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Research on the Dynamic Relationships among Taiwan's Early Childhood Education and Its Stakeholders: The System Dynamics Perspective

Tung-Shan Liao* Jyun-Tai Wang

College of Management, Yuan Ze University, Taiwan

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ABSTRACT

In Taiwan, the low birth rate has become one of the most critical problems faced by the government and educational institutions at all levels. The enrolling student number of kindergartens perhaps is the most directly affected by such trend. The purpose of this study aims at constructing a system dynamics model to depict the relationships between the preschool children and their stakeholders for deducing the evolutionary trends of, and the interactions of, governmental policies and the operations of the early childhood education institutions. Through the interpretation of policies and simulation analysis of the twenty-year growth trend related to the child population in Taiwan, this study found that governmental policies and the promotion of education and care services have a positive effect on the growth of all levels of kindergarten classes. Besides, the relationship between the education and care service staff and the kindergarten play a causal balancing role in our proposed model. We suggest that the system dynamics model proposed by this study can help to observe the dynamic relationships formed by the stakeholders in preschool education and care system based on the "joint responsibility" of Taiwan's early childhood education.

1. Introduction

In Taiwan, to enable young children to receive proper education and enjoy the right to be cared for, the government revised the "Early Childhood Education and Care Act" in 2018. It integrated the previous three types of institutions for child care, baby care, and young child care into "child care" expressly stipulating management rights and responsibilities as well as different management methods. The structure is divided as follows: The Ministry of Health and Welfare is in charge of "nursery centers," where licensed professional nursing staff are responsible for the care of young children under

two years old; the Ministry of Education is in charge of "kindergartens" and "after-school care centers."

Kindergartens need to have qualified teachers as instructors to be responsible for young children over two years old and younger than six years old, providing educational services such as game learning, health education, life ethics education, etc. In after-school care centers, qualified personnel who have obtained training licenses from training institutions are responsible for after-school care and academic guidance for schoolchildren over six years old. In this way, an integrated system of early childhood education and care has been built to achieve the goal of young children's healthy physical

*Corresponding Author:

Tung-Shan Liao,

College of Management, Yuan Ze University, No 135, Yuan-Tung Road, Zhongli District, 32003, Taoyuan, Taiwan;

Email: valenliao@saturn.yzu.edu.tw

and mental development.

Taiwan has become an aging society, and low birth rate has a significant impact on the operation of educational institutions. The government released a population estimation report (for 2018 to 2065) in August 2018, indicating that the birth rate will decrease year by year, and the school-age population will show a downward trend. This population estimation was made using the internationally adopted “Cohort Component Projection Method”^[1]. In the current education scheme in Taiwan, young children must go through early childhood education before the primary school stage. Therefore, the issue of supply and demand of the preschool education population is an essential issue of concern to the government and education and care service institutions.

The purpose of this study is to use the system dynamics perspective to construct the systematical causal model of education and care services. In Taiwan, preschool education is mostly provided by various public and private kindergartens. The main service areas of the education and care service system include early childhood education, care, and community (tribe) mutual assistance; education and care services are encouraged to center on the children, upholding gender, ethnic, and cultural equality. Education and care service institutions and the government, society, families, and young children themselves form a common operating system.

The stakeholders (as mentioned above) influence each other as the complexity of the operation of social systems. In addition to the time-postpone characteristics of the interactions, they perform mostly nonlinear. Thus, the relationship among them is suitable for proceeding with the observation with the system dynamics perspective. In thinking so, in this study, we first started by constructing the theoretical model. We then ran the empirical simulation test using the database available from the Department of Household Registration of Ministry of the Interior, and simultaneously we conducted the consistency check on the relevant dynamic trends. Further, we implemented a system model test, verifying the reliability and validity of the proposed model structure, model sensitivity, and model behavior. In the final phase of the study, we proceeded with the policy simulation analysis.

2. Theoretical Backgrounds and Underpinnings

2.1 Low Birth Rate and Aged Society

According to a national profile published by the Ministry of the Interior in February 2020, Taiwan had a total population of 23.6 million by the end of 2019 and a pop-

ulation density of 652 people per square kilometer. Such statistics make Taiwan second worldwide in density (per 10 million people). As the population under 15 years of age continues to decline, the rate of the elderly population (over 65 years old) is increasing^[2]. The population estimate (2018-2065) reports that the total population of Taiwan will reach its peak in 2021, after which it will show a downward trend^[15].

Besides, according to the Ministry of the Interior’s demographic data from 1958 to 2019, Taiwan has a year-on-year birth rate decline, calculated per 1,000 births per year with the average live births per 1,000 women of childbearing age (15-49 years old). The birth rate even dropped to 7.53% in 2019. In addition, Taiwan has a year-on-year upward death rate trend in terms of the number of deaths per thousand people per year, and simultaneously the death rate may exceed the fertility rate in the future (Figure 1).

