



Flood damage in Bangkok: disaster or an opportunity for creative destruction

A Major Qualifying Project Report

submitted to the Faculty of

*WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirements for the
Degree of Bachelor of Science*

by

Peerapas Thongsawas

An Interactive Qualifying Project Report

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Abstract

We attempt to evaluate the paths to recovery following the devastating floods in 2011 in Thailand, which submerged a large part of the country for six months and severely damaged the infrastructures and the economy. We use system dynamic to simulate the impact of flood and test the performance of post-flood recovery effort. Since most of Thailand's economic activities are located in the capital, we set the boundary of our study to Bangkok metropolitan area. We build on Saeed's model of Schumpeter's concept of creative destruction, which he has posited as forerunner to Forrester's Urban Dynamics model (Saeed 2010). We extend Saeed's model to subsume the infrastructure aging chains and land constraints of the Urban Dynamics model. We also added to the model mechanisms for taxation and service provision as on ground in Bangkok. We study the damage recovery policies implemented by Thai government as well as those alluded to in Urban Dynamics. We find that encouraging new investment and reducing cost of capital help recovery to some degree. These policies paired with increasing demolition of old infrastructure seem to facilitate the recovery process.

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Introduction

The Merriam-Webster's dictionary defines "disaster" as something that happens suddenly and causes much suffering or loss to many people. The causes of disaster are recognized in two types: natural disaster and man-made disaster. While man-made disasters usually affect a small number of people, natural disasters such as flood, drought, and tsunami can be in a much larger scale. Regardless, disaster leads to vast loss of life and property. Furthermore, it affects people's mental, physical, and social well-being.

Flood is one of the most common and costly disasters affecting human race throughout the history. It occurs when water overflows the land. Conditions that cause flood include precipitation, rise of sea level, and dam failure (Nelson, 2013). The effects of flood can be devastating: loss of lives, infrastructures damages, insufficient water and food supplies, diseases, and species extinction. In long term, flood also affects mental health and the economy.

Our project begins with an idea to simulate the impact of 2011 flood to Thai economy and find effective policies to fasten the recovery. Since system dynamics is an effective tool for policy analysis and design in various fields, we decide to use system dynamics to create a model of Thai economy and analyze alleviation policies.

Synopsis of flood in Thailand

In 2011, one of the biggest floods in Thailand's history occurred. The flood was caused by the Nuktane Cyclone, which approached Thailand from the Northeast then move to the South. This caused extremely heavy rainfall as well as tidal waves that flowed into the densely populated urban/industrial areas. The flood last for 175 days, from 25 July 2011-16 January 2011. More than three quarters of the country was affected and approximately 6 million hectares of land came under water. In terms of population, 4 million families (13.5 million people) were affected and about ten thousand houses were destroyed or damaged. (Thaiwater, 2011)

Not only the flood caused damaged to people and infrastructure, it also greatly impact Thai economy. The World Bank approximated that more than 500 billion dollars was lost. According to fiscal policy office, the growth of GDP in 2011 had drop from 4.52 percent to 2.71

percent. This is because the major industries – producing cars, electronics, and hard drive – were heavily damaged. In addition, Bangkok – the capital of Thailand – was flooded. This caused a serious break in commerce and production of all types.

For 4 months, the water level in Bangkok was over a meter high, confining most families to their houses. Boats became the primary means of transportation. All activities in Bangkok stopped. After the floodwater receded, a large proportion of the infrastructures remained damaged and unusable for an extended period of time.

Bank of Thailand predicted that the economy will return to normal within 4 months. It has been almost 2 years after the flood, however, the economy had not yet returned to normal. In addition, there has been little restoration of damaged infrastructures due to poor planning and ineffective action on part of the government.

Boundary

Our project focuses on studying the impact of flood on the economy by combining the models that were developed by Saeed (2010) and Forrester (1969). We simulate the flooding in the model by disturbing the equilibrium and implement policies to study the alleviation of the economic damage created by floods. These alleviation policies are not only current policies implemented by Thai government but also those we explored. Although the 2011 flood impacted several provinces in Thailand, we scope the area of our study within Bangkok and its surrounding provinces since they are the center of Thailand's economic activities. In addition, most infrastructures and businesses that were destroyed during the flood are located in this area. Our model will focus on the impact of flood on the economy. Other factors that may affect the economy of Thailand during our research such as political policies, corruption, and recession in Europe are outside of the scope of our study.

Literature Review

Previous Work

Although it has been almost 2 years after the 2011 flood, only a small amount of research has been published. The published research was mostly done by the Bank of Thailand. Bank of Thailand used econometric, a traditional economic modeling method, to evaluate the impact of flood to the economy and predict the alleviation.

The result shows that 16.7 billion dollars was lost because of the flood. This is approximately 2.3 percent decrease in GDP. Of the 16.7 billion dollars lost: 69.2 percent was industry sector's, 24.3 percent was service sector's, and 6.6 percent was agricultural sector's (Chantapong, 2012). The industry sector was most heavily impacted because the flood had hit 7 major industry districts, which is approximately 17 percent of Thailand's industries (Bank of Thailand, 2012).

Regarding the workforce, since 7 major industry sectors and Bangkok (the capital) were flooded, 7.3 million workers were affected (Chantapong, 2012). This is approximately one fifth of Thailand's workers. Nevertheless, Bank of Thailand predicted that most of the employers will not layoff their employees in order to resume production when the factories are restored.

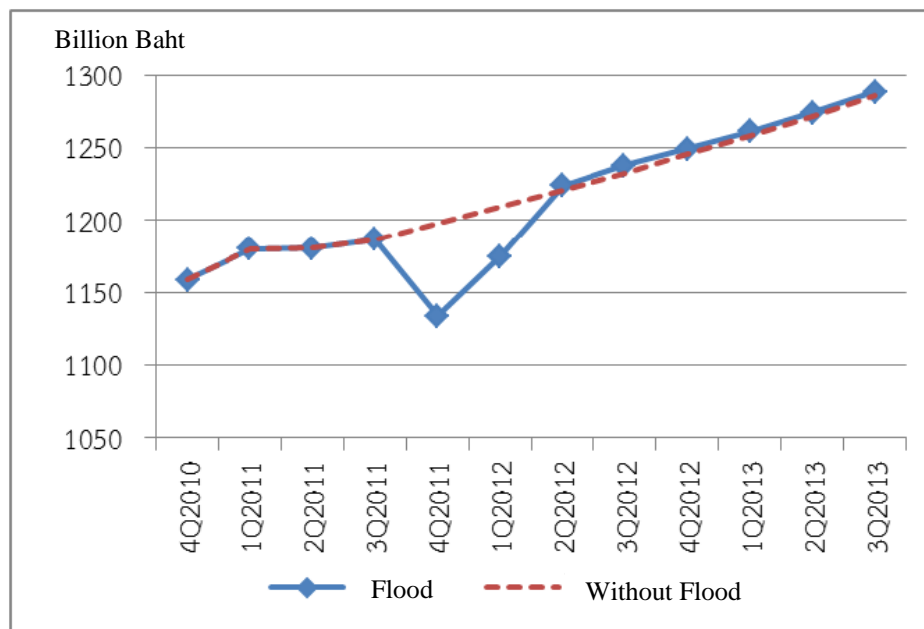


Figure 1: The effect of flood on Thailand's GDP (Suracht, 2011)

Bank of Thailand estimated that the economy will be back to normal by the 2nd quarter of 2012 as shown in the diagram above. However, this has proven to be inaccurate since the economy has not been fully restored by early 2013, the time this paper is written. This is because Bank of Thailand did not take into account of the destruction of capital infrastructures, which is a permanent decrease in production capacity.

By using system dynamic, our work will take into account of how the permanent damages caused by flood have affected the economy. We will build upon Forrester's urban Dynamic model and Schumpeter's idea of Creative Destruction, which is created into a system dynamic model in Saeed (2010).

Forrester

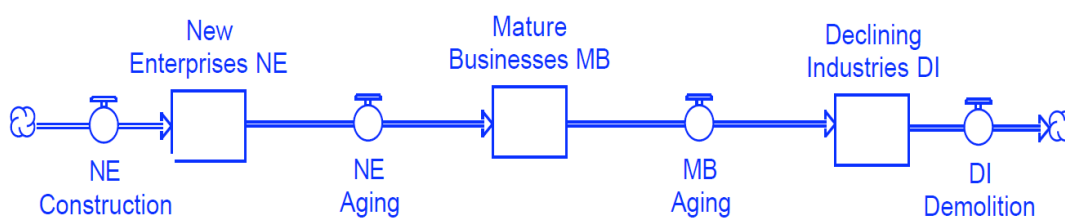


Figure 2: Third-order aging capital structure (Saeed, 2010)

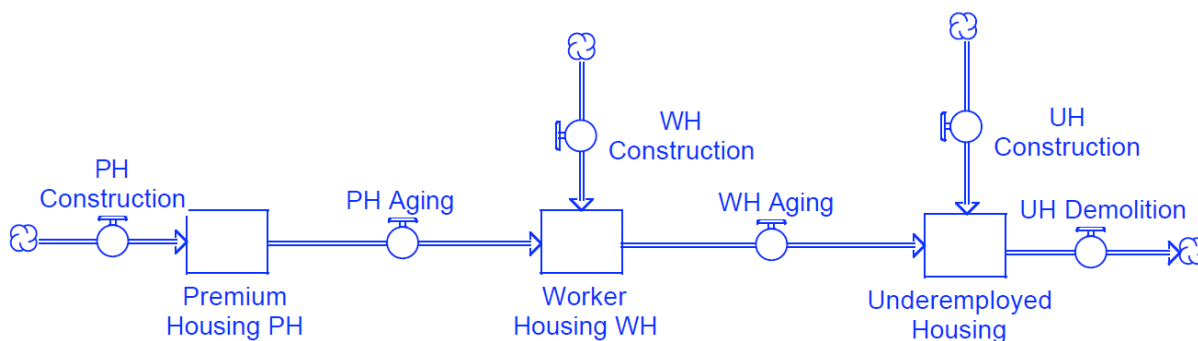


Figure 3: Third-order aging housing structure (Saeed, 2010)

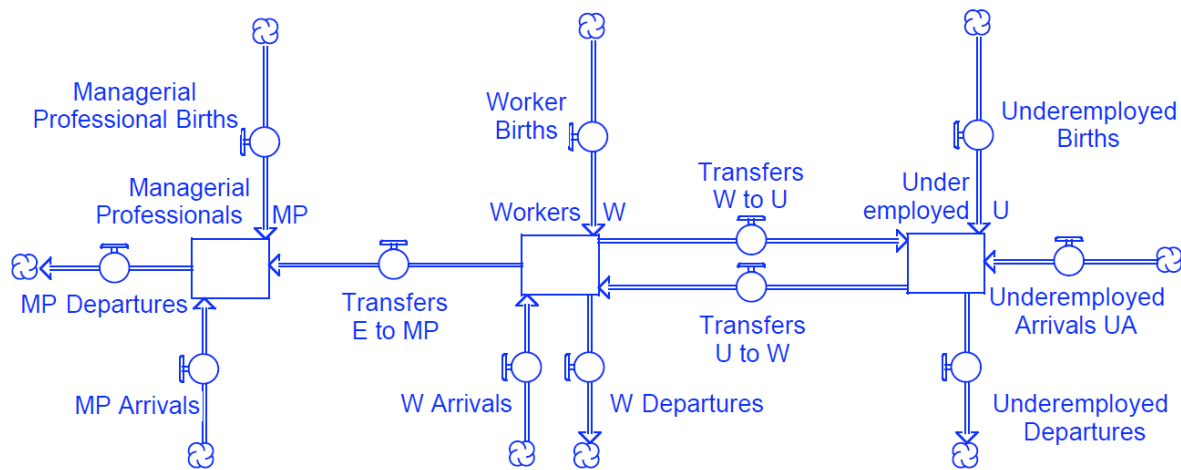


Figure 4: Three classes of workforces (Saeed, 2010)

Jay Wright Forrester, known as the founder of System Dynamics, has published a book called *Urban Dynamics* in 1969. The book represents a system dynamic model of urban structure. Forrester explained that the model is a theory of urban structures and internal relationships.

Forrester's model consists of third-order aging structure of industry, third-order aging structure of housing units, and three classes of workforces. The model covers several factors which represents relationship between those structures such as job constraint, land constraint, taxation, and how they affect the workforce growth and the aging processes of industry and housing. Forrester's simulation starts with an empty land area and reaches the equilibrium point by the generation the flows. Forrester explains in his book that the growth process would lead to a new equilibrium.

In the later chapter of the book, Forrester has used his model to simulate the result of applying policies in his virtual urban area. The simulation shows that any improvement policies applied to the model will not be effective as intended unless combined with policy to destroy old business or housing structures (which Forrester called "Slum-Clearance").

Schumpeter

Joseph Schumpeter, one of the most influential economists of the 20th century, explained the concept of “Creative Destruction” in one of his books called “*Capitalism, Socialism and Democracy*.” Contrary to Karl Marx who viewed class struggle as responsible for moving history, Schumpeter viewed entrepreneur as the agent provocateur of capitalism who created new products, opened new markets, promoted new capitals, and destroyed old ones in the process (Lipartito, 2008).

Schumpeter said that the growth of capitalism is inevitable due to the process of Creative Destruction – the endless process in industry by which innovative mechanical products replace outdated one. The instability of capitalist process is not merely due to the fact that the economic life goes on in the social or natural changes such as semi-automatic growth in workforces and capital, the unpredictability of monetary systems, wars, revolutions, and so on. These changes only condition industrial change. However, the fundamental impulse that drives capitalism comes from the constant creation of entrepreneurs who produce: new consumers’ goods, new methods of production, new method of transportation, new markets, and new forms of industrial organization (Schumpeter, 1942).

Saeed

Schumpeter idea of creative destruction was modeled by Saeed (2010) using system dynamic. His model illustrates mobility between classes of workforces – meaning labor and unemployed can become potential entrepreneurs. These entrepreneurs will create investments that increase the amount of capital. In his model, technology and saving are the implicit factors that determine the amount of investment.

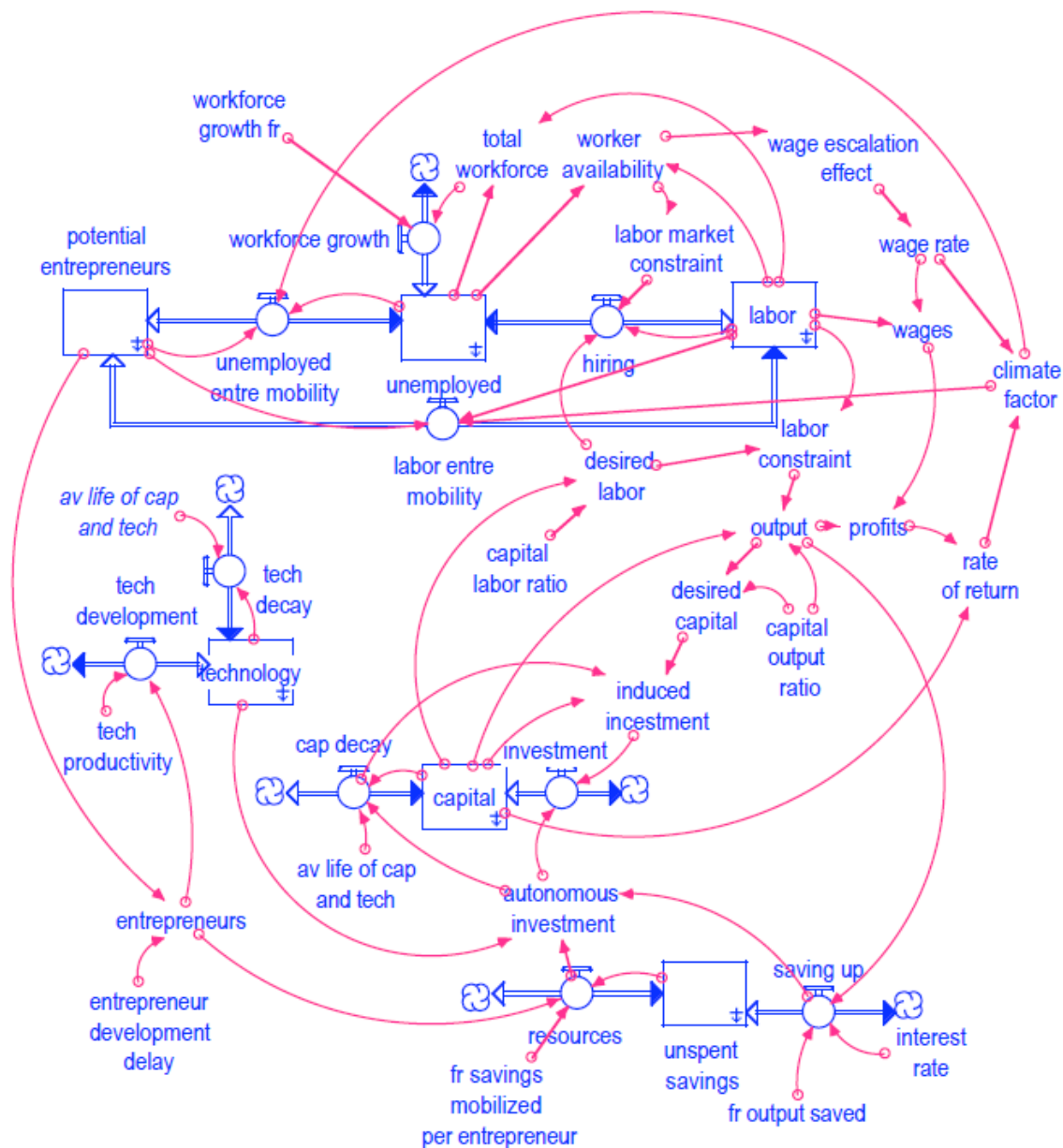


Figure 5: Model representing idea of Creative Destruction (Saeed, 2010)

Saeed also posited that there are similarities between Schumpeter's theory and Forrester's Urban Dynamic. They both model a mature economic system. In addition, these models suggest that, in order to transform the economy from stagnation into high welfare homeostasis, not only formation of new capitals but demolition of old capitals is also needed. This is a process Schumpeter called "Creative Destruction" and Forrester called "Slum Clearance."

