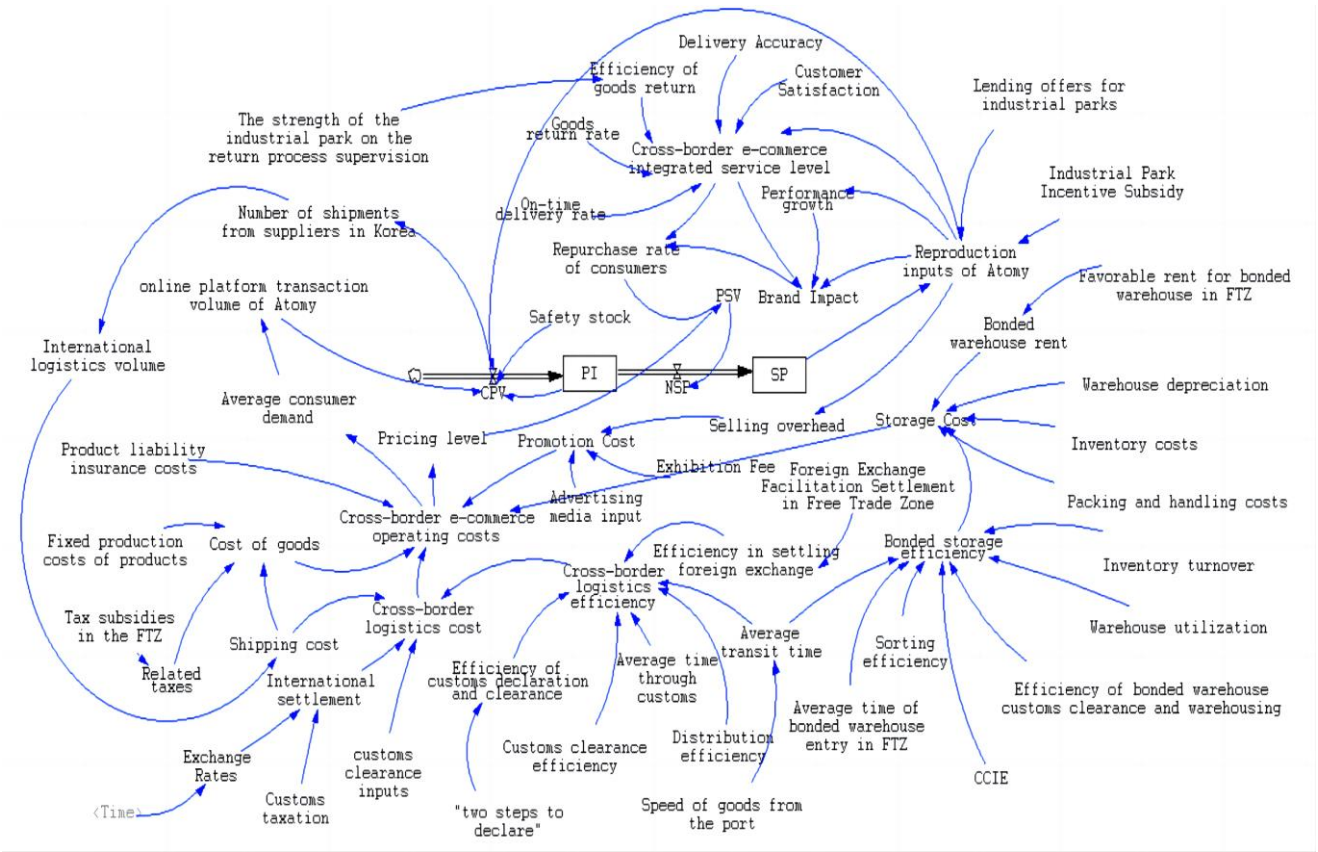


Fig. 3. Stock-flow model of the Atomy system.

System Flow Chart

Compared with the causal loop diagram, the flowchart describes the cumulative effect that influences the dynamic performance of the feedback system. In this study, VENSIM software was used to create a system flow chart with 63 variables, including two state variables, two rate variables, 31 auxiliary variables, and 28 constants (Fig. 3). The state variables included purchase inventory (PI) and sales profit (SP), which reflect the state of buying and selling products, as well as the earnings of the enterprise, and they are this loop's accumulation steps. The rate variables in the flowchart included cross-border purchase volume (CPV) and new sales profit (NSP), which reflects the change rate of the state variables. In addition, several auxiliary variables were used in the flowchart to clarify the structure of the system. The constants in the flowchart were used to describe the parameters or coefficients whose values remained constant. The study period in this model ran the full 12 months of 2021, at one-month increments. The parameter values were mainly obtained from the government website of the Yantai High-tech Zone, the official website of the China-Korea (Yantai) Industrial Park, the government service website of the Yantai Area of the Shandong Pilot FTZ, the official website of Atomy Enterprise, and the national enterprise credit information public system. SPSS was used to analyze the data of the sample companies from January 2021 to December 2021. In this study, the equations were categorized into level, rate, auxiliary, and constant variables. To simplify the content, this section lists the representative formulas. The remainder are detailed in Appendix 1.

1) Level variable equation

(1) *PI=INTEG(CPV-PSV,80.5129)*

Purchasing Inventory (PI) is represented by an integral function of the increase in cross-border purchases and decrease in product sales.

INTEG: Integral Function

(2) *SP=INTEG(NSP,0)*

Sales Profit (SP) represents the integral function of the increase in enterprise benefits, calculated using the national enterprise information publicity system.