Past research, whether it is a prediction with the ARIMA model or a natural population projection, suggests the coming shortage of the young-to-middle-aged population. As a result, the population aging index rises and affects the population structure. Policymaking is thus substantially needed to respond to the declining birth-rate and aging population structure^[1]. At the same time, problems with the decreases in the supply of preschool young children will affect the demand for kindergartens^[1,3,4,5]. That is, early childhood education will be limited by the reduction of the preschool children, which in turn leads to a reduction in the number of kindergarten classes, and consequently, makes it difficult for kindergarten to operate^[6].

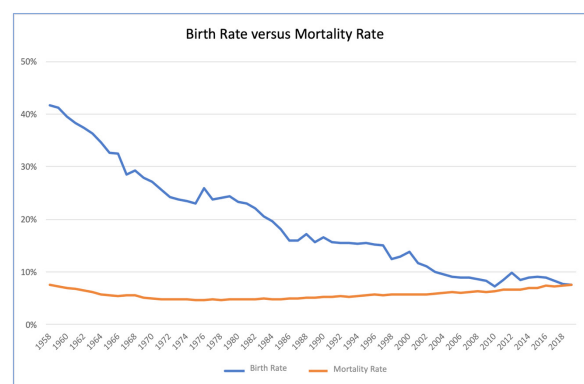


Figure 1. Comparison of birth rate and mortality rate (Source: the Department of Household Registration, Ministry of the Interior, Taiwan)

2.2 Early Childhood Education and Care System

Taiwan’s early childhood education system was inherit-

ed from China's early childhood education system and has been influenced by Western education, Japanese education, and Taiwan's early reform of early childhood education. This study refers to the classification of Duan^[7] and Weng^[8], and categorizes the development of Taiwan's early childhood education system into the following stages:

(1) Stage I (1911 to 1947): In 1904, the name "Meng Yang Yuan" was used to represent early childhood education. Later, the name "kindergarten" appeared in 1922. The services of nurseries were initially established for those families engaging in agriculture and farming in Taitung County. In this period, preschool education was considered as it is in the initial development.

(2) Stage II (1949 to 1981): In 1970, Taiwan's preschools were generally set up with the forms of primary schools with kindergarten classes, independent kindergartens, normal schools with kindergartens, and rural nurseries. The government promoted the Early Childhood Education Act in 1981 to build a preschool system. In this period, due to rapid population growth, a general shortage of public kindergartens resulted in the formation of many private kindergartens.

(3) Stage III (1981 to 2010): Due to the transformation of agricultural society and the development of industry and commerce, parents came to value preschool education under the age of 6 years, and policies were successively promoted including "Guidelines for Registration, Verification and Selection of Kindergarten Principals and Teachers," "Implementation Points for Evaluation of Taiwan Provincial Public and Private Kindergartens," and the "Kindergarten Equipment Standards." In 1987, the "10-year Development Plan for Early Childhood Education" was implemented to strengthen the evaluation of kindergartens. In 2010, the schooling of 5-year-old children was regarded as quasi-compulsory education, and the functions of kindergartens and nurseries were integrated into the larger education system. In 2006, a draft of the "Early Childhood Education and Care Act" was completed. The types of early childhood education services included childcare centers, kindergartens, home-based care services, after-school care centers, and community-based mutual help education and care services.

(4) Recently (after 2010): In order to enable young children to receive proper education and enjoy the right to be cared for, the government revised the "Early Childhood Education and Care Act" in 2018 to integrate the three original types of institutions - childcare, baby care, and young child care, gradually opening the "child care integration" model of early childhood education.

To improve the early childhood education and care system, the government passed the "Early Childhood Education and Care Act" and "Standards for Kindergartens and Classes, Basic Facilities and Equipment" in 2011 and 2019, respectively. By these acts, kindergartens and nursery schools were integrated into a single kindergarten education system (with young preschool children between the ages of 2 and 6 years old as the primary recruitment targets). According to the regulation "Kindergarten Evaluation Measures," all kindergartens are required to receive necessary evaluations for their education and care activities and courses, and safety management once every five years. This evaluation is to protect the young children's rights and interests in education and ensure that the kindergartens continue to comply with the relevant provisions of the law. According to the abovementioned decrees and referring to Chien^[9], this study, categorizes Taiwan's early childhood education and care service institutions into four types, as follows:

(1) Public kindergartens: The kindergartens are established by the government and public schools. Public kindergartens are operated by public authorities and employ qualified education and care staff to implement multi-curricular education and care services.

(2) Private kindergartens: The kindergartens set up by private sectors or institutions use commercial (for-profit) management and hire qualified education and care staff to implement early childhood education and care services.

(3) Non-profit kindergartens: This type of kindergartens is approved and provided free venues by the governments to establish to support public welfare, such as supporting the disadvantaged and promoting the healthy growth of young children. These kindergartens are advantaged by non-profit-based charging standards and more flexible operation time than private kindergartens.

(4) Quasi-public kindergartens: In 2018, the government promoted the quasi-public education and care service policy to encourage private kindergartens to transform to the quasi-public kindergartens. The purpose of this policy is to provide affordable early childhood education and care services to the public, primarily by offering subsidies to the private kindergartens to ensure the salaries of teachers and caregivers.