Methodology

Since Saeed (2010) saw the link between Forrester's Urban Dynamics and Schumpeter's concept of creative destruction, we decided to extend Saeed's model of Schumpeter's Creative Destruction to subsume in it the aging chains representing infrastructure in Forrester's Urban Dynamics model. We believe that the model resulting from this extension will best represent Bangkok, which is our system of interest.

We built on Saeed's model by extending his capital sector into third-order aging capital structure: new capitals, mature capitals, and old capitals – like Forrester's. In addition, we implement Urban Dynamics' land constraint to limit the growth of capitals. We also create a mechanism for workforce to grow – based on number of jobs available. Finally, we added a service sector into the model. We use service to represent the infrastructures provided by the government. These services are funded by taxation from workforce and industry.

We adjust several parameters in the model in order to set the model to equilibrium. We disturbed the equilibrium by destroying a large fraction of the infrastructure, simulating the impact of floods. We then simulated the interventions made by the government to mitigate the impact of floods. Finally, we explored policies that would change of the model's behavior for better.

The policies we tested are from two main sources. First, we used the policies which have been tried by the Thai government. Second, we used the policies which have been proposed in the literatures such as Urban Dynamics.

Model

We will begin this section by describing the overview of our model and explain the relationship between sector and its various. Later, we will explain the details of model structure in each sector.

Model overview

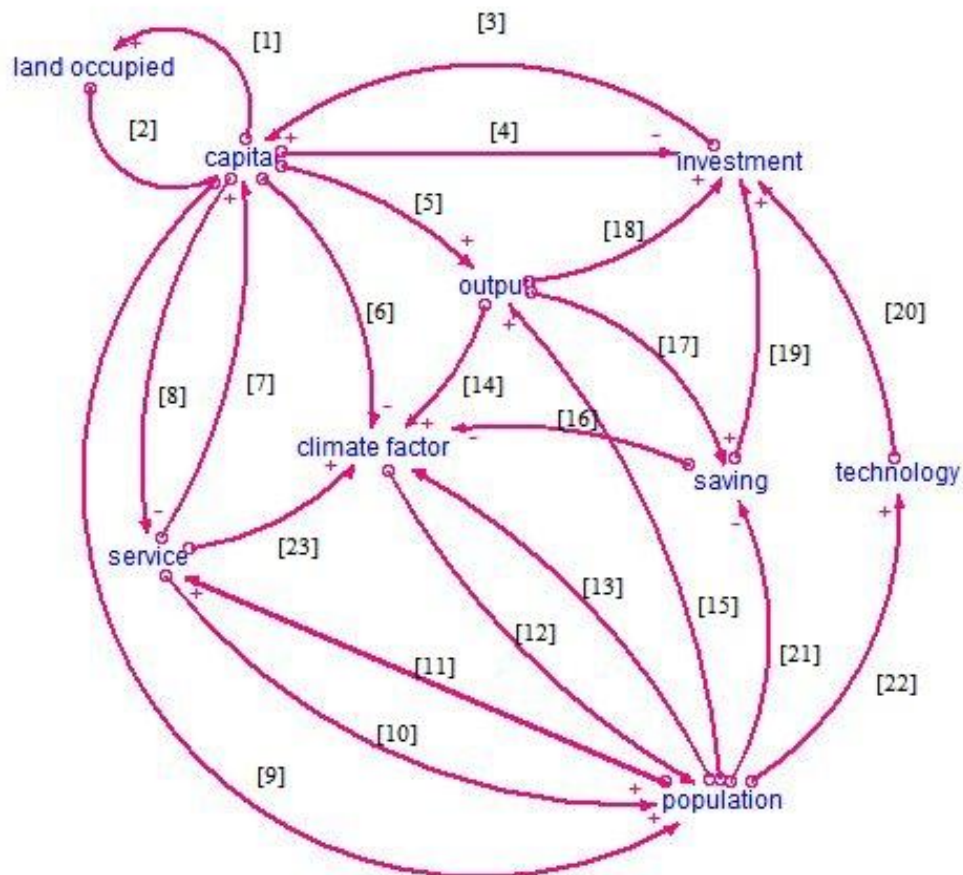


Figure 6: Aggregate Casual Diagram

Our model consists of: population sector, climate factor sector, service sector, technology sector, saving sector, investment sector, capital sector, output sector, and land sector. These sectors are interconnected, creating feedback loops as shown in Figure 6. The links are labeled and explained as follow:

- [1] A positive direct link from capital sector to land sector shows that the more capital infrastructures are constructed, the less land will be available.
- [2] A direct link from land sector to capital sector shows the effect of available land to capital. When land is freely available, people will start to develop the area; therefore, more land will be occupied with capital infrastructures. When the occupied land reaches a tipping point, the land gets too crowded, people will move out and the capital will decrease. In the other words, the link will be a positive direct link when the land occupied is low, but will be a negative direct link when the land occupied is high.
- [3] A positive direct link form investment sector to capital sector shows that more investment leads to more construction of capital infrastructure.
- [4] A negative direct link from capital sector to investment sector shows that more capital will decrease the amount of investment from entrepreneurs. The induced investment depends on the difference between the actual amount of capital and the desired amount of capital. As the capital increase, the gap between the actual amount and desired amount decreases; therefore, the induced investment decrease.
- [5] A positive direct link from capital sector to output sector shows that more capital will generate more output.
- [6] A negative direct link from capital sector to climate factor sector shows that the more capital, the less people will become entrepreneurs. Since the average profit per unit capital is defined as the total profit of overall system divide by the number of capital structures, an increase in capital will reduce profit per unit capital; therefore, discouraging people to become entrepreneurs.
- [7] A positive direct link from service sector to capital sector shows that the more service provided by the government, the more capital can be constructed.
- [8] A negative direct link from capital sector to service sector shows that the more capital, the less service can be provided. Since we assume that the government spends tax to service capital more than population; more capital will create more service demand than service supply; therefore, decreases service ratio.

- [9] A positive direct link from capital sector to population sector shows that capital will create jobs. As more jobs become available, more people move into the city.
- [10] A positive direct link from service sector to population sector shows that service provided by the government will create incentive for people to move into the city.
- [11] A positive direct link from population sector to service sector shows that more service supply will increase the service ratio.
- [12] A direct link from climate factor sector to population sector shows that the change in climate factor will affect the population sector both positively and negatively. A high climate factor does not directly increase the level of total workforce, but it increases the level of the potential entrepreneurs, which is sub-sector of the population sector.
- [13] A direct link from population sector to climate factor sector shows that the change in the population sector will also affect the climate factor sector. Similar to [12], the level of total workforce does not directly affect the climate factor. The labor availability – the ratio of current workers to the unemployed that can be hired – will affect the wage rate. The high wage rate will then discourage people to become entrepreneurs.
- [14] A positive direct link from output sector to climate factor sector shows that more output will create incentive for people to become entrepreneurs and increase job mobility.
- [15] A positive direct link from population sector to output sector shows that more people means more labor is available; therefore, generating more output.
- [16] A negative direct link from saving sector to climate factor sector shows that high interest rate, which implies more money is saved, encourages people to save money in the bank rather than to invest as entrepreneurs.
- [17] A positive direct link from output sector to saving sector shows that more output will generate more saving.
- [18] A positive direct link from output sector to investment sector shows that high output will increase the desired amount of capital. As a result, entrepreneurs will invest more.

[19] A negative direct link from saving sector to investment sector shows that if people save more money, less money will be spent on investment.

[20] A positive direct link from technology sector to investment sector shows that more capital infrastructures can be constructed with higher technological advancement.

[21] A negative direct link from population sector to saving sector shows that if there are more entrepreneurs, more money will be invested rather than saved in the bank.

[22] A positive direct link from population sector to technology sector shows that, as total workforce increases, potential entrepreneurs will increase; therefore, creating more technology.

[23] A positive direct link from service sector to climate factor sector shows that high service provided by the government will increase the mobility of the workforce since people are supported and encouraged to become entrepreneurs.

Population Sector

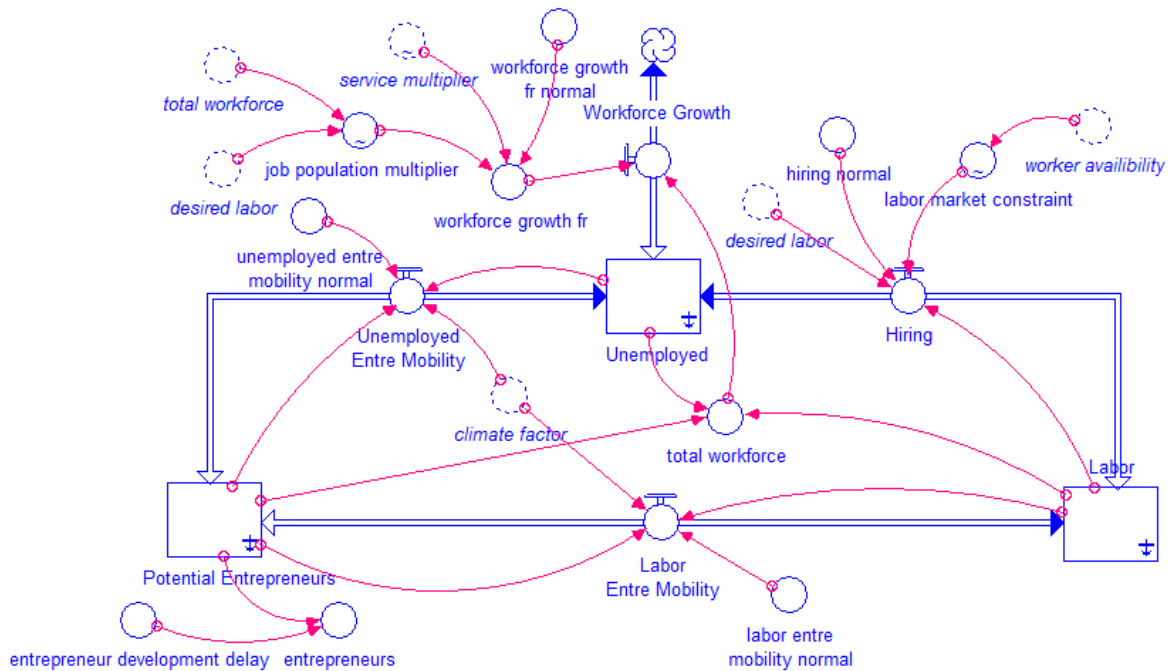


Figure 7: Population Sector

The population sector consists of three stocks representing three types of workforce: Potential Entrepreneurs, Labor, and Unemployed. These three types of workforce can freely change their status when there are shifts in the economy. The change process is represented by the following flows: (Note that CF = Climate Factor and PE = Potential Entrepreneurs)

$$\text{Labor Entre Mobility} = \text{Labor} * 0.05 * CF - \frac{PE * 0.25}{CF}$$

$$\text{Unemployed Entre Mobility} = \text{Unemployed} * 0.1 * CF - PE * 0.1$$

$$\text{Hiring} = \frac{\text{Desired Labor} - \text{Labor}}{2} * \text{Labor Market Constraint}$$

The first and second equations show that Labor and Unemployed can move to Potential Entrepreneurs if the Climate Factor is high while the number of current Potential Entrepreneurs is low. On the other hand, the third equation shows that Unemployed will become Labor if the Desired Labor is high, current Labor is low, and Labor Market Constraint is high. The labor Market Constraint is represented by Figure 8. As Worker Availability increases the Labor Market constraint increases at a declining rate (Saeed, 2010).

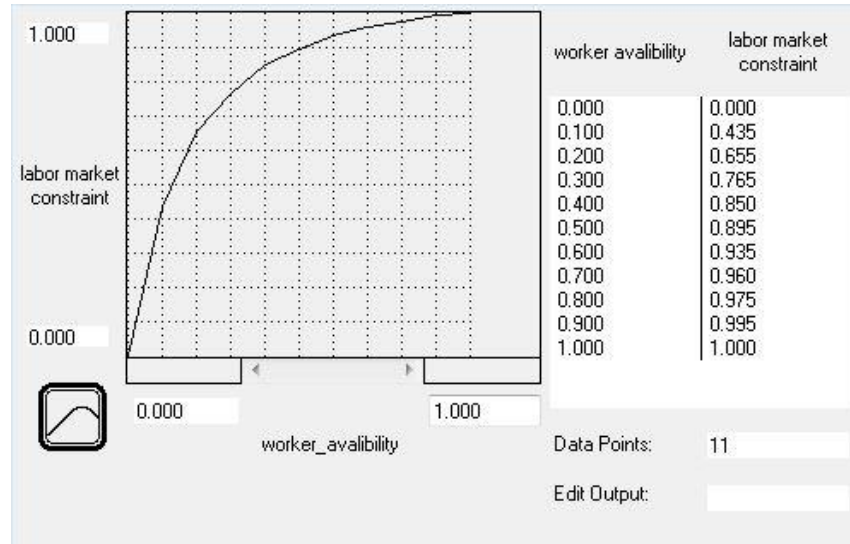


Figure 8: The effect of Worker Availability on Labor Market Constraint (Saeed, 2010)

In this model, the growth of the workforce is represented in the Workforce Growth flow, equation shown below. Note that, new workforce – by birth or immigration – is assumed to be unemployed.

$$\text{Workforce Growth} = \text{Total Workforce} * \text{Workforce Growth Fraction}$$

Where

$$\text{Total Workforce} = \text{Potential Entrepreneurs} + \text{Labor} + \text{Unemployed}$$

And

$$\begin{aligned} \text{Workforce Growth Fraction} \\ = \text{Workforce Growth Fraction Normal} * \text{Job Population Multiplier} \end{aligned}$$

The Job Population Multiplier is a function of Total Workforce and Desired Labor as shown in the Figure 9. At x-axis equals 1, the Job Population Multiplier is at equilibrium. Before equilibrium, there is low need of labor (low Desired Labor compared to Total Workforce); therefore, the multiplier increases at a declining rate. After equilibrium, there is a high demand for labor; therefore, the multiplier increases at an exponential rate.