INTEG: Integral function

2) Rate variable equation

(3) *CPV=IF THEN ELSE (PSV<=Safety stock, (Reproduction inputs of Atomy*0.45+ online platform transaction volume of Atomy)/660, 0)*

Cross-border purchasing volume (CPV) is expressed when the purchasing inventory is less than or equal to the safety stock, indicating that it is necessary to increase the purchasing quantity, which is determined by the reproduction inputs of Atomy, together with the transaction volume of the online platform. When the purchased inventory was greater than the safety stock, there was no need to replenish the safety stock.

*(4) NSP=660*0.1*PSV*

3) Auxiliary variable equation

(5) *Cost of goods=Fixed production cost of products +Related taxes +Shipping cost*

(6) *International settlement= (Exchange Rates-DELAY1(Exchange Rates, 1))/DELAY1(Exchange Rates, 1) *1287.83+Customs taxation*

(7) *Bonded storage efficiency= (Efficiency of bonded warehouse customs clearance and warehousing*(30/ (Average time of bonded warehouse entry in FTZ +Average*

*transit time)) +(Sorting efficiency +Customs clearance and inspection efficiency of bonded warehouses in FTZ) *22)/4+((15182.4*Inventory turnover)/297) * Warehouse utilization*

(8) *Storage Cost=(Inventory costs +Warehouse depreciation +Bonded warehouse rent +Packing and handling costs)/Ln (Bonded warehouse efficiency)*

(9) *Cross-border e-commerce operating costs=Storage Cost +Promotion Cost +Cross-border logistics cost +Cost of goods +Product liability insurance costs*

(10) *Reproduction inputs of Atomy=SP*0.0605+Lending offers for industrial parks/12+Industrial Park Incentive Subsidy*

Constant

The initial value settings of the constants are presented in Appendix 2.

V. Simulation

As the case enterprise promoted the program of the Industrial Park linked with the FTZ in May 2020, the policy under each linkage path fully penetrated all aspects of the enterprise's trading system. Considering that the development of an enterprise is influenced by a series of factors, fixed evaluation indicators must be selected. This study assumes that the economic efficiency of an enterprise is a reflection of the level of the park linkage to the FTZ, and the profits of Atomy and the sales volume of products in the model are evaluation indicators of economic efficiency.

In simulation studies, theoretical constructs are usually represented numerically to systematically vary the parameters and compare the simulation results [42]. Therefore, this study modeled the parameters regarding the strength of policy implementation as a continuum from 0 to 1, where 0 represents a complete lack of policy implementation and 1 represents an extremely strong policy implementation. For the other parameter values, the settings were selected and measured according to official platforms and existing studies mentioned previously [43].

Policy incentives for Trade & Investment should focus on increasing investments in Korea and creating international business environments. The specific presentation of this linkage path is as follows. In the actual case, in 2021, enterprises sped up foreign exchange settlement by 90%, and the supervision of the product return process in the park reached 1. The “tax subsidy in the FTZ” and “Lending offers for industrial parks” were stabilized at 20.83 million and 20.87 million yuan per month, respectively, after the data measurement.

The policy of industrial innovation linkage between the China and Korea (Yantai) Industrial Park and the FTZ mainly provides policy incentives to promote China-Korea cultural exchanges and the entry of new business models, such as cross-border e-commerce. This is reflected in the case model in the “Industrial Park Incentive Subsidy” and “Favorable rent for bonded warehouse in FTZ” aspects, which are valued at 55.21 million and 44.88 million yuan per year on average, respectively.

The third pathway focuses on Port Transportation. The “growth rate of FTZ overlay industrial park two-step declaration” policy can accelerate cross-border logistical efficiency, and the implementation of the “Industrial park to accelerate the lifting of goods from the port” policy can save cross-border product transit time. The former was assumed to increase by 90%, and the latter by 30% by 2021.

This model’s dimension consistency was tested and verified using the VENSIM software. By inputting the initial data, Fig. 4 shows the trends in the cumulative changes in monthly sales and profits of atomic products under the model’s current operating conditions. The deviations between the simulated and actual values were all less than 5%, indicating that the simulation model was effective. In Fig. 4, the monthly sales of Atomy fluctuate steadily at 500,000 pieces. Policy simulation is essential for achieving faster development of park enterprises based on existing conditions.

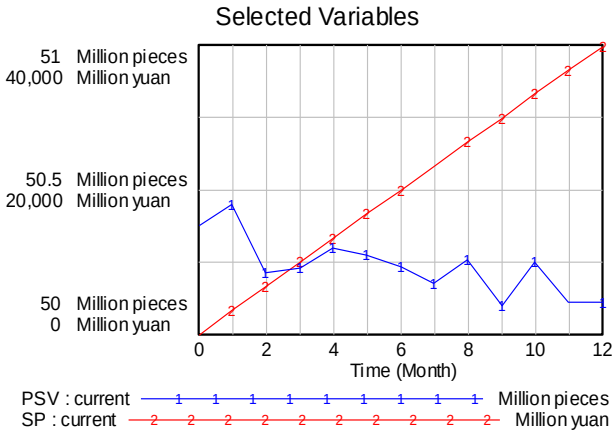


Fig. 4. Current PSV and SP.

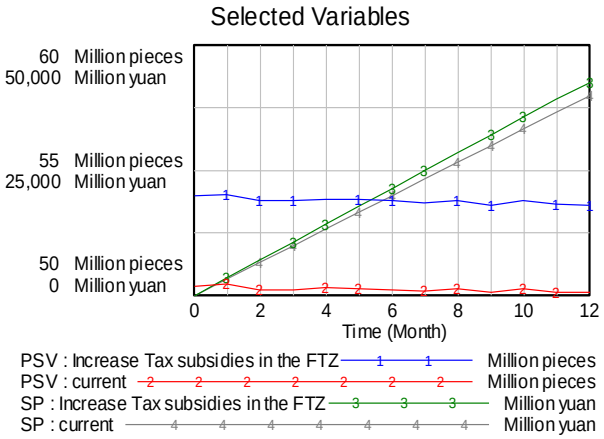


Fig. 5. Sensitivity analysis diagrams of "tax subsidies in the FTZ.”