The Taiwanese government also regulates the establishment of educational service agencies to a considerable extent. Education and care service agencies should have persons in charge and employ principals, teachers, caregivers, and assistant caregivers; implement class placement setting according to the age of young children and "Standards for Kindergartens and Classes, Basic

Facilities and Equipment”; provide a healthy diet and health care safety education; focus on personality development and interpersonal interaction; cultivate essential living ability and habits; and promote learning and other services. Besides, education and care service personnel must meet the relevant qualifications according to the “Educational and Care Service Staff Regulations.”

(1) Kindergarten principals: They are qualified as kindergarten teachers or caregivers and have served in the associated institutions for more than five years. They must have received and completed professional training early childhood education and care in a junior college or higher, or those educational institutions entrusted by the competent authorities of municipalities and counties (cities).

(2) Kindergarten teachers: They should be qualified through completing 26-credit professional courses for kindergarten teachers and a 6-month kindergarten internship course in universities. Besides, they must pass the qualification test hold by the Ministry of Education.

(3) Caregivers: They have received the diploma majored in kindergarten education and care professionals from a junior college or higher.

(4) Assistant caregivers: They need to receive a diploma majored in early childhood care from a domestic senior secondary school.

The Taiwanese government also clearly regulates the class placement mechanism of education and care service institutions. According to Article 18 of the “Education and Care Service Personnel Regulations,” children over the age of 2 and under 3 years old constitute the toddler class, the number of children in a toddler class is limited to 16 children and these children must not be mixed with children of other ages. Each class of young children from 3 years old to school age (divided into the beginner class (K1), junior class (K2), and senior class (K3) in the order of age) is limited to 30 children. The K3 class is staffed with one kindergarten teacher; the K2 class is staffed with one caregiver (one more caregiver will be staffed if the number of children in a class exceeds nine); the K1 class is staffed with one caregiver (one more caregiver will be staffed if the number of children in a class exceeds sixteen); and the toddler class is staffed with one caregiver (one more caregiver will be staffed if the number of children in a class exceeds eight). Assistant caregivers must not exceed one-third of the school’s caregiver staff.

3. Methodologies

3.1 System Dynamics

System dynamics defines a system as an entity that con-

tains interconnected things or elements, such as parts, components, components, or sub-systems. Each element interacts with the others through specific behaviors, and the overall structure of the system should have the characteristics of being hierarchical and self-organized. When external forces impact the system, the operations of the system change, but then the system will further be getting stabilized. In practice, when system dynamics are applied for society or organizations, it can help policymakers or managers understand the dynamic trends of system changes^[10].

Jay W. Forrester proposed the system dynamics perspective in the 1960s^[11]. A system dynamics model is built through the causal relationship between system operations to form a circular feedback loop. The circular feedback loop can be converted into a series of systematic variables, such as product quantity, rate quantity, and relationship symbols. Researchers can thus test, through computer simulations, the system dynamics model and predict the system’s changes for then long-term, periodical, nonlinear, dynamic, and complex issues^[12].

This study focused on early childhood education, making the joint responsibility of various stakeholders as the structural basis of the proposed model. In promoting early childhood education and care services, kindergartens have formed complex and mutually-affecting stakeholder structures with the government, society, families, education and care service personnel, and even other education and care service organizations. In addition, the class placement of kindergartens has the characteristics of time lag for different ages of young children. Based on the above, this study holds that the use of system dynamics methods is appropriate and reflects the dynamic trends of practical operations on this topic.

3.2 Data Adopted

In this study, we collected the demographic data from the website of Taiwan’s Department of Household Registration (DOHR), Ministry of the Interior (MOI). DOHR is mainly responsible for records of household registration, nationality, household, and population. The data that is open to the public to a certain extent is widely used by academics and other governmental institutions to explore related research on housing, education, low birth rate, and population forecasting.

The demographic data involved and used in the dynamic simulation analysis of this study include the national birth rate and estimated birth rate (1989-2019), the fertility rate of women of childbearing age in counties and cities (2007-2018), the number of townships, villages, neighborhoods, households, and people (1997-2019),

the sex ratio in households (1997-2019), and the number of deaths (by gender and estimated mortality rate, 1994-2019). This study combined the data sets to calculate the total number of children born each year and the number of young children who can attend the toddler, K1, K2, and K3 classes in kindergartens.