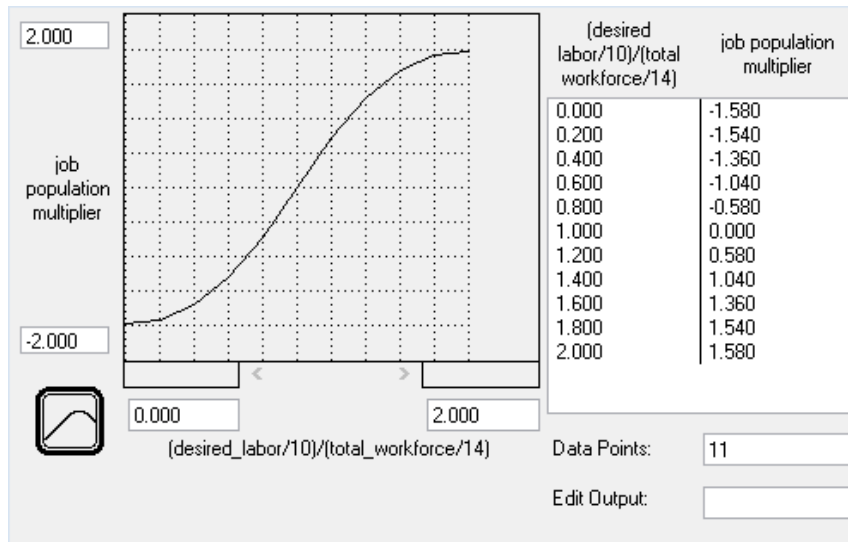


Figure 9: The effect of Desired Labor and Total Workforce on Job Population Multiplier

Climate Factor Sector

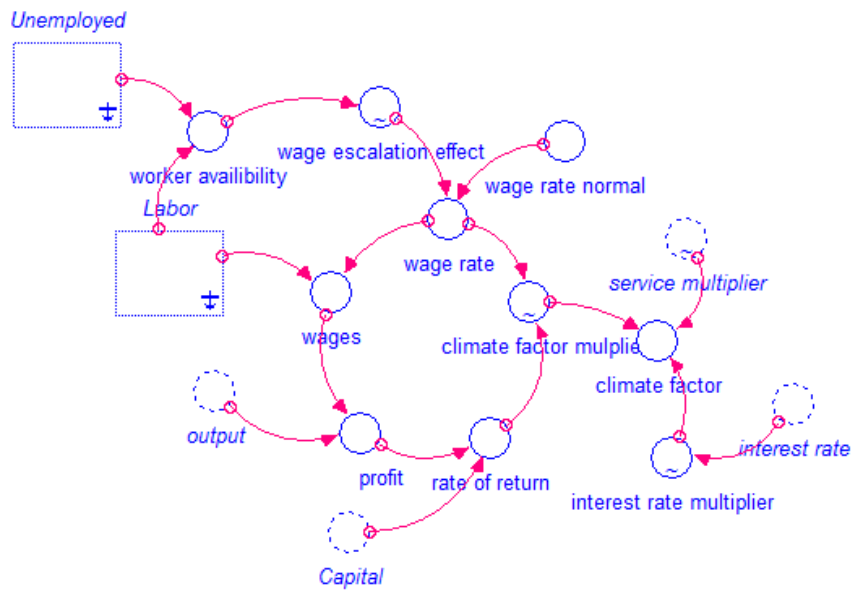


Figure 10: Climate Factor Sector

The climate factor can be defined as the environment that encourages entrepreneurial activity. It is the product of the following multipliers:

Climate Factor

$$= \text{Climate Factor Multiplier} * \text{Service Multiplier} * \text{Interest Rate Multiplier}$$

In this section, we will explain how the Interest Rate Multiplier and Climate Factor Multiplier are calculated while the calculation of Service Multiplier will be explained in the service sector.

Interest Rate Multiplier:

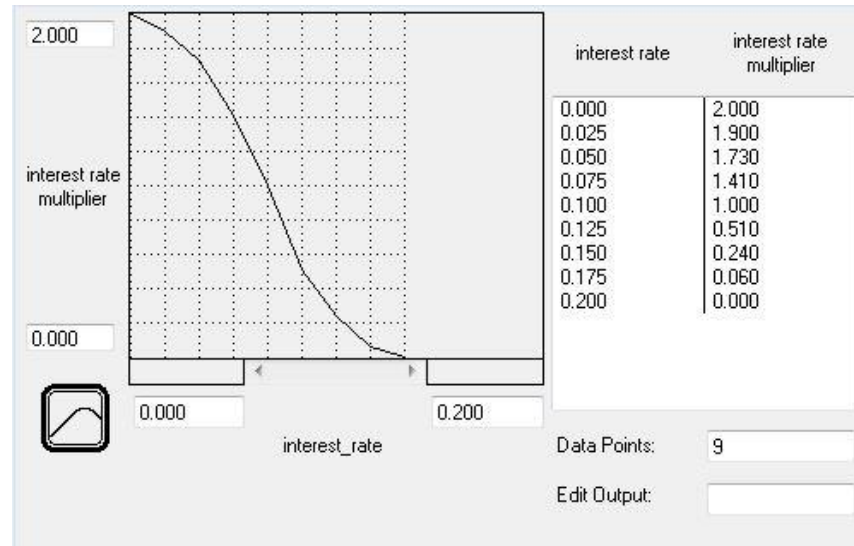


Figure 11: The effect of Interest Rate on Interest Rate Multiplier

The Interest Rate Multiplier is a reverse s-curve function of Interest Rate as shown in Figure 11. It shows that as the interest rate decreases, entrepreneurs will be less likely to invest (high interest rate multiplier).

Climate Factor Multiplier:

In order to define climate factor multiplier, we first need to know that Worker Availability is defined by Unemployed divided by Labor. In addition, Worker Availability is also directly related Wage Escalation Effect. As the Worker Availability declines, the Wage Escalation Effect decline with a declining rate as shown in Figure 12 (Saeed, 2010).

$$Worker\ Availability = 0.2 * \frac{Unemployed}{Labor}$$

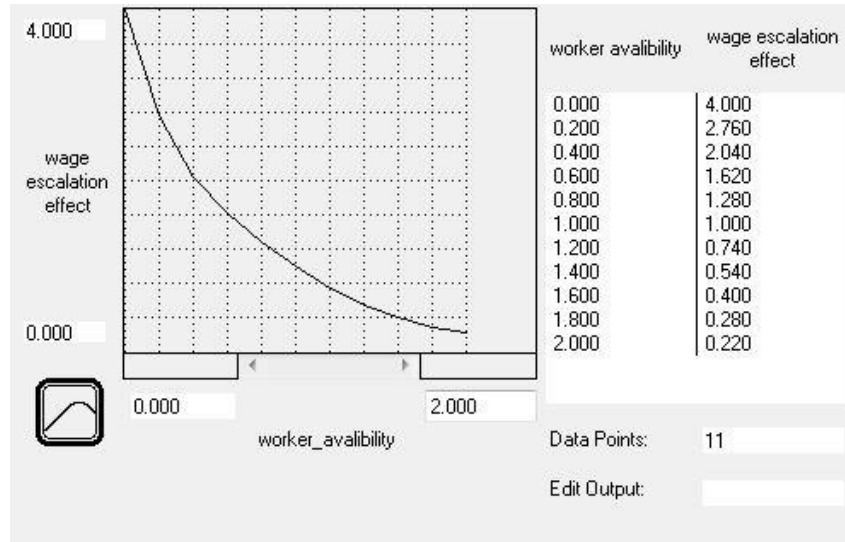


Figure 12: The effect of Worker Availability on Wage Escalation Effect (Saeed, 2010)

Wage Escalation Effect is positively correlated with Wage Rate. By multiplying Wage Rate by Labor, we can then determine the Wages. Respectively, Profit can be calculated by subtracting Output from Wages. Finally, dividing Profit by Capital will yield the Rate of Return.

$$\text{Wage Rate} = \text{Wagr Rate Normal} * \text{Wage Escalation Effect}$$

$$\text{Wages} = \text{Labor} * \text{Wage Rate}$$

$$\text{Profit} = \text{Output} - \text{Wages}$$

$$\text{Rate of Return} = \frac{\text{Profit}}{\text{Capital}}$$

Knowing all the contributed factors, Climate Factor Multiplier can be defined as an s-curve function of Wage Rate and Rate of Return as shown in Figure 13 (Saeed, 2010).

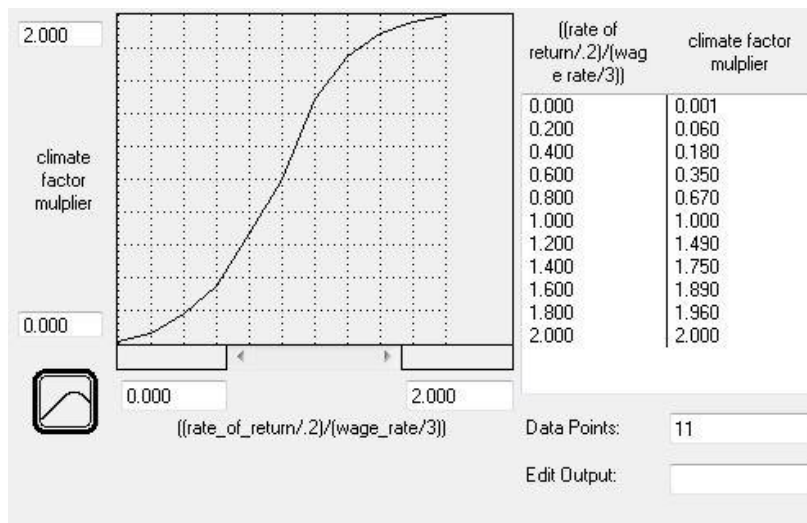


Figure 13: The effect of Rate of Return and Wage Rate on Climate Factor Multiplier (Saeed, 2010)

Service Sector

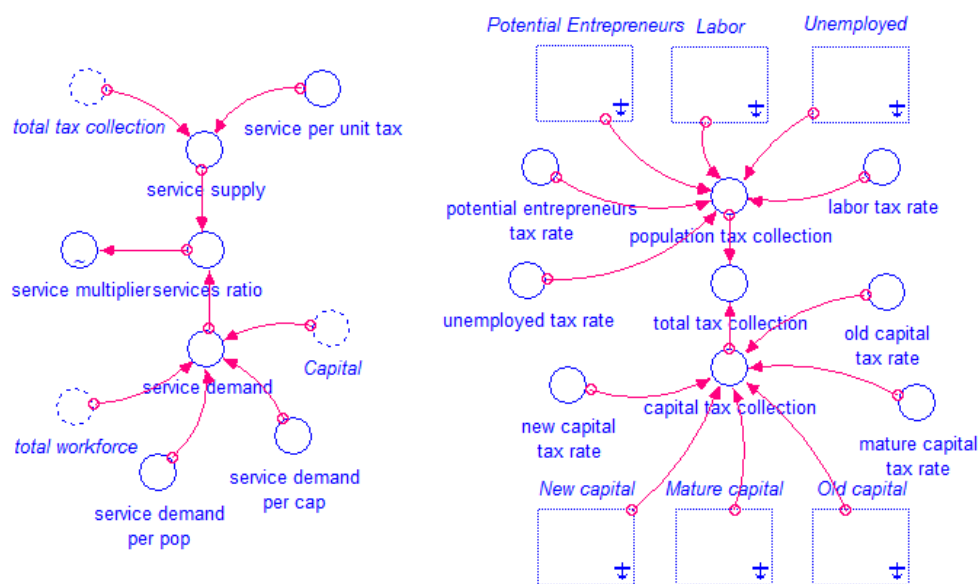


Figure 14: Service Sector

This sector represents the services provided by the government. The government collects tax from its citizens and capital. Based on Thailand’s tax system, we assume that the government collects tax from people more than capital.

$$\textit{Service Supply} = \textit{Service per Unit Tax} * \textit{Total Tax Collection}$$

Where

$$\textit{Total Tax Collection} = \textit{Capital Tax Collection} + \textit{Population Tax Collection}$$

The Population Tax Collection consists of tax collected from Potential Entrepreneurs, Labors, and Unemployed. Since progressive tax is assumed, Potential Entrepreneur is taxed twice as Labor's while Unemployed is not taxed due to the lack of income. In order to adjust the model to equilibrium, Potential Entrepreneur Tax Rate is 15 US dollar per month per people, Labor Tax Rate is 7.5 US dollar per month per people, and Unemployed Tax Rate is 0 US dollar per month per people.

Population Tax Collection

$$\begin{aligned} &= \textit{Unemployed} * \textit{Unemployed Tax Rate} + \textit{Labor} * \textit{Labor Tax Rate} \\ &+ \textit{Potential Entrepreneurs} * \textit{Potential Entrepreneurs Tax Rate} \end{aligned}$$

The Capital Tax Collection consists of New Capital, Mature Capital, and Old Capital. Since the newer capital earns more profit than the older capital, we assume that New Capital Tax Rate is 1 US dollar per month per productive unit, Mature Capital Tax Rate is 0.5 US dollar per month per productive unit, and Old Capital Tax Rate is 0.25 US dollar per month per productive unit.

Capital Tax Collection

$$\begin{aligned} &= \textit{Old Capital} * \textit{Old Capital Tax Rate} + \textit{Mature Capital} \\ &* \textit{Mature Capital Tax Rate} + \textit{New Capital} * \textit{New Capital Tax Rate} \end{aligned}$$

Population and capital in the city desire for better services to improve their living conditions. In this model, service demand is defined as the sum of the demand from both capital sector and population sector.

Service Demand

$$\begin{aligned} &= \textit{Capital} * \textit{Service Demand per Cap} + \textit{Total Workforce} \\ &* \textit{Service Demand per Pop} \end{aligned}$$

In return, the government uses the collected taxes provide service supply.

$$\text{Service Ratio} = \frac{\text{Service Supply}}{\text{Service Demand}}$$

The ratio of service supply to service demand is defined as a Service Ratio. The Service Ratio value less than one means there is an excess of Service Demand with respect to Service Supply and vice versa.

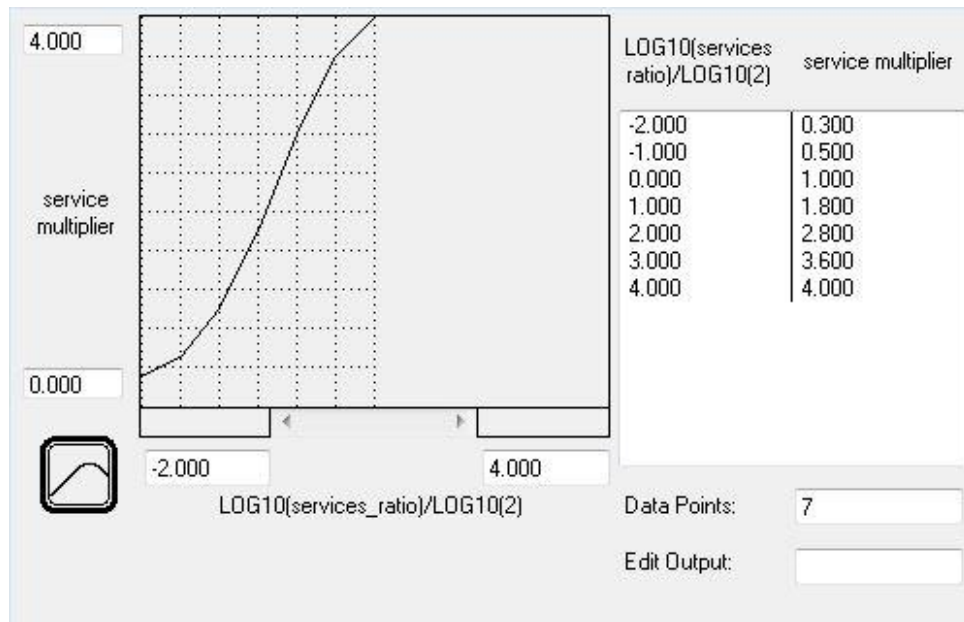


Figure 15: The effect of Service Ratio on Service Multiplier (Forrester, 1979)

Figure 15 shows that Service Multiplier is positively associated with Service Ratio; the higher the Service Ratio, the higher the Service Multiplier and vice versa. The Service Multiplier reflects the living condition of people and the economic situation of capital in the city. The high Service Multiplier will create incentive for people to move into the city, to become entrepreneurs, and to construct more capital infrastructures.