C. Trade & investment

Increasing investment is the most direct way to access business development processes. In this study, the concrete policy of Trade and Investment mainly includes the four variables of “tax subsidies in the FTZ” (Policy 1), “The strength of the industrial park on the return process supervision” (Policy 2), “Foreign Exchange Facilitation Settlement in the Free Trade Zone” (Policy 3) and “Lending offers for industrial parks” (Policy 4). The impact of Trade & Investment policies was simulated by debugging the proportional coefficients of specific parameters under this linkage policy, with other factors held constant. After simulating the above four variables, Policy 1 had the most obvious impact, whereas the adjustment of Policy 4 had almost no impact.

When the subsidy increased by 50%, the parameter value increased from 2083.33 million yuan (actual value) to 3124.99 million yuan (simulated value). As shown in Fig. 5, the simulation results in an average monthly sales increase of approximately 36,000. Atomy's cumulative incremental sales profit rose from 397.96 million to 426.06 million yuan, an increase of approximately 7.06%.

The simulation results show that under the same strength the "tax subsidies in the FTZ" can most directly improve the economic efficiency of enterprises. However, the positive impact of strengthening a single policy on the entire enterprise is not obvious.

Based on this, the following combined policy was studied: In the study of the single policy described above, the adjustment of Policy 4 did not have a significant effect; therefore, this factor was excluded from the study of the combined policy.

This study first obtained three combination results by stacking the remaining three policies two by two, with the same increase of 0.5 for each policy. The effects of the simulation, from large to small, are a combination of Policies 1 and 2, Policies 1 and 3, and Policies 2 and 3, up 11.59%, 7.08%, and 4.25%, respectively. Fig. 6 shows a combination of 1.

Further study of the above three policy combinations to measure their effects–that is, Policy 1, Policy 2, and Policy 3--increased by 0.5 each. The average monthly sales growth of enterprises was approximately 59,000 pieces, and the total annual revenue growth was 46.22 million yuan, up 11.61%.

The positive impact of the three policy combinations on an enterprise's revenue was only 0.17% higher than that of Combination 1 with diminishing marginal utility. The simulation results show that the Trade & Investment policy brought about by the park linked to the FTZ had a significant impact on the park's enterprises.

However, there was also an individual policy that did not have a significant effect, while the combination of "tax subsidies in the FTZ" and "The strength of the industrial park on the return process supervision" had a relatively significant effect and can be used as the focus of subsequent policy.

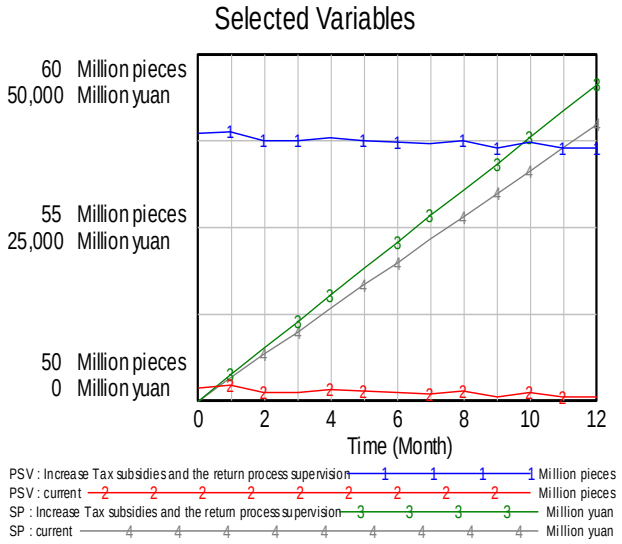


Fig. 6. Sensitivity analysis diagrams for Combination 1.

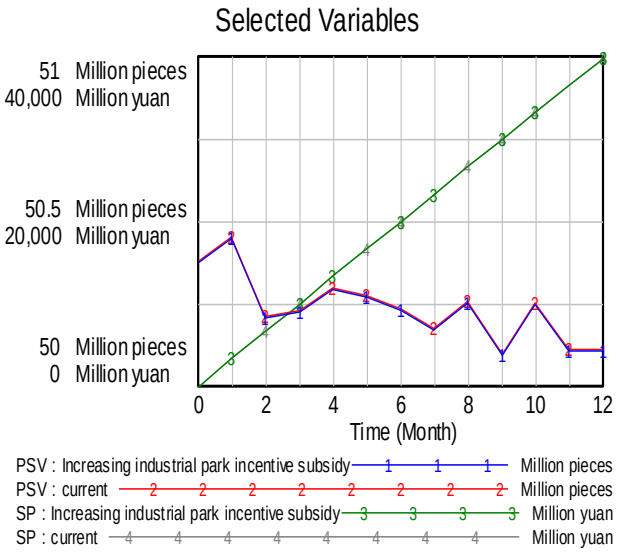


Fig. 7. Increasing industrial park incentive subsidies.