3.3 Model Construction and Simulation Design

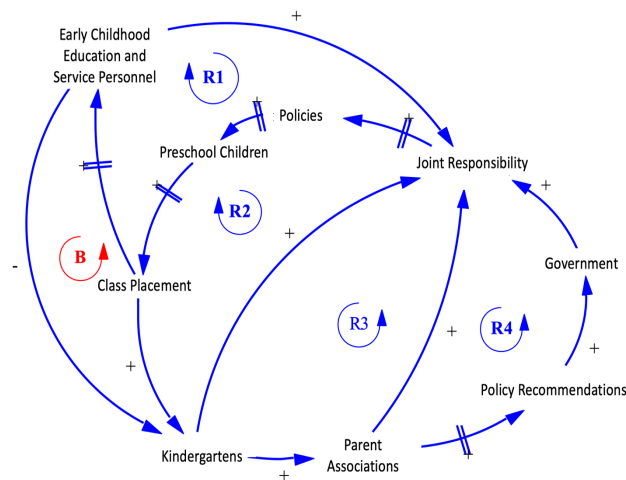


Figure 2. The System Dynamics Model of Taiwan's Early Childhood Education System

In this study, the relevant policies, regulations, and literature were incorporated to extend to the stakeholder structure to build the system dynamics model for early childhood education. Based on the core hypothesis of the empirical simulation of this study - “the growth of the number of young children enrolled in kindergartens increases the number of classes in kindergarten (preschool children → class placement (with time delay))” (Figure 2) - we presumed five major causal relationship loops: (1) the causal relationship loop between education and care service staff and joint responsibility; (2) the causal relationship loop between kindergartens and joint responsibility; (3) the causal relationship loop between parent associations and joint responsibility; (4) the causal relationship loop between the government and joint responsibility, and (5) the causal relationship between education and care service personnel and kindergartens. Among them, the former four causal relationship loops are considered as reinforcing (positive) feedback loops, marked as “R”; the last causal relationship loop is a balancing (negative) feedback loop, labeled as “B” (Figure 2). In addition, this study used Vensim DSS (simulation software) to conduct the empirical simulation test for these causal relationship loops. For the definitions of the elements (variables) involved in the proposed model and the relevant literature, please refer to Table 1.

Table 1. Variable Definitions

Variables and Definitions	Sources/Acts/Literature
Government: the competent unit of the education and care institution Policies: Education and care policy and the formulation Joint responsibility: the government provides care education together with the education and care institutions and families	Article 7 of the Early Childhood Education and Care Act
Education and care service personnel: the principal, teachers, caregivers and assistant caregivers who provide education and care services	
Preschool Children: Number of young children over 2 years old but under 6 years old. Kindergartens: provide early childhood education and care services	Article 3 of the Early Childhood Education and Care Act
Class Placement: the education and care service staff are equipped based on young children's age and number	1. Article 8 of the Early Childhood Education and Care Act 2. Standards for Kindergartens and Classes, Basic Facilities and Equipment
Parent Associations: the association built by the parents in each kindergarten	Article 30 of the Early Childhood Education and Care Act
Policy Recommendations: provide timely advice on improving education and care services	Article 31 of the Early Childhood Education and Care Act

The causal relationship loop between education and care service personnel and joint responsibility (labeled R1 in Figure 2) is built according to Article 7 of the “Early Childhood Education and Care Act.” This article notes that the direction and promotion of education and care services development is the joint responsibility of education and care service personnel, involving principals, kindergarten teachers, caregivers, etc. They shall jointly promote the implementation of education and care policies.

Before entering kindergarten, children are placed in different age groups to distinguish between the toddler, K1, K2, and K3 classes. The number of students in each class affects the benchmarking of the education and care service personnel staffing (according to Article 16 of the same Act mentioned above). The maximum number of children of the toddler class is 16 at most, with one caregiver assigned to every eight young children. The number of children in each K1 class and K2 is 30 at most, and one caregiver is assigned to every 15 children. The number of children in each K3 class is 30 at most, and each class is staffed with one caregiver and one kindergarten teacher.

Based on the core hypothesis of the empirical simulation of this study “the growth of the number of young children enrolled in the kindergarten increases the number of classes in kindergartens (preschool children → class placement (positive and with time delay characteristics)),” we presumed that the number of education and care service

personnel needed would increase (class placement → education and care service personnel (with time delay)). Then, the “joint responsibility” that the education and care service personnel bear should increase accordingly (education and care service personnel → joint responsibility). Early childhood education “policy” suggestions and formulations, in response to the increase in joint responsibility, would gradually take shape (joint responsibility → policy). Further, the formulation of sound policies would have a positive impact on the growth of “preschool children” enrollment (policy → preschool children (with time delay characteristics)). In sum, this loop cycle forms a reinforcing causal relationship loop as the increasing joint responsibility of education and care service personnel (due to the increases of the education and care service personnel).

Like the R1 loop, the causal relationship loop between kindergartens and joint responsibility (labeled R2 in Figure 2) is built based on Article 7 of the Early Childhood Education and Care Act. Where it demonstrates that Kindergartens must bear joint responsibility for the promotion and implementation of early childhood education and services. In a general investigation on the management of kindergartens, more classes in a kindergarten represent the greater expansion of the scale of kindergarten operations. Such increases reflect the performance growth of a kindergarten.

Based on the core hypothesis (preschool children → placement (positive with time delay)), we presumed that an increase in the number of classes has a positive impact on a kindergarten’s performance (class placement → kindergarten) when considering economic scale expansion. Because of such development, the “joint responsibility” that a kindergarten should bear would then be affected positively (kindergarten → joint responsibility). To sum up, this causal nexus shapes up a reinforcing causal relationship loop as the increases of joint responsibility of kindergartens (see R2 loop in Figure 2).