Technology Sector

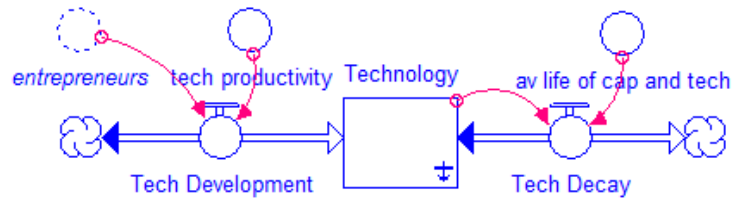


Figure 16: Technology Sector

The technology sector consists of Technology stock and two flows – inflow and outflow. The inflow is called Tech Development while the outflow is called Tech Decay. Equations for both flows are illustrated below:

$$\text{Tech Development} = \text{Entrepreneurs} * \text{Tech Productivity}$$

$$\text{Tech Decay} = \frac{\text{Technology}}{\text{Av Life of Cap and Tech}}$$

Where

$$\text{Entrepreneurs} = \text{SMTH3}(\text{Potential_Entrepreneurs}, \text{entrepreneur_development_delay})$$

The higher the number of Entrepreneurs and Technological Productivities, the higher the Technological Development will be. On the other hand, Technology will decay at a higher rate if its Average Life is low and vice versa.

Saving Sector

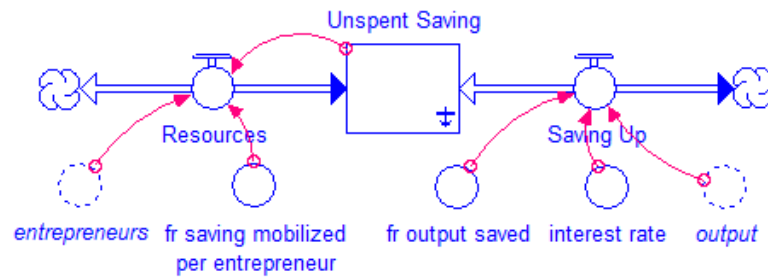


Figure 17: Saving Sector

The saving sector consists of Unspent Saving stock, inflow, and outflow. The Saving Up inflow is a function of Output, Fr Output Saved, and Interest Rate. It represents the rate which capital is being accumulated. More money will be saved when the interest rate is high.

$$\text{Saving Up} = \frac{\text{Output} * \text{Fr Output Saved} * \text{Interest Rate}}{0.1}$$

The Resources outflow is a function of Entrepreneurs, Fr Saving Mobilized per Entrepreneur, and Unspent Saving. It represents the rate which capital is used for investment. More entrepreneurs and current capital will contribute to higher investment as shown in the equation below.

$$\text{Resources} = \text{Entrepreneurs} * \text{Fr Saving Mobilized per Entrepreneur} * \text{Unspent Saving}$$

Investment Sector

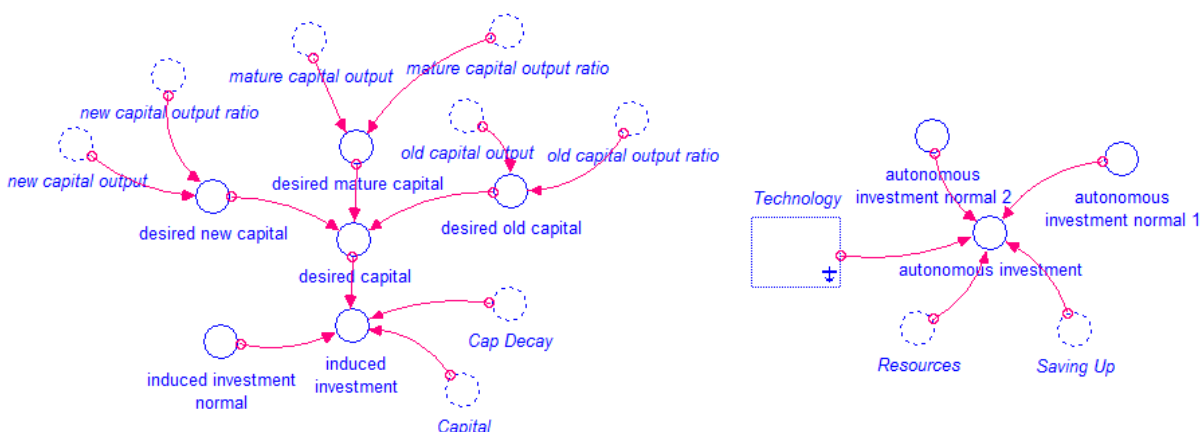


Figure 18: Investment Sector

There are two kinds of investment which generates the inflow of new capital: Induced Investment and Autonomous Investment.

Induced Investment depends on the difference between the amount of supply (actual) and demand (Desired Capital). (Saeed, 2010)

Induced investment

$$= (\text{Desired Capital} - \text{Capital}) * \text{Induced Investment Normal} + \text{Cap Decay}$$

Desired Capital represents the product of output of capital and Capital Output Ratio (Saeed, 2010). Since capital is separated into three parts, total desired capital is computed by adding up desired capital of each capital. In addition, since newer capital can produce more output than older capital, the output ratio of New Capital, Mature Capital, and Old Capital are $\frac{4}{3}$, 2, and 2 units/US dollars respectively. Note that, for each type of capital, capital output is computed by dividing capital output ratio from capital.

Desired Capital

$$= \text{Desired New Capital} + \text{Desired Mature Capital} + \text{Desired Old Capital}$$

$$\text{Desired New Capital} = \text{New Capital Output} * \text{New Capital Output Ratio}$$

$$\text{Desired Mature Capital} = \text{Mature Capital Output} * \text{Mature Capital Output Ratio}$$

$$\text{Desired Old Capital} = \text{Old Capital Output} * \text{Old Capital Output Ratio}$$

Autonomous Investment is the investment from Resources and Technology created by entrepreneurs. (Saeed, 2010)

Autonomous Investment

$$= \text{Resources}^{0.5} * \left(\frac{\text{Technology}}{10}\right)^{0.5} * \text{Autonomous Investment Normal 1}^{0.5}$$

$$- \text{Saving Up} * \text{Autonomous Investment Normal 2}$$

Capital Sector

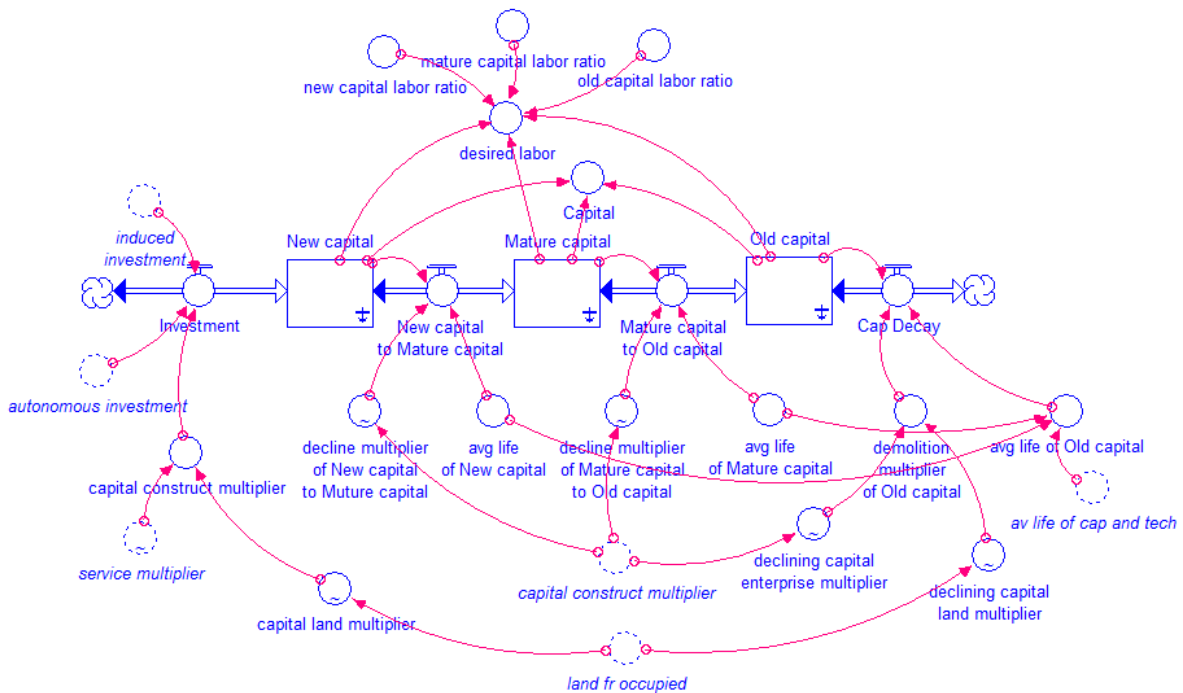


Figure 19: Capital Sector

The capital sector shows a third-order aging structure of capital infrastructures. When capital infrastructure is constructed, it is considered New Capital. In time, it becomes Mature Capital, and then Old Capital respectively.

Investment, an inflow of New Capital, is the product of Capital Construct Multiplier and the sum of Induced Investment and Autonomous Investment. Capital Construct Multiplier is the facilitation for a new capital to be constructed. As the multiplier goes up, the more capital can be constructed within the same amount of investment. As the multiplier decreases, spending the same amount of investment can construct less new capital (Saeed 2010).

$$\text{Investment} = (\text{Autonomous Investment} + \text{Induced Investment}) \\ * \text{Capital Construct Multiplier}$$

Capital Construct Multiplier depends on two factors: Land Fraction Occupied and Service Multiplier.

$$\text{Capital Construct Multiplier} = \text{Capital Land Multiplier} * \text{Service Multiplier}$$

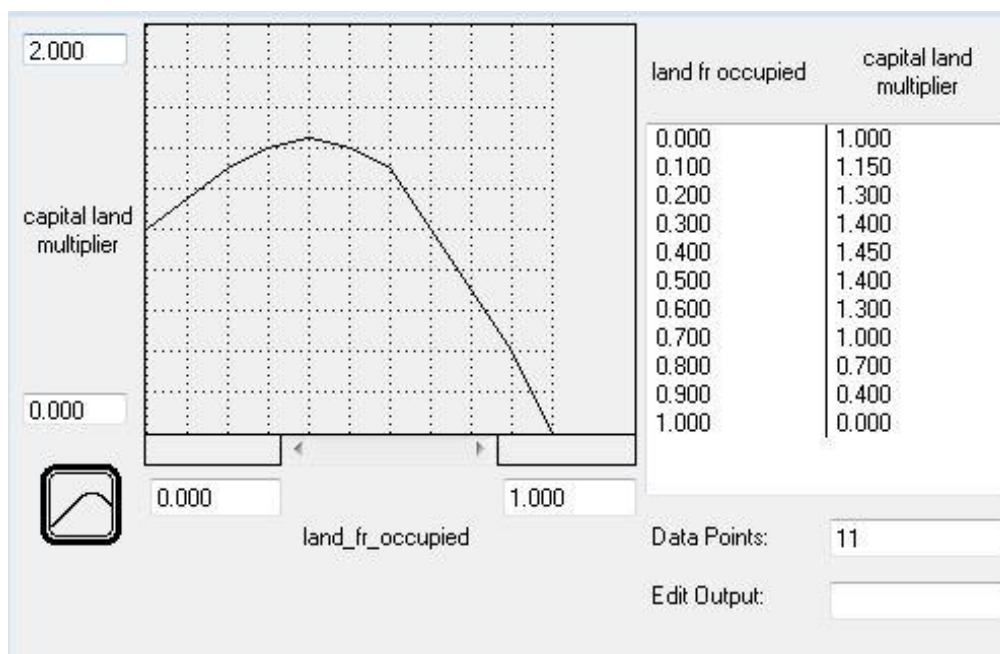


Figure 20: The effect of Land Fraction Occupied on Capital Land Multiplier (Forrester, 1979)

Figure 20 shows that, when Land Fraction Occupied is very low, the area has not yet been developed. As Land Fraction Occupied increases, the area has been more developed, which

makes the construction of new capital infrastructures easier to be done. When Land Fraction Occupied reaches 0.4, the land becomes rare and more expensive, therefore discourages investor to buy more land and construct new capital. (Alfeld, 1976)

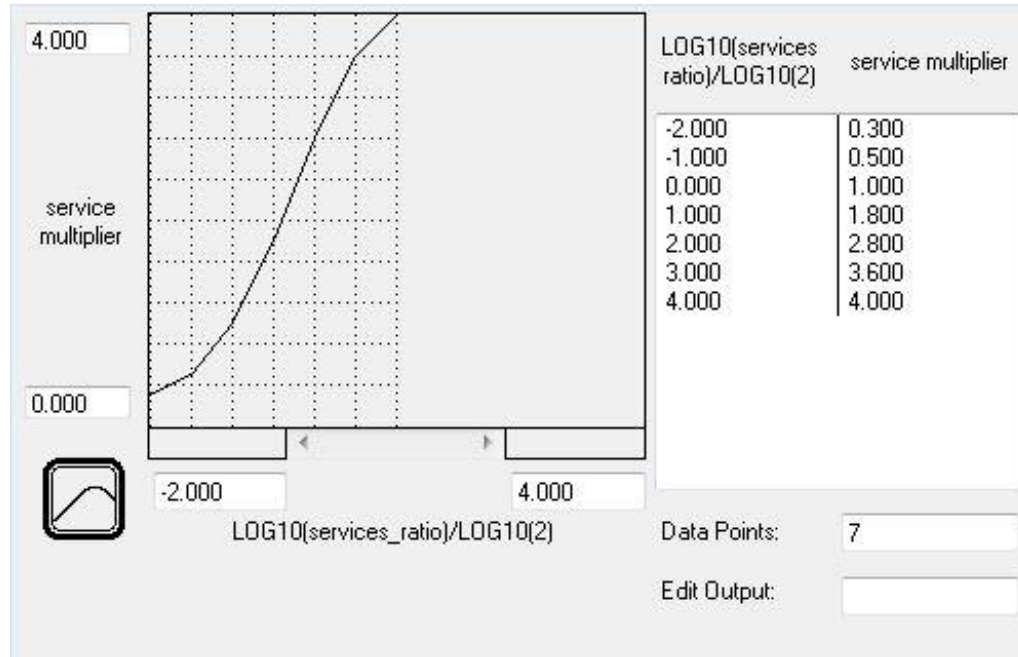


Figure 21: The effect of Service Ratio on Service Multiplier (Forrester, 1979)

A high Service Multiplier means the government will support and help entrepreneurs to construct new capital infrastructures. On the contrary, the low Service Multiplier means that the government barely supports entrepreneurs. (Forrester, 1979) Figure 21 shows the relation between service ratio and service multiplier.

According to Urban Dynamics' model, the ratio of average lifetime of each kind of capitals is approximately 2:3:5. In this model, the New Capital's lifetime is 2 years; therefore, the lifetime of Mature Capital and Old Capital will be 3 years and 50 years respectively.

$$Av\ Life\ of\ Cap\ and\ Tech = 10$$

$$Avg\ Life\ of\ New\ Capital = 2$$

$$Avg\ Life\ of\ Mature\ Capital = 3$$

Avg Life of New Capital

$$= \text{Av Life of Cap and Tech} - \text{Avg Life of New Capital} \\ - \text{Avg Life of Mature Capital}$$

The normal decline rate of each capital is the total amount of each capital divide by the average lifetime that of capital (Forrester, 1979).

New Capital to Mature Capital

$$= \text{Decline Multiplier of New Capital to Mature Capital} \\ * \frac{\text{New Capital}}{\text{Avg Life of New Capital}}$$

Mature Capital to Old Capital

$$= \text{Decline Multiplier of Mature Capital to Old Capital} \\ * \frac{\text{Mature Capital}}{\text{Avg Life of Mature Capital}}$$

$$\text{Cap Decay} = \text{Demolition Multiplier of Old Business} * \frac{\text{Old Capital}}{\text{Avg Life Of Old Capital}}$$

Demolition Multiplier of Old Business

$$= \text{Declining Capital Enterprise Multiplier} \\ * \text{Declining Capital Land Multiplier}$$

The other multipliers which affect the decline rate of capital are the decline multiplier of New capital to Mature capital, decline multiplier of Mature capital to Old capital, declining capital enterprise multiplier, and declining capital land multiplier.