D. Industry innovation linkage

Similarly, in this scenario, the study first adjusted the values of the individual variables to observe their impact on an enterprise. When the "Favorable rent for bonded warehouse in FTZ" was adjusted upward by 50%, i.e., the value increases from 44.88 million yuan (actual value) to 67.32 million yuan (simulated value), the impact on the sales profit of the enterprise was negligible. The "Industrial Park Incentive Subsidy" was first increased by 50%, i.e. from the initial value of 55.21 million to 82.81 million yuan, and the results are shown in Fig. 7. Sales declined by approximately 37 boxes monthly, and total sales at the end of the year were reduced by 480 boxes. The sales profit decreased from 397.96 million (actual value) to 397.93 million yuan (simulated value), representing a total decrease of 29,000 yuan. These results indicate that long-term park subsidies negatively impacted enterprise growth. The main reason is that organizers have no incentive to strive for better performance, and the enterprise loses its internal dynamics. This finding indicates that excessive external subsidies affected sustainable development. As a result, the model began to reduce the initial value of the "industrial park incentive subsidy," diminishing it to 276,045 yuan (approximately 50 percentage points), and the result was the opposite of that found in the above study. This further indicated that in the late stage, the park subsidy could be appropriately slowed down to provide a more effective guarantee of sustainable development for enterprises. The study further examined the effects of the sustained impact in industrial innovation linkage, and it extended the model to 2025 on the basis of slowing down "Industrial Park Incentive Subsidy" and increasing "Favorable rent for bonded warehouse in FTZ." By the end of 2025, the sales profit (SP) growth rates for the three linkage paths were 8.19% for trade and investment, 13.81% for industrial innovation linkage, and 6.1% for port transportation. The results show that the industrial innovation linkage path has a long-term impact on improving enterprises' efficiency and has the best development potential among the three paths.

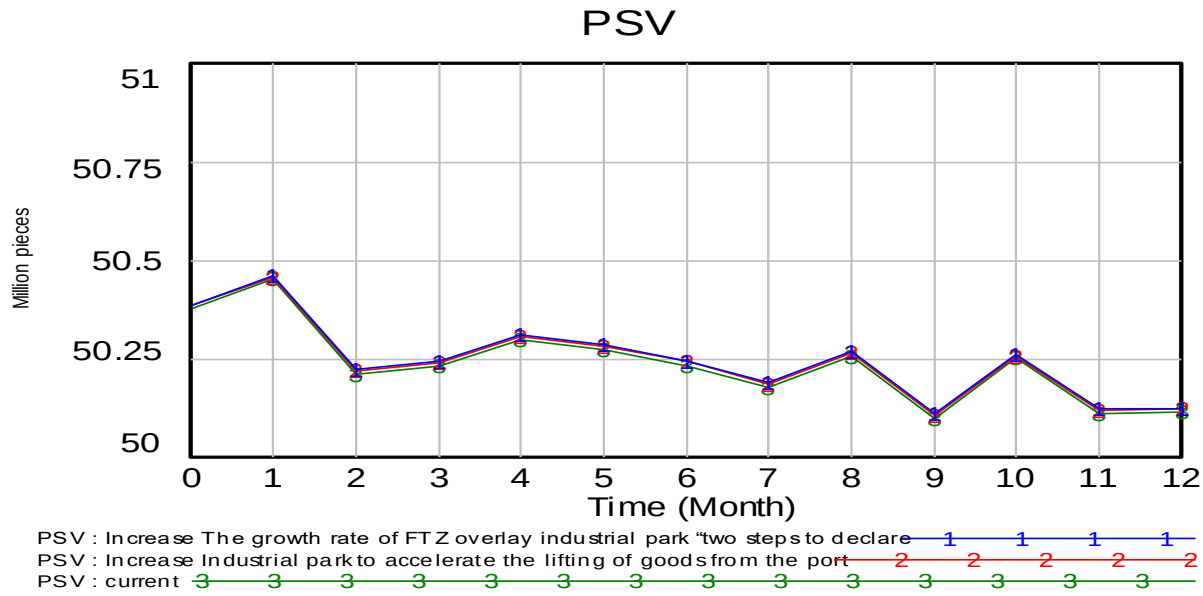


Fig. 8. Sensitivity analysis diagrams of individual policy parameters in Port Transportation policies

E. Port transportation

In this section, "Industrial park to accelerate the lifting of goods from the port" and "The growth rate of FTZ overlay industrial park 'two steps to declare'" were the two parameters in the linkage path of Port Transportation. Similar logic for the two paths can be used to study port transportation paths. First, the speed was increased by 50%, and the proportional coefficients of both increased from 0.3 to 0.45 and 0.9 to 1.35, respectively (Fig. 8). From the graph, it can be seen that when "Industrial park to accelerate the lifting of goods from the port" was on top of the original 50%, the enterprise monthly sales increased from 95 to 151 pieces, a total annual sales increase of 1464 pieces. As expected, the simulation results verified that although a single policy was beneficial for improving the economic efficiency of enterprises, focusing on strengthening individual policies had no significant improvement effect on long-term development.

However, the overlapping policy of the "two steps to declare" of the FTZ overlay industrial park was used to speed up the process of international exchange of goods and the logistical facilitation of cross-border e-commerce enterprises. It is still relatively obvious compared horizontally with other policies. The results of the combination policy that increased each of the two variables by 50 percentage points are shown in Fig. 9. The average monthly increase in the sales volume of the enterprise was 272.3 pieces, and the total profit reached 398.18 million yuan in the year, with a cumulative increase of approximately 0.05%. In summary, since the international exchange of goods mainly relies on shipping, Port Transportation plays an important role in cross-border e-commerce enterprises, including the whole of Yantai City. Therefore, the optimization of the port transportation policy between the China and Korea (Yantai) Industrial Park and the FTZ had a positive impact on the economy of the park's enterprises.