This study develops the causal relationship loop between parent associations and joint responsibility in the proposed model (labeled R3 in Figure 2) based on the “Child Care Education and Care Act.” In this Act, Article 30 regulates that kindergartens need to set up a parent association. To explore the parents’ or parent associations’ responsibility, we referred to Article 11 of such Act. It clearly states that the parents (or the family) have considerable responsibilities in taking care of the child’s physical and mental health^①. Accordingly, the purpose of setting up

the parent association in kindergartens is to supervise and require the government (for the improvement of education and care policies) and kindergartens (for implementing education and care services per regulations) to improve the quality of preschool education and care services. Therefore, when more kindergartens are set up (or the scale of kindergarten operations increases), the number of parent associations (or the size of the parent association) would increase. The parent associations’ joint responsibility for early childhood education would also increase.

As far as the construction of the R3 loop is concerned, the R2 loop (increasing the number of kindergartens or the scale of operations) would be considered as the basis. When the scale of kindergartens is larger, the number or size of parent associations will increase immediately (kindergarten → parent association), and the joint responsibility of the parent associations would be higher (parent association → joint responsibility). The system further affects the change of the joint responsibility sharing structure of the stakeholders and affect the basis for the implementation of education and care policies (needs further improvement) (joint responsibility → education and care policy). Finally, the causal loop enters into the causal nexus with preschool children, class placement, and kindergartens. Overall, the R3 loop forms a reinforcing relationship loop in light of the increases in parent associations’ joint responsibility for early childhood education.

This study identifies the causal relationship loop between the government and joint responsibility (labeled R4 in Figure 2) by referring to Article 7 of the “Early Childhood Education and Care Act.” This article emphasizes that the government is responsible for formulating education and care policies and supervising early childhood education institutions to ensure that preschool children can be well educated and cared for.

To develop the R4 loop, the R3 loop is treated as the basic presumption. One of the functions of the kindergarten parent association is to make suggestions to the government on the governance of early childhood education (parent association → education and care policy recommendations). Recommendations can be about the diversity of education and care services, the practicality of education, and the richness of the curriculum. A parent association can also require the government to provide the kindergarten evaluation report, and promote and supervise the joint responsibility of the government. Therefore, the “joint responsibility” that the government should bear will increase accordingly (government → joint responsibility). Further, in response to the increase in joint responsibility, the government’s effectiveness in improving early childhood education policy and governance will also gradually

① Such as developing good habits, life experience, and ethics; cultivating group habits; expanding aesthetic experiences; developing creative thinking; constructing cultural identity; and providing an enlightening, caring environment

increase (joint responsibility → education and care policy (with time delay)). Just as it is in the development of the R3 loop, the R4 loop enters into the causal nexus of preschool children, class placement, and kindergartens. Overall, the R4 loop forms a reinforcing causal relationship loop according to the increases of the joint responsibility of the government.

The causal relationship loop between education and care service personnel and kindergartens (labeled B in Figure 2) is developed primarily based on Article 6 of the “Education and Care Service Personnel Regulations.” In this article, the qualification of caregivers, teachers, and other staff are regulated. With such employment standards, the employment of education and care service personnel in terms of both quality and quantity, reflecting the operational cost, has a certain degree of pressure on kindergartens (i.e., costs in salary, personnel management and training, insurance for health and safety cover, and so on). That is, more preschool children enroll, the more education and care service staff are needed, and hence the more marginal cost generates in kindergartens. Therefore, the B loop demonstrates its feature of the balancing causality in the whole model that this study proposes.

With the core hypothesis in heart (as mentioned above: preschool children → class placement) for developing the B loop, this study presumes that the rise in the number of class placement has a positive impact on “education and care service personnel” in kindergartens (class placement → education and care service personnel (positive with time delay)), which in turn has a negative impact on kindergartens in operational performance (education and care service personnel → kindergarten). Finally, the B loop enters the causal paths of the joint responsibility of the kindergarten, the parent association, and the government. In sum, the B loop forms a balancing causal relationship loop for the whole proposed model in this study as considering the potentially negative impact of the education and care service personnel on kindergartens.

3.4 Simulation Reliability and Validity

In addition to constructing the model through the study of relevant early childhood education policies and literature, this study followed the testing and validation methods for system dynamics models proposed by Forrester^[11,12], Barlas^[13], and Sterman^[14] for the tests of reliability and validity of the proposed model. This study arranged the test steps as follows:

First, the data that this study collected from the DOHR was used for the empirical simulations and consistency check with the historical trend. Second, tests for the model’s structure, sensitivity, behavior, and reliability and

validity were conducted. Finally, based on Taiwan’s birth rate growth from 2015 to 2019 and the birth rate and the total population in 2019, this study carried out the policy simulation analysis for the next 20 years.