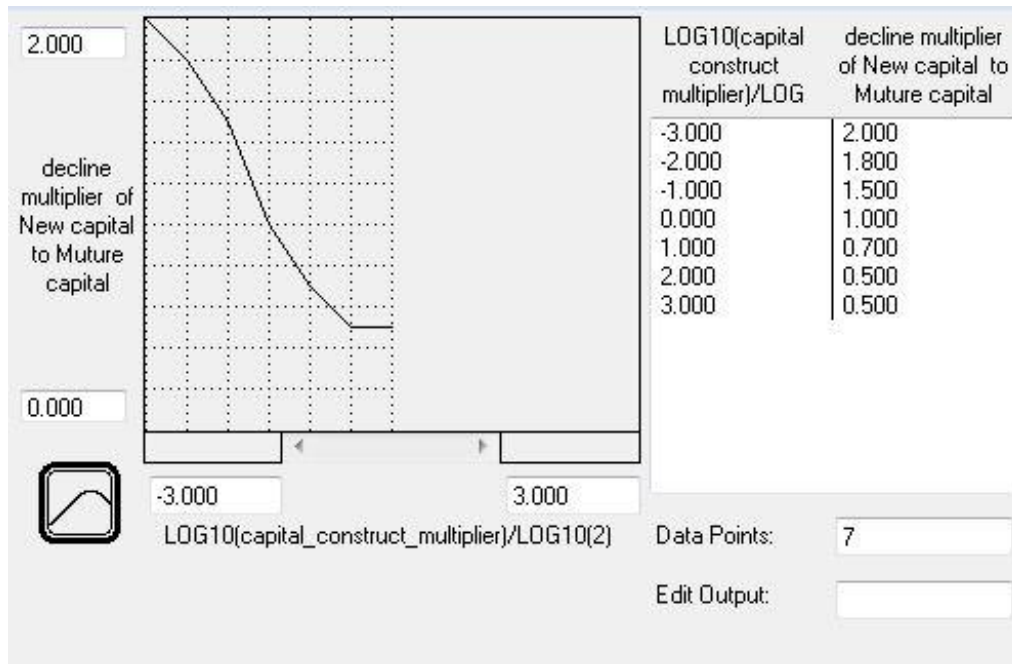


Figure 22: The effect of Capital Construct Multiplier on Decline Multiplier of New Capital to Mature Capital (Forrester, 1979)

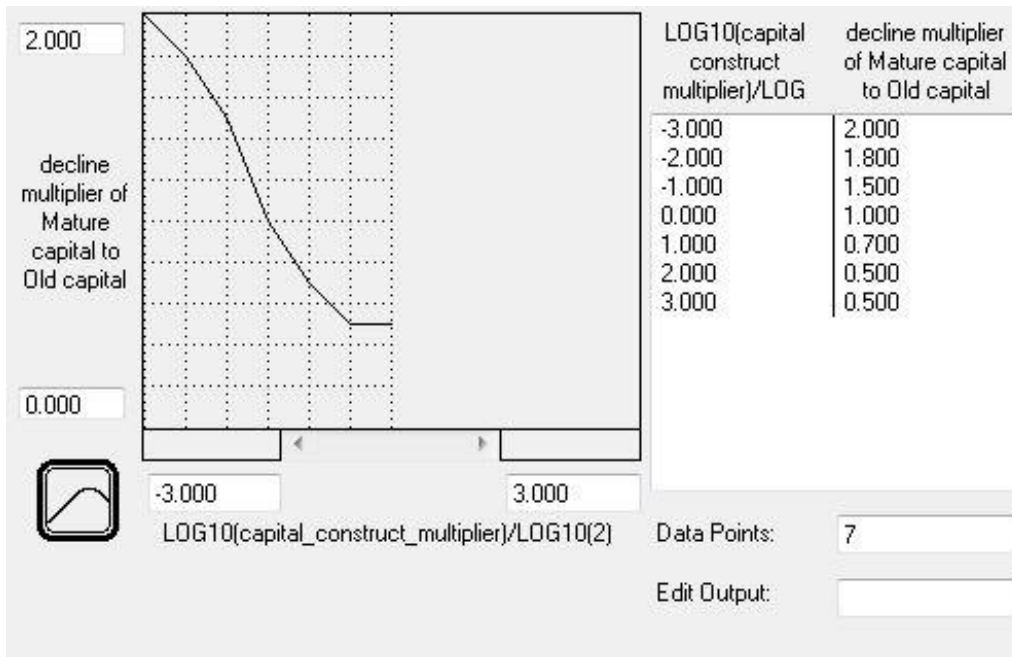


Figure 23: The effect of Capital Construct Multiplier on Decline Multiplier of Mature Capital to Old Capital (Forrester, 1979)

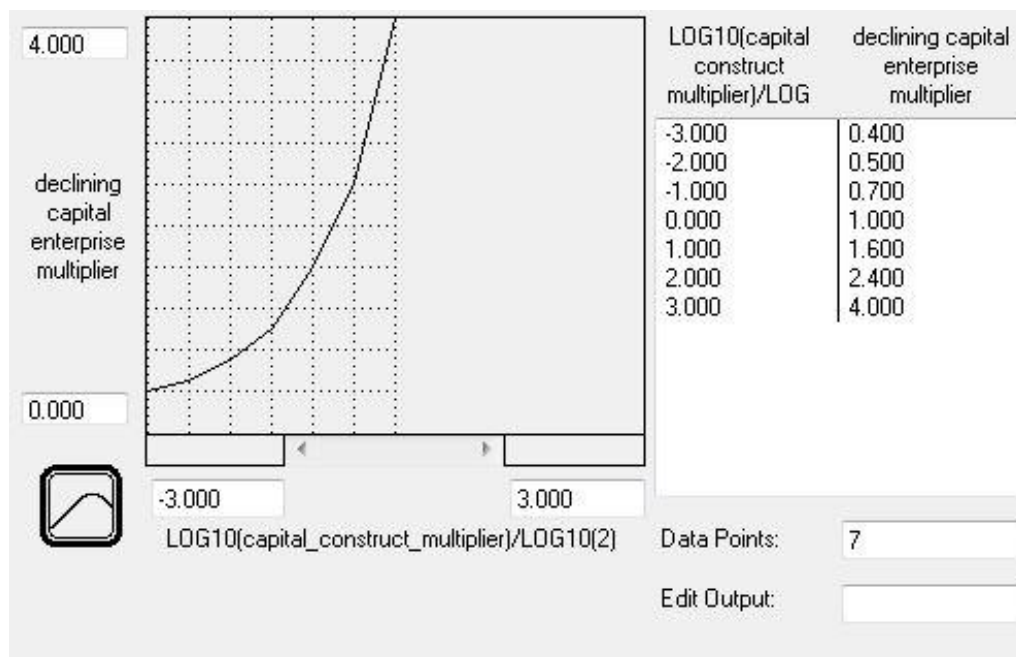


Figure 24: The effect of Capital Construct Multiplier on Declining Capital Enterprise Multiplier (Forrester, 1979)

The first three multipliers – decline multiplier of New capital to Mature capital, decline multiplier of Mature capital to Old capital, and declining capital enterprise multiplier – depend on capital construct multiplier. Forrester mentioned in “Urban Dynamics” book that, as capital construct multiplier goes up, there will be an active demand for new enterprise. It is assumed that the existing new enterprise will retain its vitality for a longer period, but old capitals will be forced to be destroyed. As a result, the decline rate of new capital and old capital will decrease (multiplier less than 1), but the decline rate of old capital will increase (multiplier greater than 1).

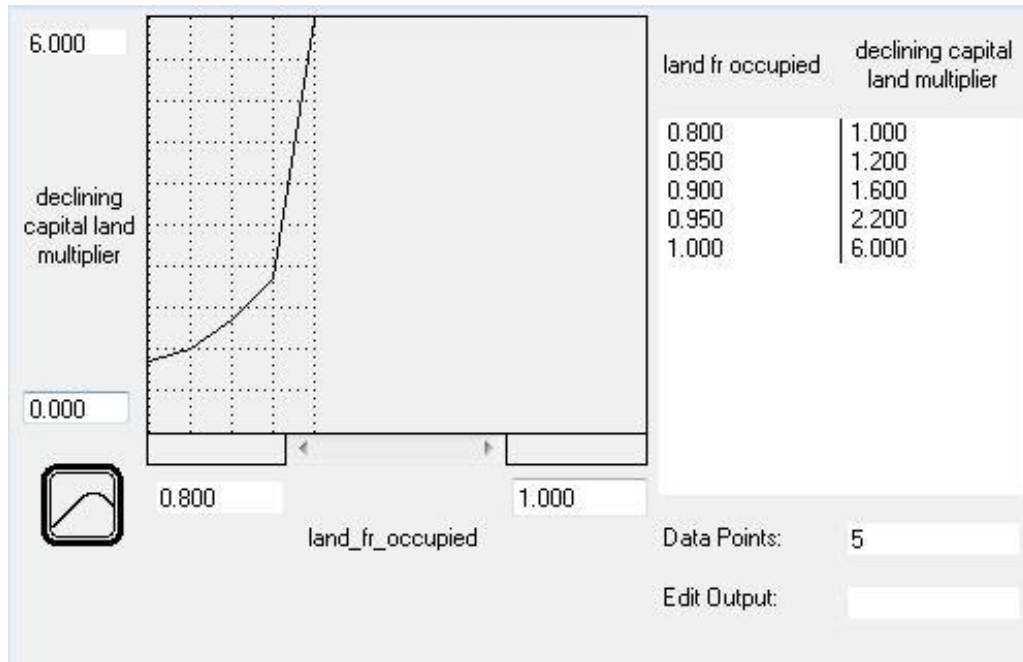


Figure 25: The effect of Land Fraction Occupied on Declining Capital Land Multiplier (Forrester, 1979)

As land fraction occupied reach maximum capacity (0.8 or more), the declining capital land multiplier increases. As a result, old capitals are destroyed and some land will be available again. (From Urban Dynamics' model, Forrester 1979).

Desired labor depends on capital and capital labor ratio (Saeed 2010). It represents the total available jobs in the whole business and is computed by adding the multiplication between each type of capital and the capital labor ratio. The capital labor ratio, the ratio of capital to desired labor of the capital, represents the hiring ability of the capital. New Capital is able to hire more labor than the older one. According to Urban Dynamics' model, the ratio of labor required by each type of capital is approximately 2:3:4. In this model, the 2:3:4 ratio is inversed (Saeed, 2010) and scaled to: new capital labor ratio of $\frac{1}{0.16}$ productive units/people, mature capital labor ratio of $\frac{1}{0.11}$ productive units/people, and old capital ratio of $\frac{1}{0.07}$ productive units/people. Note that these numbers are used to adjust the model to equilibrium.

Desired Labor

$$= \frac{\text{New Capital}}{\text{New Capital Labor Ratio}} + \frac{\text{Mature Capital}}{\text{Mature Capital Labor Ratio}} + \frac{\text{Old Capital}}{\text{Old Capital Labor Ratio}}$$

Output Sector

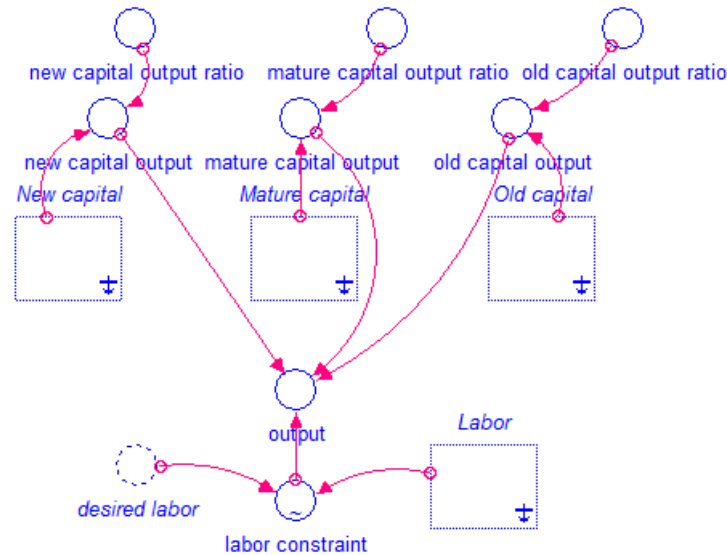


Figure 26: Output Sector

This sector represents the output, which is produced by capital and labor (Saeed 2010). For each type of capital, its output is computed by dividing the number of capital by the output ratio. Based on our assumption, New Capital is capable to produce highest amount of output; its output ratio is 4/3. Mature Capital produces the lesser amount of output; its output ratio is 2. Old Capital produces least amount of output among the others, so its output ratio is 2.5.

$$\text{New Capital Output} = \frac{\text{New Capital}}{\text{New Capital Output Ratio}}$$

$$\text{Mature Capital Output} = \frac{\text{Mature Capital}}{\text{Mature Capital Output Ratio}}$$

$$\text{Old Capital Output} = \frac{\text{Old Capital}}{\text{Old Capital Output Ratio}}$$

In our model, the output is derived by multiplying the Labor Constraint with the sum of New Capital, Mature Capital, and Old Capital.

$$\text{Output} = (\text{New Capital Output} + \text{Mature Capital Output} + \text{Old Capital Output}) \\ * \text{Labor Constraint}$$

Land Sector

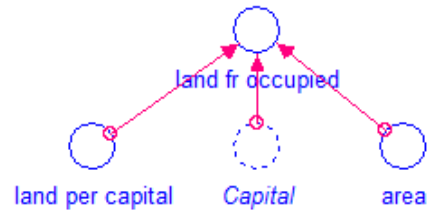


Figure 27: Land Sector

The land sector represents the amount of land available in the city. Land availability is calculated by Land Fraction Occupied, which is one of constraints obstructing the growth in the city.

$$\text{Land Fr Occupied} = \text{Capital} * \text{Land per} \frac{\text{Capital}}{\text{Area}}$$

Flood Simulation

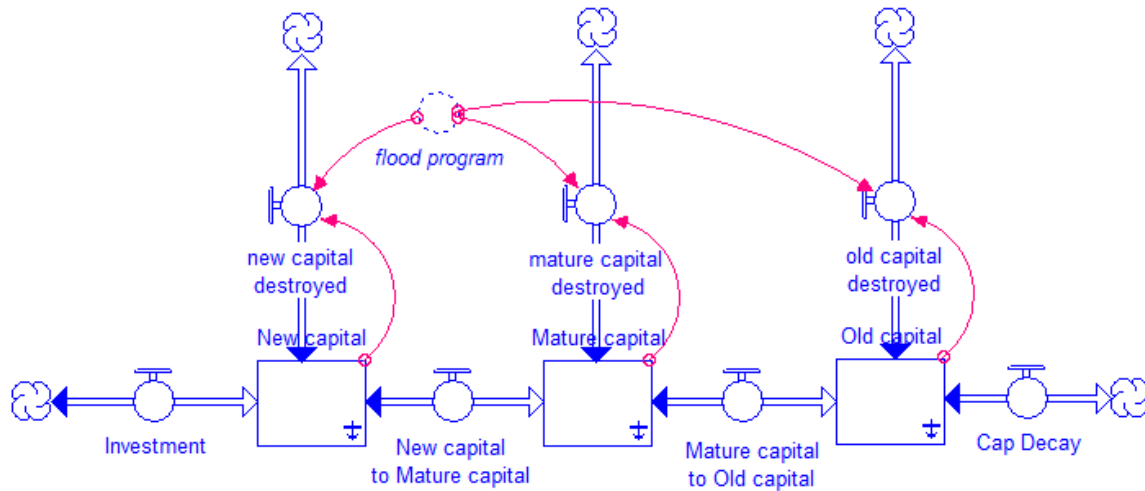


Figure 28: Flood Simulation

The effect of flood is represented in the capital sector, as shown in Figure 28. When flood occurs, every type of capital is permanently destroyed. As a result, flood is represented in the model by using 3 outflows at New Capital, Mature Capital, and Old Capital. The equation of the flood outflows are shown below:

$$\text{New Capital Destroyed} = \text{New Capital} * \text{PULSE}(.3,1,10000)$$

$$\text{Mature Capital Destroyed} = \text{Mature Capital} * \text{PULSE}(.3,1,10000)$$

$$\text{Old Capital Destroyed} = \text{Old Capital} * \text{PULSE}(.3,1,10000)$$

The pulse function indicated that 30 percent of each capital is destroyed; therefore, the higher the capital, the more it is destroyed.