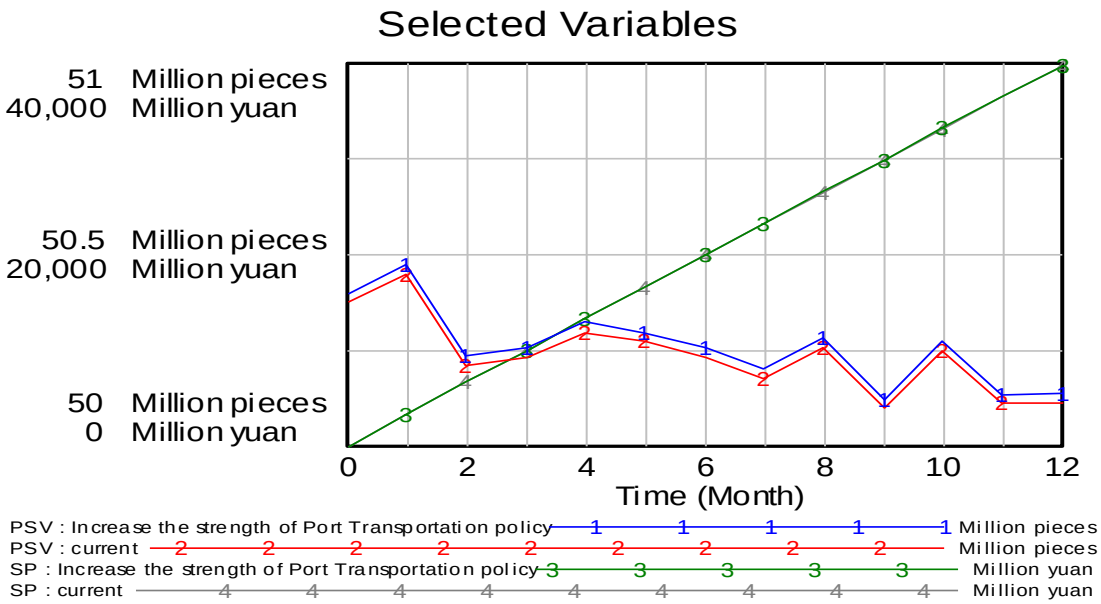


Fig. 9. Sensitivity analysis diagram of the "Port Transportation" policy

VI. Conclusions

In recent years, China has continued to innovate the path of Sino-Korean cooperation, and foreign trade has developed significantly. This study examines the impact of the linkage policy between industrial parks and FTZ on the economic efficiency of enterprises using SD theory. The linkage paths were implemented individually and in combination to evaluate the combined implementation effect among the policies and to find the optimal combination of linkage policies. The results of this study not only provide a new theoretical reference for multi-directional linkage within the China-Korea (Yantai) Industrial Park but also make an exploratory attempt to apply FTZs around the world together with the China-Korea Industrial Park in practice. The main conclusions of this study are as follows.

(1) The linkage path of trade and investment, port transportation, and industrial innovation had a significant impact on the trade activities of park enterprises, and the incentive effect was trade and investment > port transportation > industrial innovation.

(2) The implementation of policies under the above linkage paths had different degrees of impact on the trade activities of enterprises in the park; however, not all policies implemented with greater intensity had a positive impact on the economic efficiency of enterprises. Fig. 8 shows that the "Industrial Park Incentive Subsidy" became stronger, instead of losing their sales profits. This is not conducive to long-term enterprise development. The above simulation results show that long-term external subsidies will adversely affect the growth of enterprises and cause them to lose their internal vitality, while the reduction of subsidies at a later stage can improve the enterprise's autonomy and promote the healthy development of park enterprises. Any positive adjustment to other policies stimulates enterprise development.

(3) Overlapping horizontal policies on the same path is not always better. In the path of Trade & Investment, strengthening the "Lending offers for industrial parks" policy does not have a significant effect on the model results.

(4) Moreover, the combination of "tax subsidies in the FTZ" and "The strength of the industrial park on the return process supervision" policies were significantly more effective than the combination of all single policies.

(5) The implementation strengths and combinations of linkage policies required by enterprises differ at different times. According to the development of enterprises, we should flexibly adjust the strength of the policy and boldly implement a combination of policies to optimize assistance. In the path of Industrial Innovation Linkage, downward adjustment of "Industrial Park Incentive Subsidy" and enhancement of "Favorable rent for bonded warehouse in FTZ" can positively promote enterprises' development and solve practical problems.

(6) For the persistence analysis of the model's subsequent impact, the path of industrial innovation linkage shows a steady upward trend in the incentives of park enterprises, and development potential is the most prominent among the three paths. Therefore, adjusting policies along this path had a significant effect on enterprises' long-term development. With Yantai's emphasis on industrial innovation linkages, an industrial park linked with an FTZ is bound to find the optimal combination under this path, and future development needs to be focused on.

F. Suggestions

According to the above conclusions, the key issue in promoting regional investment and the development of enterprises in the park is to fully consider the formulation and implementation of a linkage policy between the China and Korea Industrial Park and the FTZ. Considering the current environment in which China and South Korea are actively improving the joint construction of cooperative industrial parks, the specific policy suggestions of this study are as follows.

(1) Overall linkage policy: Upgrade the support policies and create a strong radiation policy chain. The China-Korea (Yantai) Industrial Park needs to actively learn from advanced industrial parks to upgrade and reform corresponding policies and explore new cooperation mechanisms for in-depth linkage development with the FTZ. First, the park should not only find the right position in the existing linkage policy and grasp the opportunity to carry out in-depth cooperation, but it should also have a vision for future linkage policies, such as the implementation of joint projects. Further, it should promote mechanism reform to further improve the upgrading level of supporting linkage policies. Second, parks should consider the entire country and build a wide-ranging partnership system. The park should not only take the Yantai FTZ as the only partner for cooperation, but it should also look for other FTZs that fit the direction of local development to reach cooperation intentions. This will then create an interconnected platform to form a friendly partnership and build a policy chain with a strong radiation effect.