4. Results

4.1 The Tests of the Simulation Model

Table 2. Variable Parameters Used in Empirical Simulation Tests

Variable	Value (unit)	Definition	Sources/Acts/Literature
Birth rate	7.42% (2019)	Newborn population per 1,000 people (person/year)	Department of Household Registration
Total population	23,603,121 (2019)		Department of Household Registration
Toddlers		Toddlers who are younger than 2 years old	Department of Household Registration
Toddler enrolling age	2 (years)	Toddlers who are 2 years old	Article 16 of the Early Childhood Education and Care Act
K1 class enrolling age	1 (1 year)	Toddlers who are 3 years old	Article 16 of the Early Childhood Education and Care Act
K2 class enrolling age	1 year	Toddlers who are 4 years old	Article 16 of the Early Childhood Education and Care Act
K3 class enrolling age	1 year	Toddlers who are 5 years old	Article 16 of the Early Childhood Education and Care Act
Toddler enrollment	(Person/year)	Total number of toddler class students	Article 16 of the Early Childhood Education and Care Act
K1 enrollment	(Person/year)	Total number of K1 students	Article 16 of the Early Childhood Education and Care Act
K2 enrollment	(Person/year)	Total number of K2 students	Article 16 of the Early Childhood Education and Care Act
K3 enrollment	(Person/year)	Total number of K3 students	Article 16 of the Early Childhood Education and Care Act
Elementary enrollment	180,656	Number of births in 2018	Department of Household Registration
Toddler students	207,600	Number of births in 2018	Department of Household Registration
K1 students	213,093	Number of births in 2018	Department of Household Registration
K2 students	211,399	Number of births in 2018	Department of Household Registration
K3 students	194,939	Number of births in 2018	Department of Household Registration

The simulation model was built based on the core hypothesis that the growth in the number of young children enrolled in kindergartens increases the number of classes in kindergartens. In designing the simulation model, this study used Taiwan's birth rate and population as the inputs, age as the rate, the student number of the toddler, K1, K2, and K3 classes as the levels, and enrolling student number to the primary school as the output (Figure 3).

The variables used in the simulation model with their definitions, test units, and references are listed in Table 2. The settings of the simulation model that are based on the relevant literature reflect the real conditions in Taiwan's education and care service system. Besides, this study used Vensim DSS software to check the model logics. The results showed that the simulation model is validated with its structure and semantic equations.

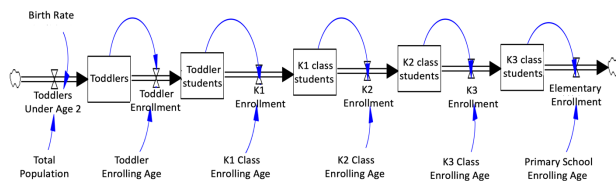


Figure 3. The System Dynamics Flow Diagram of the Early Childhood Education System

The model sensitivity evaluation is to test whether the simulation model's stability when the parameters involved in the model change. This study conducted 500 times of structural sensitivity test and actual parameter sensitivity test on the simulation model, respectively. The results that present a high degree of the convergence in both of the tests show that the simulation model designed in this study has high stability and is insensitive to the changes in parameters within the value ranges of the tests, hence confirming the model's simulation validity (Figure 4 for structural sensitivity test and Figure 5 for actual parameter sensitivity test).

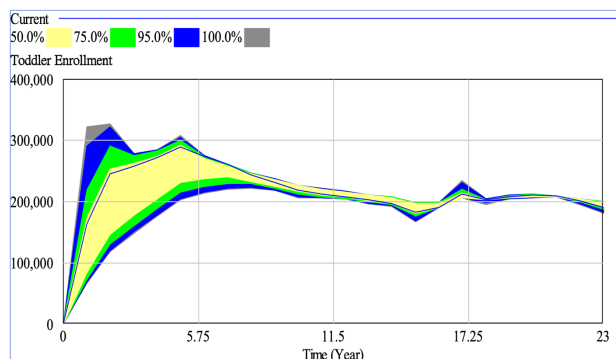


Figure 4. Model Structure Sensitivity Test (Vensim DSS)

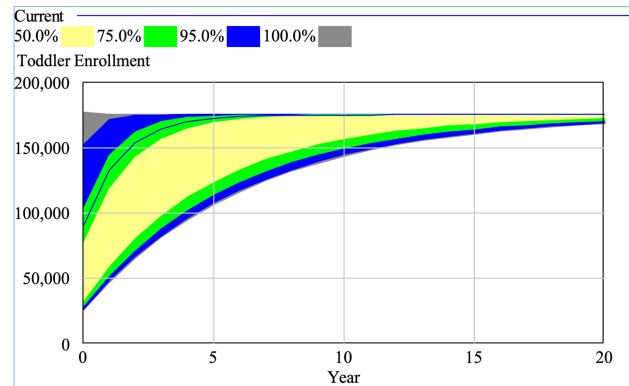


Figure 5. Model Structure Sensitivity Test with Actual Values (by Vensim DSS)

For the model behavior test, the data of the birth rate and total population (1992 to 2019) was used. This study conducted a comparison between the real behavior and the simulations for the student number of the K3 to toddler classes from 1992 to 2019. The results (Figure 6) show that the model presents a similar behavior trend with real and simulation data. Hence, the model can be used to forecast the potential trend of the enrollment of preschool students in Taiwan's kindergarten education system.