Policies

In this sector we will analyze policies that might fasten the economic alleviation. These policies are based on both literature and Thai government's policies.

New Capital Construction Policy

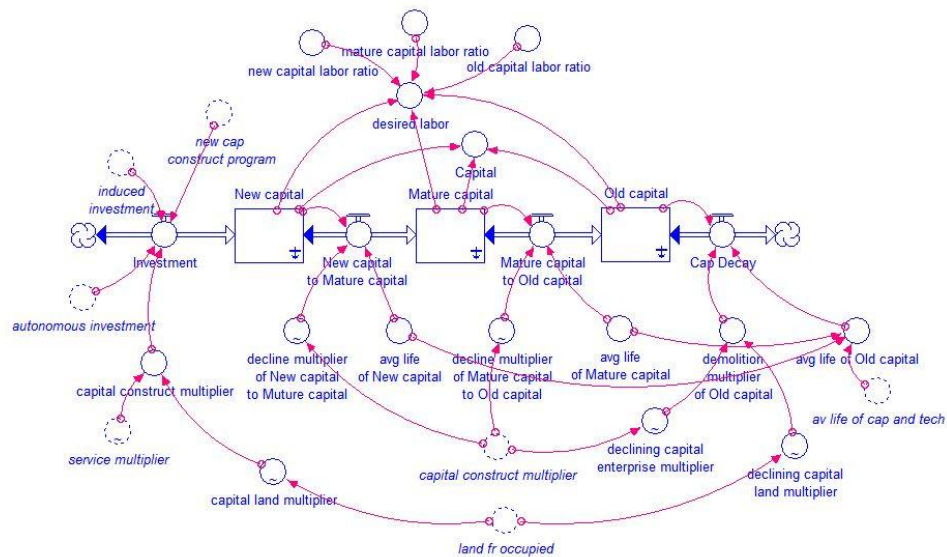


Figure 29: Increase Interest Rate Policy (NCCP)

This policy aims to increase new capitals by increasing government's investment. In the model, the policy is implemented by increasing the inflow of the New Capital by 12%

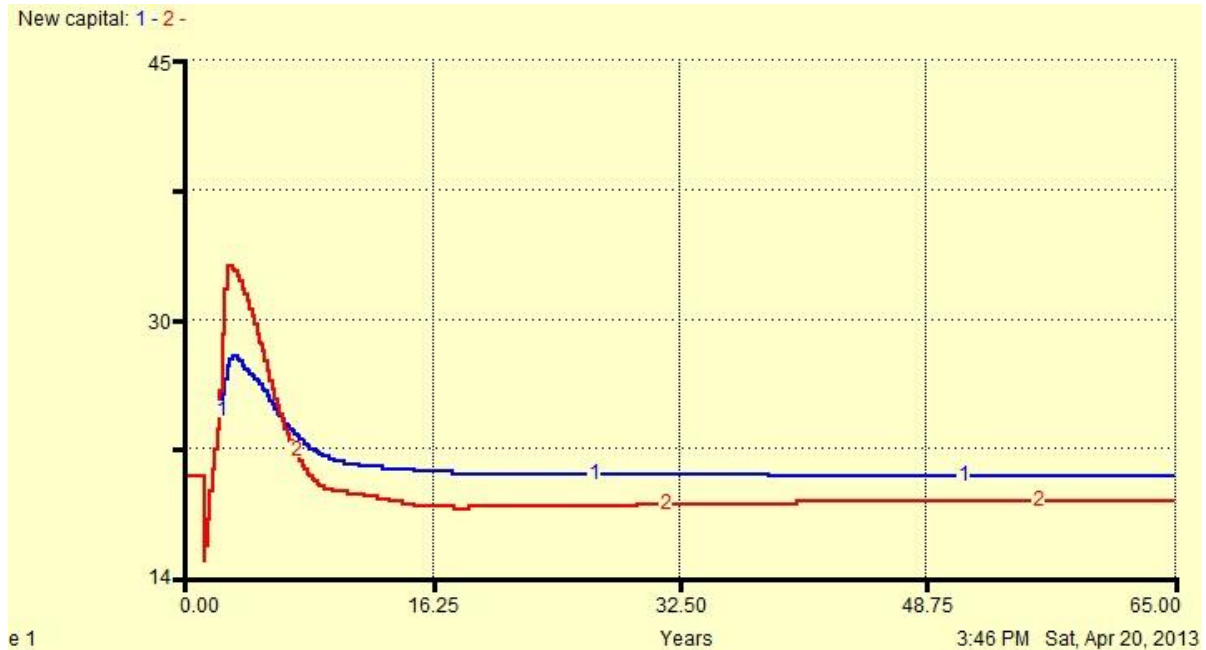


Figure 30: New Capital (NCCP)

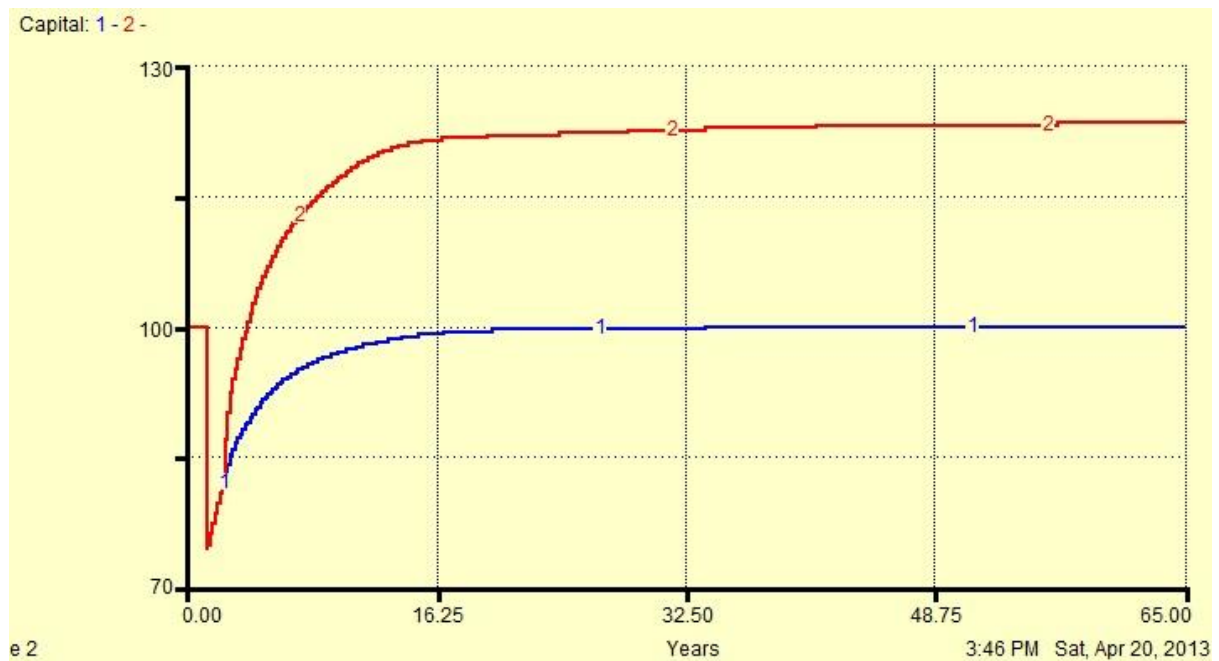


Figure 31: Total Capital (NCCP)

Figure 31 shows that, by implementing this policy, Total Capital increases from line 1 to line 2. The total amount of capital increases because of the higher capital inflow. Yet, Figure 30 shows that New Capital decreases. An increase of capital inflow causes a rapid growth of New

Capital (Figure 30 line 2), however, soon land becomes full thus limiting the growth. As a result, the New Capital overshoot then decreases more than the normal recovery (Figure 30 line 1). Since the age of Old Capital is much longer than New Capital's, more fraction of land is occupied by Old Capital instead of being available for New Capital construction.

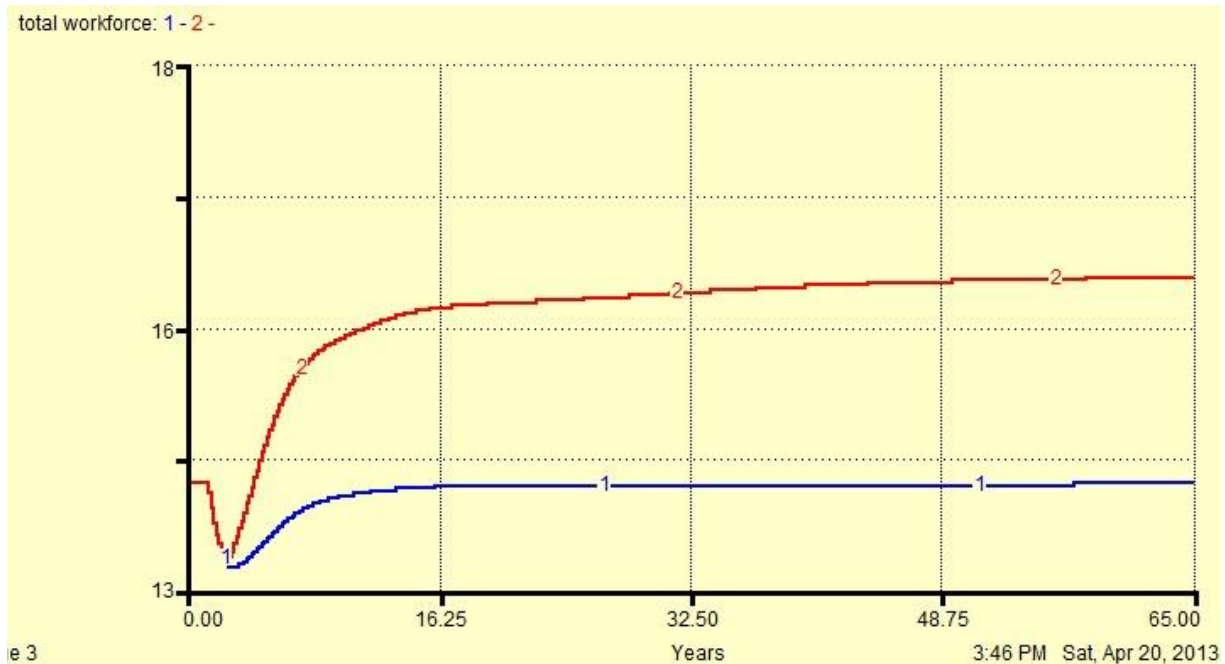


Figure 32: Total Workforce (NCCP)

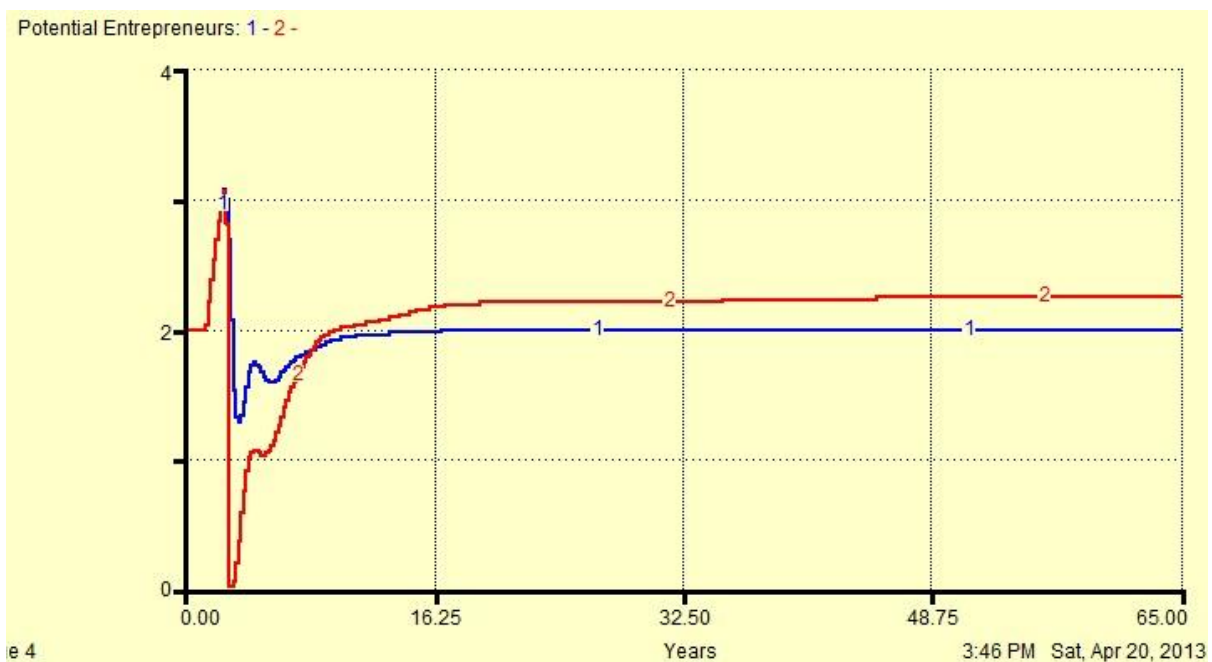


Figure 33: Potential Entrepreneurs (NCCP)

Comparing line1 and line2 of the Figure 33, more people move into the city since an increase of Total Capital creates more jobs. In addition, entrepreneurs also increase proportionately (diagram 3).

In conclusion, this policy improves the economy of the city by increasing the amount of capital; therefore, create more jobs for both its citizens and immigrants. However, most fraction of the land is occupied by old capital instead of new capital, which has more productivity.

Decrease Interest Rate Policy

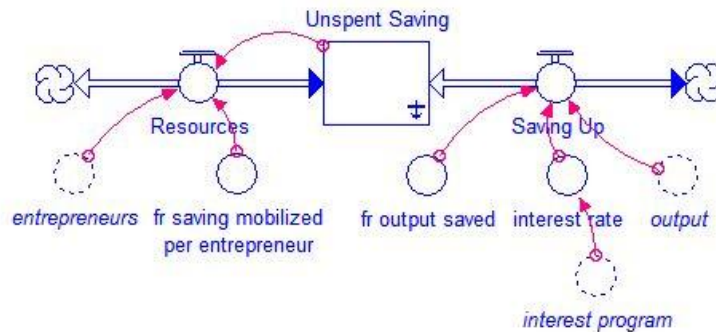


Figure 34: Decrease Interest Rate Policy (DIRP)

The objective of this policy is to speed up the economic recovery by encouraging potential entrepreneurs to construct more new capital infrastructures. By decreasing interest rate, saving money in the bank becomes less attractive. On the other hand, taking investment loan will be more attractive. As a result, it is easier for potential entrepreneurs to construct new capital infrastructures. This policy can be implemented in the model by changing the value of interest rate parameter. Our policy will decrease interest rate from originally 10% to 5%.