(2) Trade & Investment: Strengthen park supervision and build a variety of policy-supported platforms. According to the simulation results, the incentive effect of the "tax subsidy in FTZ" combined with "The strength of the industrial park on the return process supervision" is significantly better than that for the combinations of other policies. Therefore, parks should seek a better policy combination with the actual development of enterprises and gradually shift the policy focus to tax subsidies and park supervision. First, the China-Korea (Yantai) Industrial Park needs to understand the relevant trade cooperation policies and tax incentives linked to the Yantai FTZ. Within the autonomy of the park, policy will be improved to adapt to Yantai's Trade & Investment prospects. The park needs to improve the traditional model of attracting investment and actively learn from the advanced experience of the Shanghai FTZ to improve its taxation system and increase its attractiveness. In addition, the park should link with the FTZ to increase the supervision of cross-border e-commerce import and export good returns, improve the after-sales service environment, open a worry-free green channel for consumer shopping, and effectively improve the level of facilitation services for Trade & Investment between the industrial park and Korea.

(3) Industrial innovation linkages and port transportation: Strengthen the positive guiding role of Industrial Innovation Linkage policies and improve Port Transportation infrastructure to enhance the business environment.

According to the simulation results, the China-Korea (Yantai) Industrial Park should focus on promoting the entry of cross-border e-commerce, industrial design, environmental protection, and other emerging businesses. Based on adequate communication and legal compliance, a green channel will be created for these types of enterprises to accelerate the Industrial Innovation Linkage process. After the enterprises mature, the park and government should appropriately slow down or reduce their external subsidies to promote their independent dynamics and innovative development. In terms of Port Transportation, the FTZ and the government should continue to improve the infrastructure of Yantai port, and the FTZ linked with the industrial park should continue to promote the policy about the lifting of goods from the port and "two steps to declare." One of the important missions of the FTZ is to promote reform, prompting the government to transform into a regulatory service that requires decentralization. This means that the Park will have more space for cross-border trade by linking with the FTZ, providing enterprises with a port transportation environment of "extremely simple approval, extremely fast processing, and excellent service," and building the park into an international business environment model.

G. Limitations and future research

A major limitation of this study was the low availability of empirical data. Since the case company only started the linkage program between the China and Korea industrial park and FTZ in May 2020, the late start made the sample size of available data after the linkage development small, and it lacked large-scale data support. In addition, this study focused on the existing linkage development of parks; however, future trends were not addressed. Future research will need to combine more data, examine the park's overall economic development, and pay continuous attention to how China and South Korea further contribute to the optimization of the industrial structure and economic growth under the existing docking situation of both sides to meet the potential risks of future cooperation.

APPENDIX

Appendix 1: Auxiliary variable equation

(1) *Related taxes= (39982-Tax subsidies in the FTA*12)/12*
(2) *Number of shipments from suppliers in Korea=CPV*
(3) *International logistics volume=Number of shipments from suppliers in Korea*0.0012*
(4) *Shipping cost= (International logistics volume/27.5) *15.36+International logistics volume*18.1*
(5) *Exchange Rates = WITH LOOKUP (Time, [(0,0) -(12,10)], (1,0.0057), (2,0.0058), (3,0.0059), (4,0.0058), (5,0.0059), (6,0.0058), (7,0.0058), (8,0.0057), (9,0.0057), (10,0.0056), (11,0.0055), (12,0.0055))*
(6) *Cross-border logistics cost= (Inbound and outbound customs clearance inputs +Shipping cost)/ (Cross-border logistics efficiency*0.0036) +International settlement*
(7) *Efficiency of customs declaration and clearance=1.79262*(1+"The growth rate of Free Trade Zone overlay industrial park "two steps to declare")*
(8) *Average time through customs=RANDOM UNIFORM (6, 10, 0)*
(9) *Average transit time=1.5-1.5*Industrial park to accelerate the lifting of goods from the port*
(10) *Efficiency in settling foreign exchange= (1+Foreign Exchange Facilitation Settlement in Free Trade Zone) *32.3157*
(11) *Cross-border logistics efficiency= (Efficiency of customs declaration and clearance*3.83*0.5*Average time through customs+ Customs clearance efficiency*3.83*0.3125*Average time through customs+ Distribution efficiency*3.83*Average time through customs+ Efficiency in settling foreign exchange)/ (4+Average transit time)*
(12) *Bonded warehouse rent= (100.98-Favorable rent for bonded warehouse in FTZ)/12*
(13) *Average consumer demand=6305.7/ (Cross-border e-commerce operating costs*0.00774)*
(14) *online platform transaction volume of Atomy=DELAY1I (Average consumer demand*660, 1, 0)*
(15) *Pricing level= (Cross-border e-commerce operating costs/521796)/0.45*
(16) *Performance growth=Reproduction inputs of Atomy*0.3*
(17) *Brand Impact=Performance growth/Reproduction inputs of Atomy+ Cross-border e-commerce integrated service level*
(18) *Repurchase rate of consumers=Brand Impact*0.392+Cross-border e-commerce integrated service level*0.407*
(19) *On-time delivery rate=RANDOM UNIFORM (0.989, 1, 0)*
(20) *Efficiency of goods return=2.27/The strength of the industrial park on the return process supervision*
(21) *Delivery Accuracy=RANDOM UNIFORM (0.98, 0.997, 0)*
(22) *Cross-border e-commerce integrated service level= (On-time delivery rate+ Customer Satisfaction+1+(3-Efficiency of goods return)/3+(1-Goods return rate) +Delivery Accuracy)/5+Reproduction inputs of Atomy/413300*
(23) *Selling overhead= (Reproduction inputs of Atomy*0.89)/12*
(24) *Promotion Cost=Exhibition Fee+ Advertising media input+ Selling overhead*
(25) *PSV= (35506.9*Repurchase rate of consumers)/ (Pricing level*10000)*