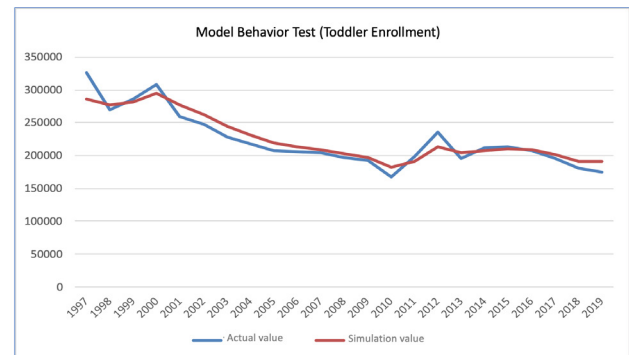


Figure 6. Model Behavior Test (by Vensim DSS)

4.2 Policy Simulation

The data for the implementation of the policy simulation in this study was the growth rate of Taiwan's total population in the past 22 years (1997 to 2019). The highest population growth rate was 0.8% in 1997 and 1999; the second highest was 0.4% with 6 occurrences in 2002, 2003, 2004, 2006, 2008, and 2011; the third-highest 0.2% happened 4 times in 2009, 2012, 2014, and 2015. Finally, the lowest of the population growth rate at 0.1% in 2016, 2017, and 2018.

Based on this historical information, this study designed the "policy1 simulation" proceeding with three growth rates of the population. These were high-growth at 0.4%, medium at 0.2% and low-growth at 0.1%. For

the analytical settings of “policy simulation 2”, this study referred to the population estimation for Taiwan within 2018 and 2065 [15]. Taking Taiwan’s birth rate of 7.42% in 2019 as the basis, this study carried out the simulations with high-estimation (with a birth rate increase by 1.5%), mid-estimation (with a birth rate increase by 1.2%), and low-estimation (with a birth rate increase by 0.9%) for up to 20 years.

The policy1 simulation was to forecast the growth of the enrolling numbers of preschool children in the toddler, K1, K2, and K3 classes of kindergartens by assuming Taiwan’s birth rate remaining unchanged as it in 2019. This study proceeded with the simulation analyses under the conditions that the total population of Taiwan increases by +0.4% (total increase = 94,412), +0.2% (total increase = 472,062) and +0.1% (total increase = 23,603), respectively. The simulation results (Figure 7) show that while the student numbers of each class almost have no significant change for up to 20 years, the changing trend of the student enrollment in each class has different and significant time lags as the limitation of the enrolling age for each class.

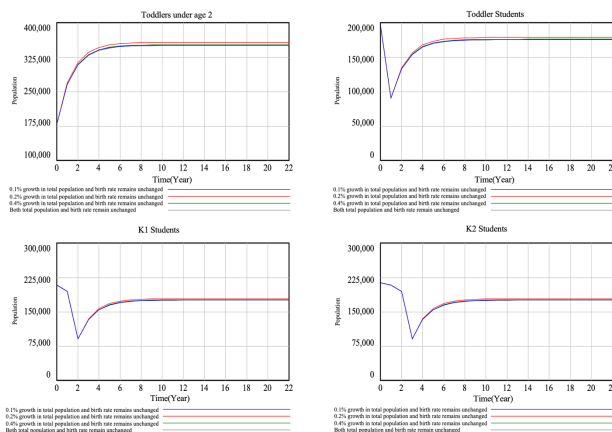


Figure 7. Policy1 Simulation

By assuming that Taiwan’s total population remains unchanged, the policy2 simulation carried out for the prediction of the growth of the enrolling numbers of preschool children in the toddler, K1, K2, and K3 classes of kindergartens. With the simulation settings: the birth rate in high growth +1.5% (the birth rate = 8.92%), the medium growth +1.2% (the birth rate = 8.62%), and low growth +0.9% (the birth rate = 8.32%), this study proceeded with the simulations. The results show the number of young children in toddler, K1, and K2 classes will all increase to a significant extent in light of the growing trend of the birth rate (Figure 8).

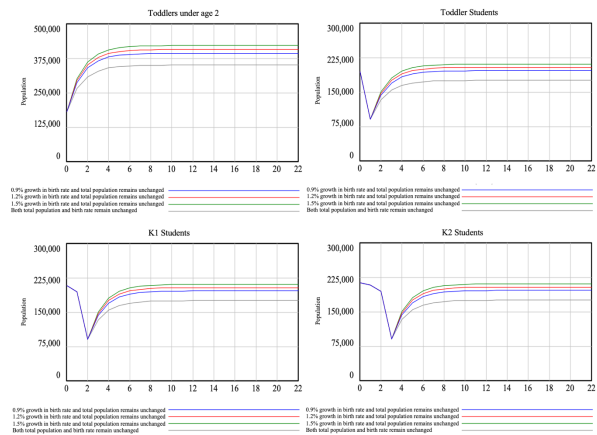


Figure 8. Policy2 Simulation

5. Discussions and Conclusions

With the heart in preschool children with the associated stakeholder structure, the research has developed the model to investigate the system dynamics of preschool education in Taiwan. We have identified five causal loops in this model, including (1) the causal loop linking the education-and-care-service staff and the joint responsibility; (2) the causal loop involving the kindergartens and the joint responsibility; (3) the causal loop connecting the parent councils and the joint responsibility; (4) the causal loop connecting the governments and the joint responsibility; and (5) the causal loop connecting the education-and-care-service staff and the kindergartens.