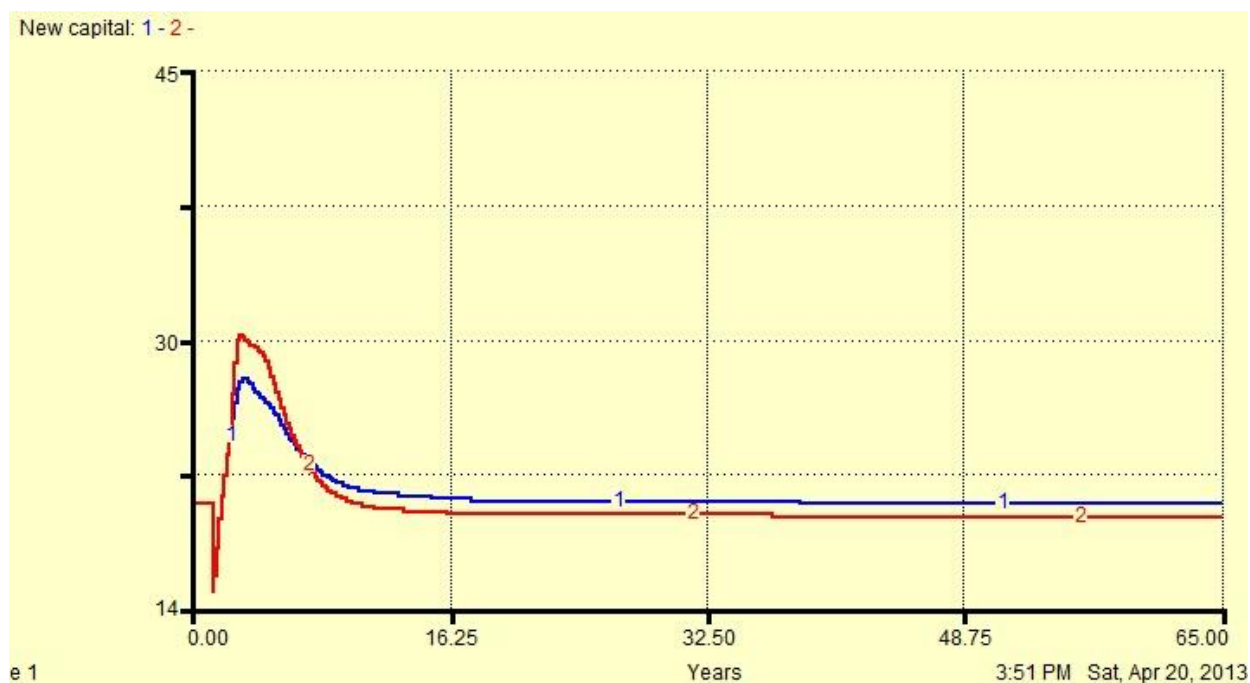


Figure 35: New Capital (DIRP)

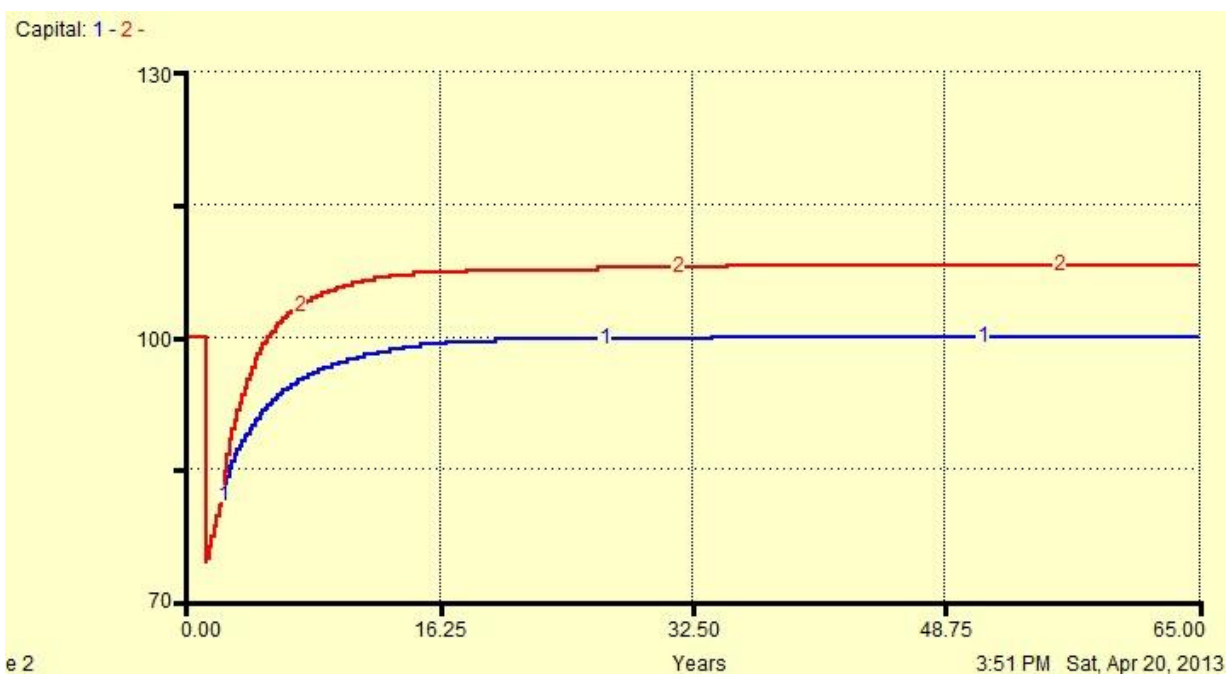


Figure 36: Total Capital (DIRP)

Comparing between line 1 and line 2, Figure 36 shows that Total Capital increases. Decreasing the interest rate will create incentive for entrepreneurs to invest money in capital infrastructure construction rather than saving. However, Figure 35 shows that New Capital decreases. Since entrepreneurs invest more money constructing capital infrastructures, the

amount of New Capital go up rapidly (Figure 35 line 2). Soon, land becomes full and limits the growth. As a result, New Capital overshoots then decrease to lower than the normal recovery's – without applying this policy. Similar to previous policy (Figure 35 line 1), the age of Old Capital is much longer than New Capital; therefore, more land fraction is occupied by Old Capital instead of being available for New Capital construction.

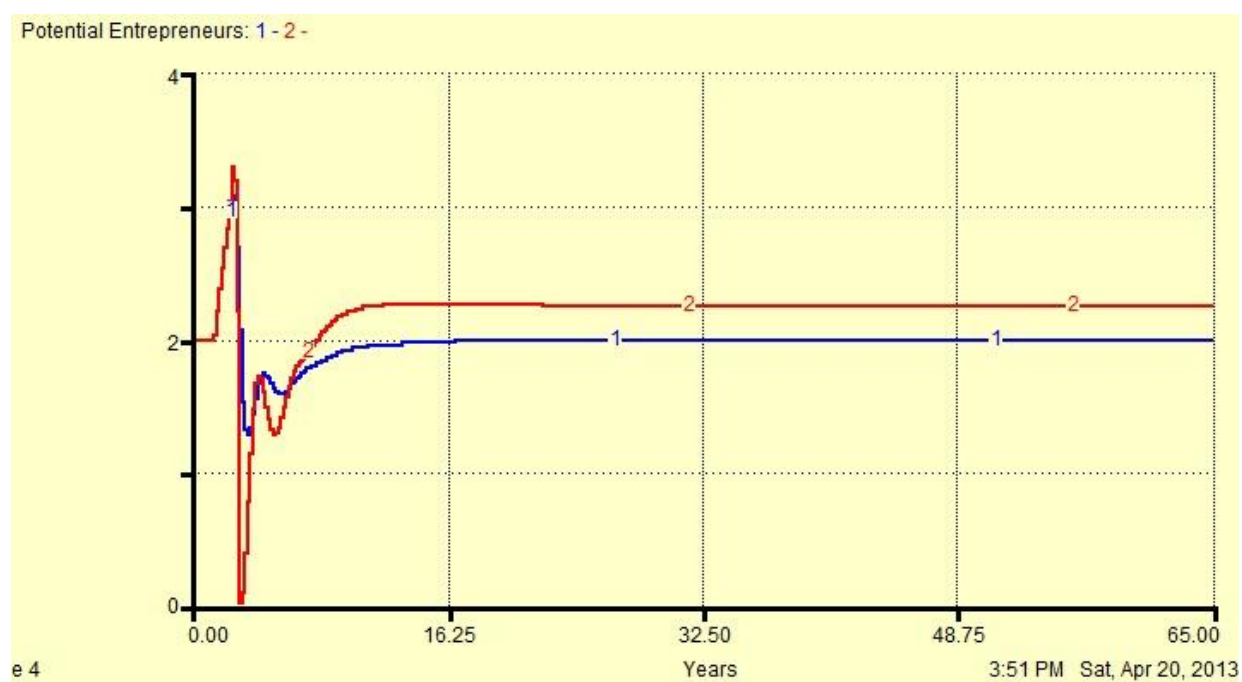


Figure 37: Potential Entrepreneurs (DIRP)

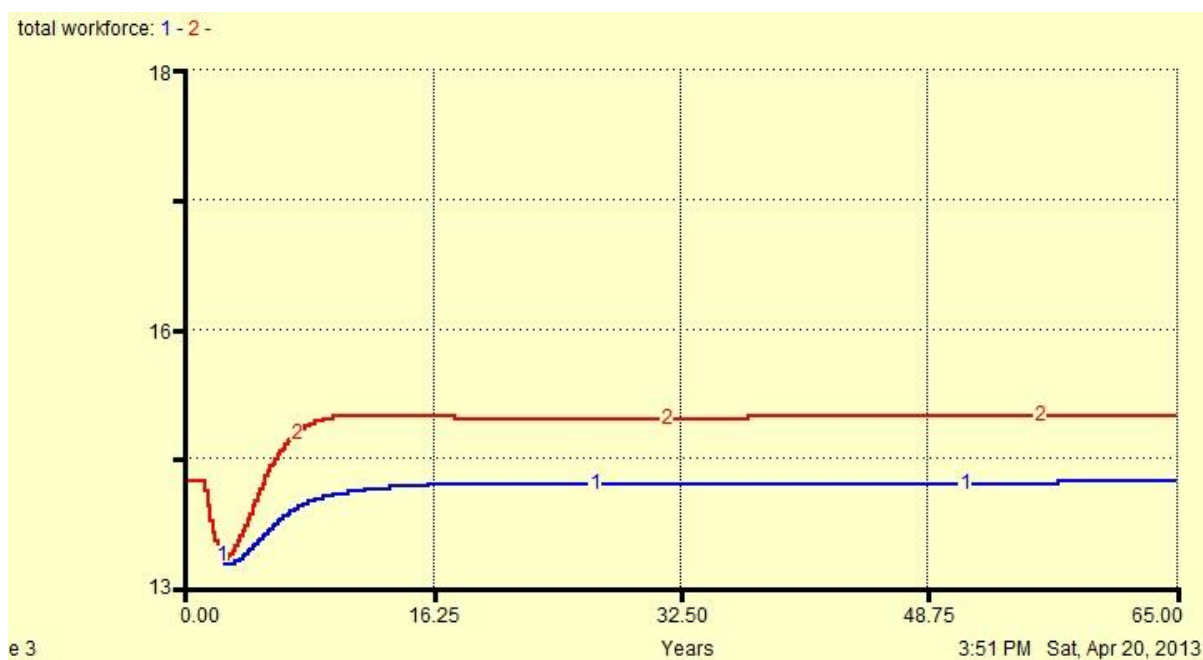


Figure 38: Total Workforce (DIRP)

Comparing between line1 and line2 of Figure 38, more people move into the city because more jobs become available from an increase of capital. Entrepreneurs also increase proportionately (Figure 38).

In conclusion, this policy improves the economy of the city by giving an incentive for people to become entrepreneurs and construct more capital infrastructures. An increase of capital will create more jobs – creating incentive for people to move into the city. However, most fraction of the land is occupied by old capital instead of new capital, which have more productivity. Bank of Thailand can implement this policy by announcing a decrease of national interest rate.

Import Technology Policy

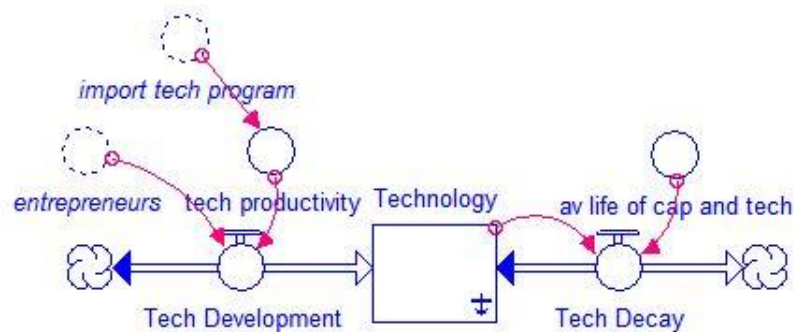


Figure 39: Import Technology Policy (ITP)

This policy encourages potential entrepreneurs to import new technology from outside the country. The goal of this policy is to allow new technology to facilitate construction of new capital infrastructures. In this model, the policy will be implemented by increasing the Tech Productivity from 5 to 6.

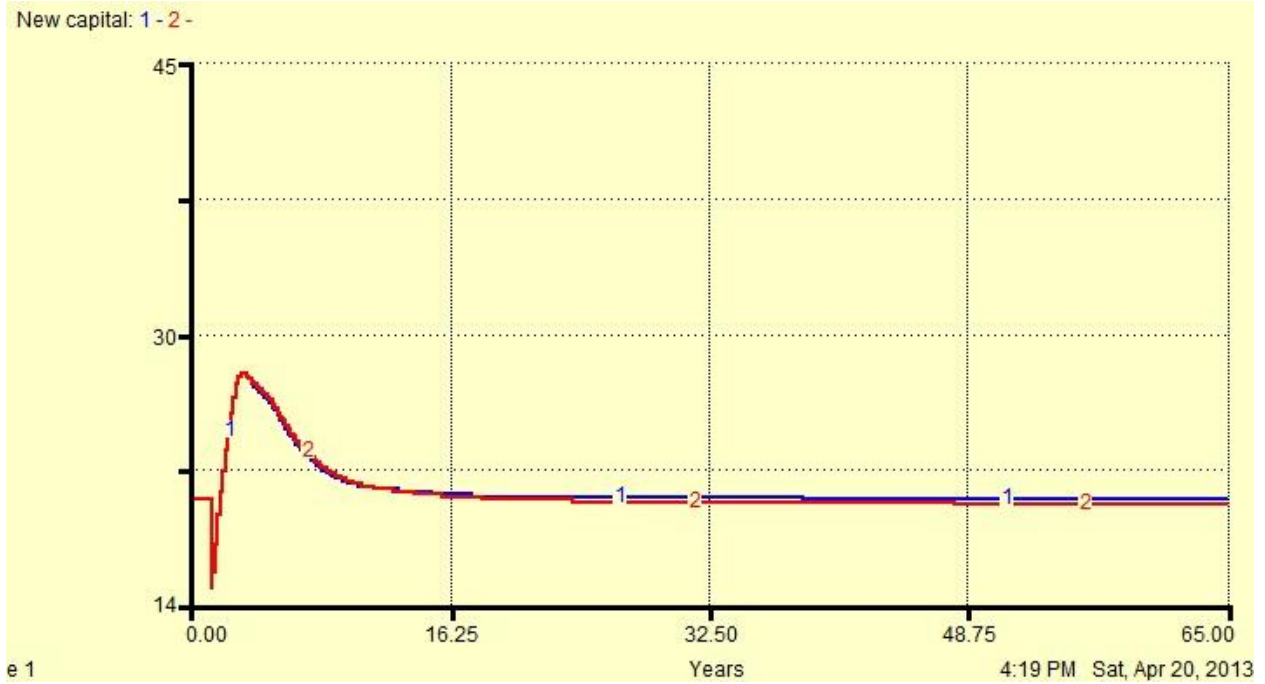


Figure 40: New Capital (ITP)

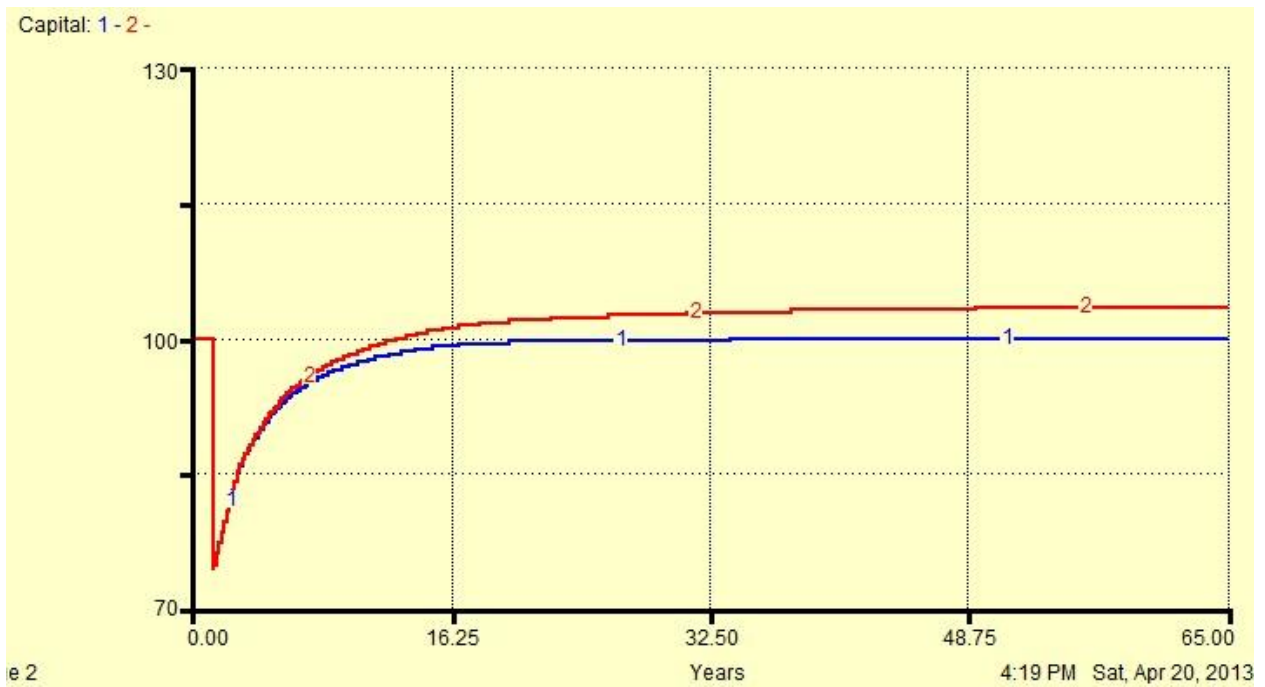


Figure 41: Total Capital (ITP)

On the Figure 41, comparing line 1 (without policy) to line 2 (with import technology policy), Total Capital is a little higher; however, the New Capital (Figure 40) is a little lower.