Appendix 2: Initial value of constants

Variable name	Initial value (Unit)
Fixed production costs of products	14205.9 (Million yuan/month)
Tax subsidies in the FTA	2083.33 (Million yuan/month)
Customs taxation	0 (Dmnl)
Inbound and outbound customs clearance inputs	5.796 (Million yuan/month)
The growth rate of Free Trade Zone overlay industrial park "two steps to declare"	0.9 (Dmnl)
Customs clearance efficiency	5.6717 (Million pieces/day)
Distribution efficiency	1.715 (Million pieces/day)
Industrial park to accelerate the lifting of goods from the port	0.3 (Dmnl)
Foreign Exchange Facilitation Settlement in Free Trade Zone	0.9 (Dmnl)
Average time of bonded warehouse entry in FTZ	1.5 (Day)
Sorting efficiency	1.639 (Million pieces/day)
Customs clearance and inspection efficiency of bonded warehouses in the Free Trade Zone	5.6717 (Million pieces/day)
Efficiency of bonded warehouse customs clearance and warehousing	1.7393 (Million pieces/day)
Warehouse utilization	0.8 (Dmnl)
Inventory turnover	3.5 (Dmnl)
Favorable rent for bonded warehouse in FTZ	4.488 (Million yuan/year)
Warehouse depreciation	0.23809 (Million yuan/month)
Inventory costs	34.282 (Million yuan/month)
Packing and handling costs	1.5654 (Million yuan/month)
Product liability insurance costs	125 (Million yuan/month)
Lending offers for industrial parks	2.08046 (Million yuan/year)
Industrial Park Incentive Subsidy	55.2089 (Million yuan/month)
The strength of the industrial park on the return process supervision	1 (Dmnl)
Goods return rate	0.02 (Dmnl)
Customer Satisfaction	0.981 (Dmnl)
Exhibition Fee	20 (Million yuan/month)
Advertising media input	0 (Million)
Safety stock	55 (Million pieces)

REFERENCES

[1] I. Cheong, "Analysis of the FTA Negotiation between China and Korea," *Asian Econ. Pap.*, vol. 15, pp. 170-187, 2016.
[2] H. W. Kim, L. Dong, S. Jung, H. S. Park, "The role of the Eco-Industrial Park (EIP) at the national economy: An input-output analysis on Korea," *Sustainability*, vol. 10, pp. 1-19, 2018.

[3] J. Ashraf, "Do political instability, financial instability and environmental degradation undermine growth? Evidence from belt and road initiative countries," *J. Policy Model.*, vol. 44, pp. 1113-1127, 2022.

[4] H. H. Lee, D. Park, D. Park, S. Tian, "RCEP's financial integration before and after the global financial crisis: an empirical analysis," *J. Int. Trade Econ. Dev.*, vol. 32, pp. 429-460, 2023.

[5] G. Z. He, I. J. C. Boas, A. P. J. Mol, Y. L. Lu, "What drives public acceptance of chemical industrial park policy and project in China?" *Resour. Conserv. Recy.*, vol. 138, pp. 1-12, 2018.

[6] Y. Bi, "Rising Mega RTA? China-Japan-Korea FTA under the new trade dynamism," *J. E. Asia Int. Law*, vol. 8, pp. 299-321, 2015.

[7] I. Cheong, "An analysis of the effect of the China-Korea FTA with the consideration of FTA sequence and FTA hub gains," *J. Korea Trade*, vol. 18, pp. 63-81, 2014.

[8] A. Anastasovski, "What is needed for transformation of industrial parks into potential positive energy industrial parks?" A review. *Energ. Policy*, vol. 173, pp. 1-18, 2023.

[9] D. Van Beers, K. Tyrkko, A. Flammini, C. Barahona, C. Susan, "Results and lessons learned from assessing 50 industrial parks in eight countries against the international framework for eco-industrial parks," *Sustainability*, vol. 12, pp. 10611, 2020.

[10] Y. Sohn, "South Korea under the United States-China rivalry: Dynamics of the economic-security nexus in trade policymaking," *Pac. Rev.*, vol. 32, pp. 1019-1040, 2019.

[11] Y. Geng, T. Fujita, H. S. Park, A. S. F. Chiu, D. Huisingh, "Recent progress on innovative eco-industrial development," *J. Clean. Prod.*, vol. 114, pp. 1-10, 2016.

[12] B. J. Huang, G. Yong, J. Zhao, T. Domenech, Z. Liu, S. F. Chiu, W. Mcdowall, R. Bleischwitz, J. R. Liu, Y. Yao, "Review of the development of China's Eco-industrial Park standard system," *Resour. Conserv. Recy.*, vol. 140, pp. 137-144, 2019.

[13] M. Delgado, K. G. Mills, "The supply chain economy: A new industry categorization for understanding innovation in services," *Res. Policy*, vol. 49, pp. 104039, 2020.

[14] W. W. Liu, J. N. Yang, "The evolutionary game theoretic analysis for sustainable cooperation relationship of collaborative innovation network in strategic emerging industries," *Sustainability*, vol. 10, pp. 1-16, 2018.

[15] B. H. Peng, Y. Y. Zhao, E. Elahi, A. X. Wan, "Pathway and key factor identification of third-party market cooperation of China's overseas energy investment projects," *Technol. Forecast. Soc.*, vol. 183, pp. 121931, 2022.

[16] M. D. Cattaneo, Y. J. Feng, R. Titiunik, "Prediction intervals for synthetic control methods," *J. Am. Stat. Assoc.*, vol. 116, pp. 1865-1880, 2021.

[17] J. H. Song, "Are industrial parks in Korea evolving? Or are they just aging?" *Asian J. Technol. Inno.*, vol. 26, pp. 90-114, 2018.