To examine this model, simultaneously, the research proceeded with the twenty-year-long (from 2019) empirical simulation test with a focus on how the population growth of young children influences the increases of kindergartens’ class size in Taiwan. Under the premising condition that the birth rate remains unchanged, the test results showed that the trends of student numbers in either the toddler, K1, K2 or K3 class levels of kindergartens would be increasing. The class numbers would thus be rising while having a postponing effect due to the different enrolling ages for each level. Such simulation results support the hypothesized system dynamics model of the preschool education this study proposed.

Another important finding of this study is what we identified for stakeholders’ joint responsibilities according to the preschool children. These stakeholders are the education-and-care service staff, kindergartens, parent councils, and governments. As presented in our proposed model, we have realized that one changing trend of the policies relating to the care services and preschool education for young children lies in how the changes and the interactions of the responsibilities for early childhood

among these stakeholders. For example, in light of the birth rate decline, Taiwan's governments amended the "Early Childhood Education and Care Act" in 2010 and 2019, respectively. In addition to neutralizing the birth rate decline, the valid promotion of this act bursts the increases of the students in the preschool education system. Such influence, furthermore, benefits kindergartens' improvement in both education and care services, as well as the performance growth in business operations.

The system dynamics model and associated findings of this study are consistent with the recent amendment and promotion of the regulations or acts for promoting birth rate and early childhood education and care in Taiwan (since 2016). These include that for "the health and safety of young children," "the friendly environment for childbirth and care," "childcare allowance," "job retention for childcare," and "the quasi-public mechanism for early childhood education." Per our system dynamics model, these regulations would be understood as the changes resulted from the interactions of the responsibilities among the stakeholders according to early childhood education and care services.

Our initial view with the system dynamics approach to the nexus among early childhood education and the associated stakeholders has several implications. Our model provides a systematical understanding with a macro view for early childhood education. One contribution of this study thus falls on proposing the potential directions of policy innovation and making for Taiwan's early childhood education, namely the stakeholder structure and the changing trend of the joint responsibilities associated with this structure. Still, the research has only little efforts on the exploration of the micro insights with the associated system dynamics. Therefore, future research may benefit from the investigation of the micro-foundations and the related system dynamics for the interactions among the stakeholders according to early childhood affairs.

In addition, the causal balancing loop that connects the education-and-care service staff and the kindergartens has been identified. In practice, this causal loop presents that the education-and-care service staff is one critical cost constraint for kindergartens' operations. Education-and-care service staff is the major personnel marginal cost in kindergartens. Although the governments can assist kindergartens in improving the operational performance, the marginal cost incurred by the education-and-care service staff significantly limits the kindergarten's growth in economic scales. The present finding suggests that the managers of kindergartens (exceptionally private schools) should understand their best economies of scale (i.e., the number of classes opened, the quality of education and

care service provided, and the personnel management), to obtain the optimized performance in the business activities.

For the policymakers, one part of the present findings, which were derived from the empirical simulations, relates to the importance of promoting the birth rate in Taiwan. As we proposed and tested, our model can work for the investigation on the system dynamics of Taiwan's early childhood education, only insofar as the birth rate remains in a positive trend. That is, the birth rate is the core for driving the development of childhood education. Consequently, our findings provide insights as to how policymakers can become keen concerned about the low birth rate and simultaneously remedy the situation. Furthermore, another implication for the governments relates to the stakeholders' joint responsibilities. This joint responsibility factor plays the hub role in connecting all of the stakeholders and forming up the reinforcing causal nexus in our proposed model. The changing trend of and the interactions among the stakeholders can be referred to as an antecedent to foresee the potential dynamics in early childhood educational affairs. In so doing, policymakers can timely and properly recalibrate or amend the relevant policies.

Finally, the proposed model was built especially for Taiwan's early childhood education and care services. Still, this study suggests that the model has strong potentials to be a reference for the countries or areas for their early childhood education, if they have similar education system with Taiwan and simultaneously they are facing to the threat of the low birth rate.

In conclusion, this study aims at developing a system dynamics model for Taiwan's early childhood education and care services. The proposed model explores the causal structure of the stakeholders according to the preschool children. In the meantime, we also elaborate on the joint responsibility factor for its central role in shaping the causal reinforcing loops among the associated stakeholders. This study proceeds a twenty-year-long simulation test. The evidence supports the expositions developed by this study.

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