[18] Q. H. Zhu, Y. Geng, J. Sarkis, K. H. Lai, "Barriers to promoting eco-industrial parks development in China: Perspectives from senior officials at national industrial parks," *J. Ind. Ecol.*, vol. 19, pp. 457-467, 2015.

[19] I. Siskos, L. N. Van Wassenhove, "Synergy management services companies a new business model for industrial park operators," *J. Ind. Ecol.*, vol. 21, pp. 802-814, 2017.

[20] T. Song, W. D. Liu, Z. G. Liu, W. Yeerken, "Chinese overseas industrial parks in Southeast Asia: An examination of policy mobility from the perspective of embeddedness," *J. Geogr. Sci.*, vol. 28, pp. 1288-1306, 2018.

[21] G. Valenzuela-Venegas, G. Vera-Hofmann, A. Diaz-Alvarado, "Design of sustainable and resilient eco-industrial parks: Planning the flows integration network through multi-objective optimization," *J. Clean. Prod.*, vol. 243, no. 10, pp. 118610.1-118610.25, 2020.

[22] S. Lee, W. Han, Y. Park, "Measuring the functional dynamics of product-service system: A system dynamics approach," *Comput. Ind. Eng.*, vol. 80, pp. 159-170, 2015.

[23] J. Xia, W. Liu, S. B. Tsai, G. D. Li, C. C. Chu, K. Wang, "A system dynamics framework for academic entrepreneurship," *Sustainability*, vol. 10, pp. 2430-2454, 2018.

[24] A. N. Mashayekhi, S. Ghili, "System dynamics problem definition as an evolutionary process using the concept of ambiguity," *Syst. Dynam. Rev.*, vol. 28, pp. 182-198, 2012.

[25] Y. H. Hsieh, S. T. Yuan, "Modeling service experience design processes with customer expectation management a system dynamics perspective," *Kybernetes*, vol. 39, pp. 1128-1144, 2010.

[26] T. G. Chen, Y. W. Qiu, B. Wang, J. J. Yang, "Analysis of effects on the dual circulation promotion policy for cross-border e-commerce B2B export trade based on system dynamics during COVID-19," *Systems*, vol. 10, pp. 1-37, 2022.

[27] J. Q. Luo, Y. Y. Ding, W. S. Chen, H. B. Kuang, "Modeling method and simulation of regional economy and port interactive development system dynamics," *Ann. Oper. Res.*, pp. 1-17, 2022.

[28] G. T. Yeo, J. Y. Pak, Z. L. Yang, "Analysis of dynamic effects on seaports adopting port security policy," *Transport. Res. A-Pol.*, vol. 49, pp. 285-301, 2013.

[29] H. N. Lin, W. J. Zeng, J. Luo, G. F. Nan, "An analysis of port congestion alleviation strategy based on system dynamics," *Ocean Coast. Manage.*, vol. 229, pp. 106336, 2022.

[30] X. Y. Li, Y. Q. Zhang, Y. Cao, "Impact of port trade on regional economic development based on system dynamics," *J. Coastal Res.*, vol. 110, no. Sp1, pp. 38-42, 2020.

[31] H. Zhang, H. H. Xiong, J. X. Xu, "Dynamic simulation research on the effect of governance mechanism on value co-creation of blockchain industry ecosystem," *Sustainability*, vol. 14, pp. 1-18, 2022.

[32] D. Bernacki, C. Lis, "Investigating the future dynamics of multi-port systems: The case of Poland and the Rhine Scheldt delta region," *Energies*, vol. 15, pp. 1-26, 2022.

[33] J. H. Chen, Z. Wan, F. W. Zhang, N. K. Park, A. B. Zheng, J. Zhao, "Evaluation and comparison of the development performances of typical free trade port zones in China," *Transport. Res. A-Pol.*, vol. 118, pp. 506-526, 2018.

[34] W. L. Chen, Y. Hu, B. Liu, H. Wang, M. B. Zheng, "Does the establishment of Pilot Free Trade Test Zones promote the transformation and upgradation of trade patterns?" *Econ. Anal. Policy*, vol. 76, pp. 114-128, 2022.

[35] L. Y. Meng, "Evaluation of scientific and technological innovation ability of free trade zone based on random forest weighting method," *Mob. Inf. Syst.*, vol. 2022, pp. 1-11, 2022.

[36] X. Yi, D. Throsby, S. S. Gao, "Cultural policy and investment in China: Do they realize the government's cultural objectives?" *J. Policy Model.*, vol. 43, pp. 416-432, 2021.

[37] G. Kiraly, P. Miskolczi, "Dynamics of participation: System dynamics and participation-an empirical review," *Syst. Res. Behav. Sci.*, vol. 36, pp. 199-210, 2019.

[38] Y. L. Fang, K. H. Lim, Y. Qian, B. Feng, "System dynamics modeling for information systems research: theory development and practical application," *Mis Quart.*, vol. 42, pp. 1303-1329, 2018.

[39] H. Yasarcan, "The four main elements of dynamic complexity," *Syst. Dynam. Rev.*, 2023.

[40] M. Zolfagharian, R. Akbari, H. Fartookzadeh, "Theory of knowledge in system dynamics models," *Found. Sci.*, vol. 19, pp. 189-207, 2014.

[41] A. Elmasry, A. Grossler, "Supply chain modularity in system dynamics," *Syst. Dynam. Rev.*, vol. 34, pp. 462-476, 2018.

[42] B. Walrave, R. Raven, "Modelling the dynamics of technological innovation systems," *Res. Policy*, vol. 45, pp. 1833-1844, 2016.

[43] W. G. Zhang, Q. Zhu, H. J. Zheng, L. L. Gu, H. J. Lin, "Economic and optimal dispatch model of electricity, heat and gas for virtual power plants in parks considering low carbon targets,". *Eng. Let.*, vol. 31, pp. 1-12, 2023.