Note that an increase of technology barely affects the inflow of the new capital. Since the autonomous investment is defined as "Resources^{0.5} * $\left(\frac{\text{Technology}}{10}\right)^{0.5}$ - Saving Up" (Saeed, 2010), increasing Tech Productivity by 20% will not increase the Autonomous Investment by 20% but only less than 10% (from 1 to 1.20^{0.5}).

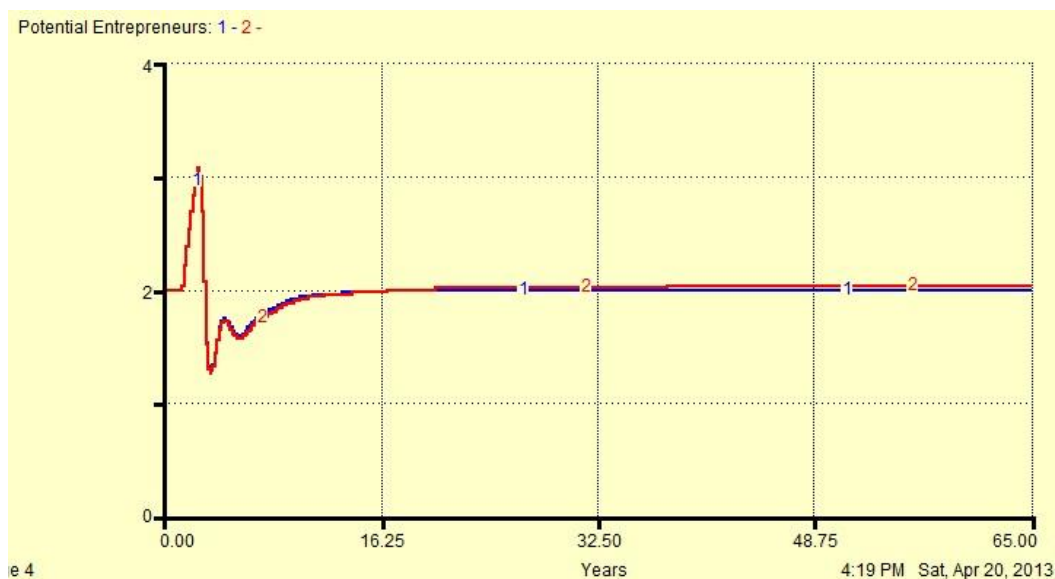


Figure 42: Potential Entrepreneurs (ITP)

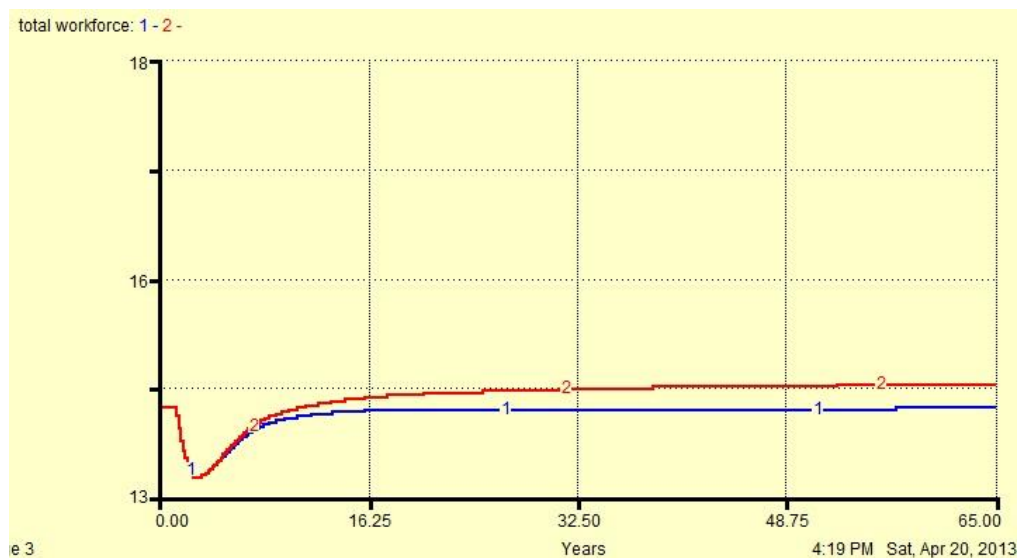


Figure 43: Total Workforce (ITP)

Figure 42 and Figure 43 show that the number of entrepreneurs and total workforce only increase by a small amount. The increase of capital, even small amount, leads to a small increase of jobs available; therefore more people moves into the city. As a result, entrepreneurs also increase proportionally.

The government can implement import-technology policy by encouraging private companies to import technology from foreign countries. However, since this policy only improves the economy by a small amount, it might not be effective for the government to implement.

Service Supply Policy

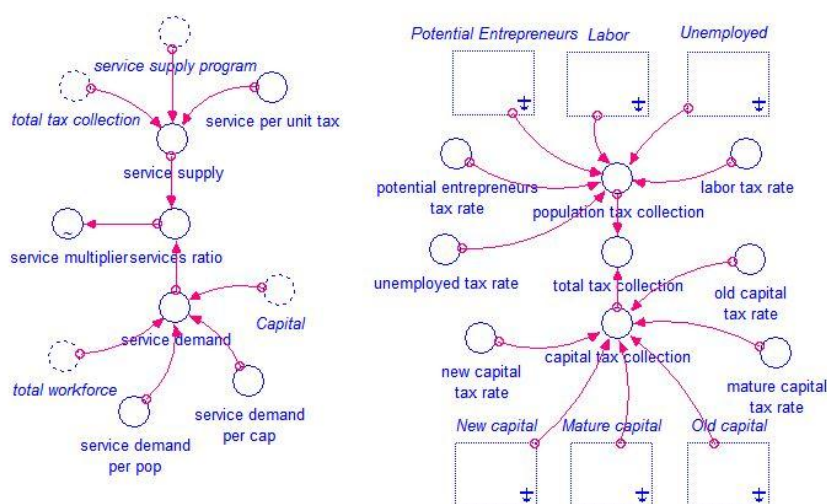


Figure 44: Service Supply Policy (SSP)

The service-supply policy is implemented in the model by directly adding a step function “step(0.1,2)” to increase the Service Supply parameter. By increasing the Service Supply, the Service Multiplier will also raise. The increased Service Multiplier will then increase the Climate Factor, Capital Construction Multiplier, and Workforce Growth Fraction. Therefore, increasing service supply is expected to provide incentive for people to become entrepreneurs, encourage capital construction, and allow the city to expand. Yet, the result after applying the service-supply policy is not as effective as we expected.

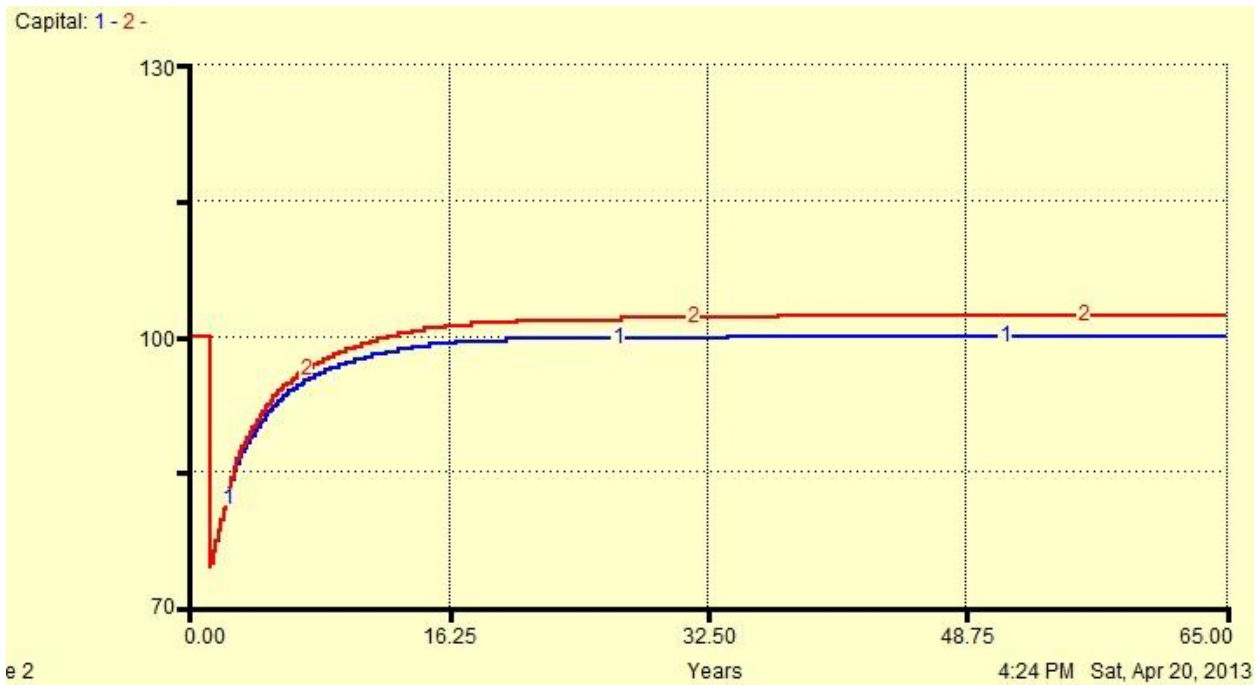


Figure 45: Total Capital (SSP)

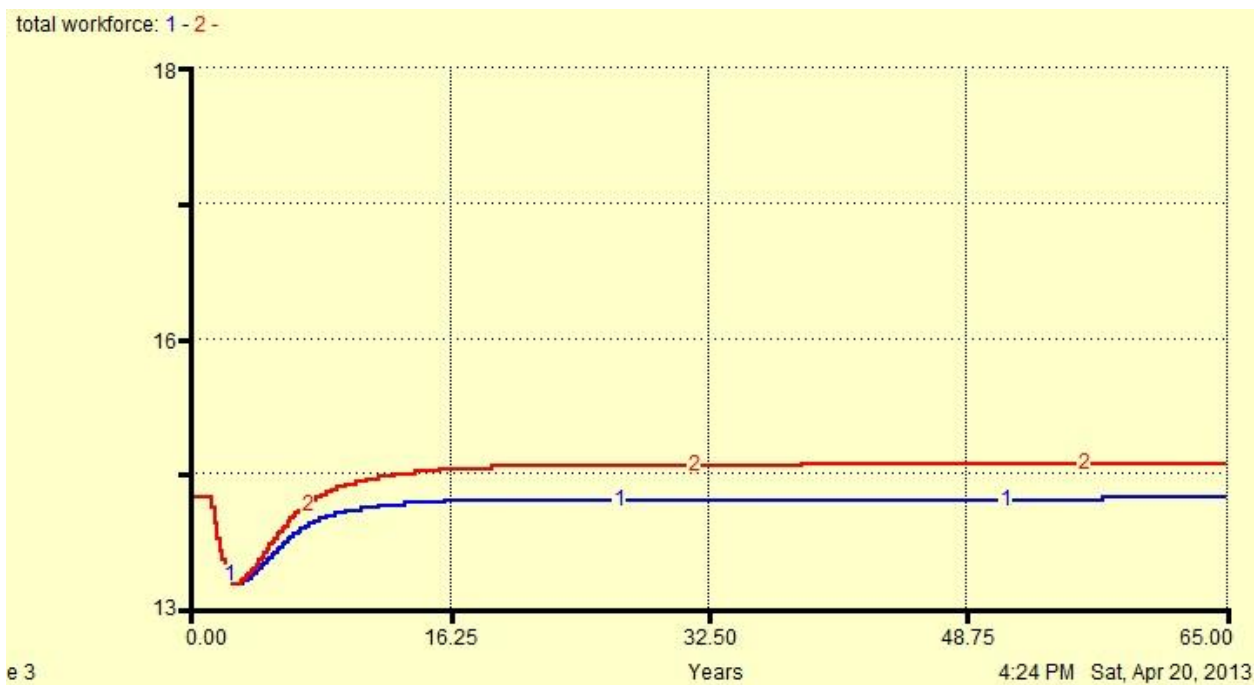


Figure 46: Total Workforce (SSP)

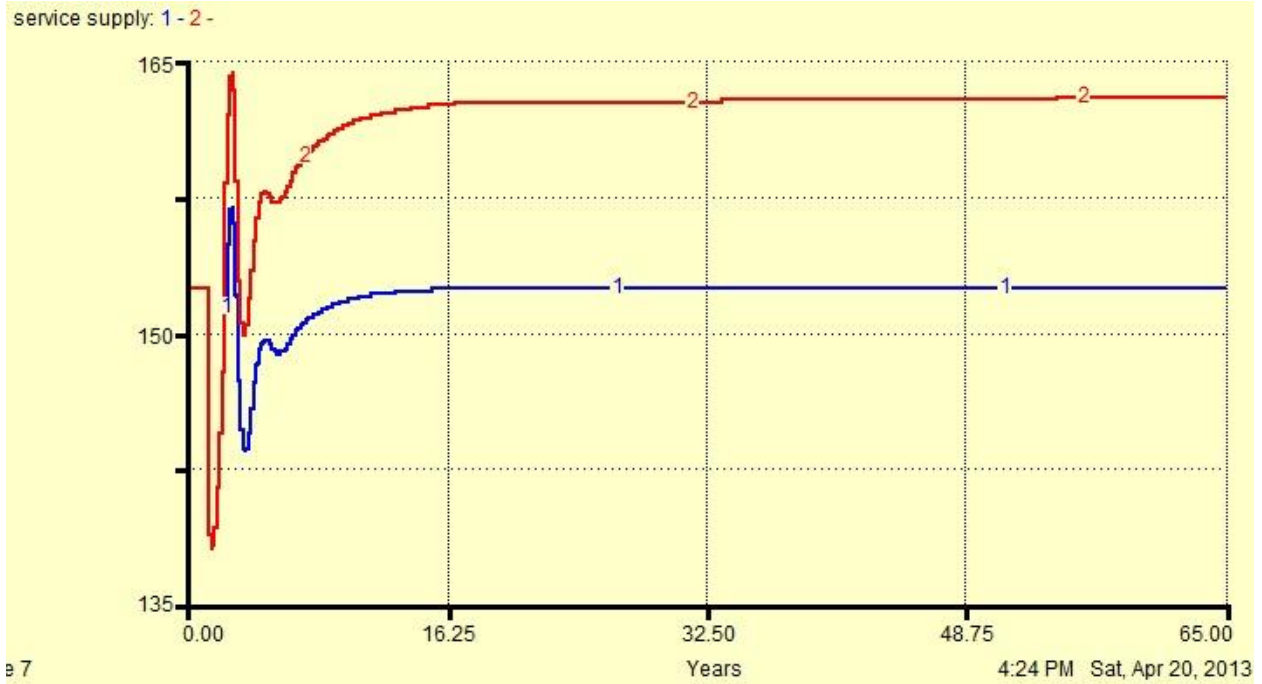


Figure 47: Service Supply (SSP)

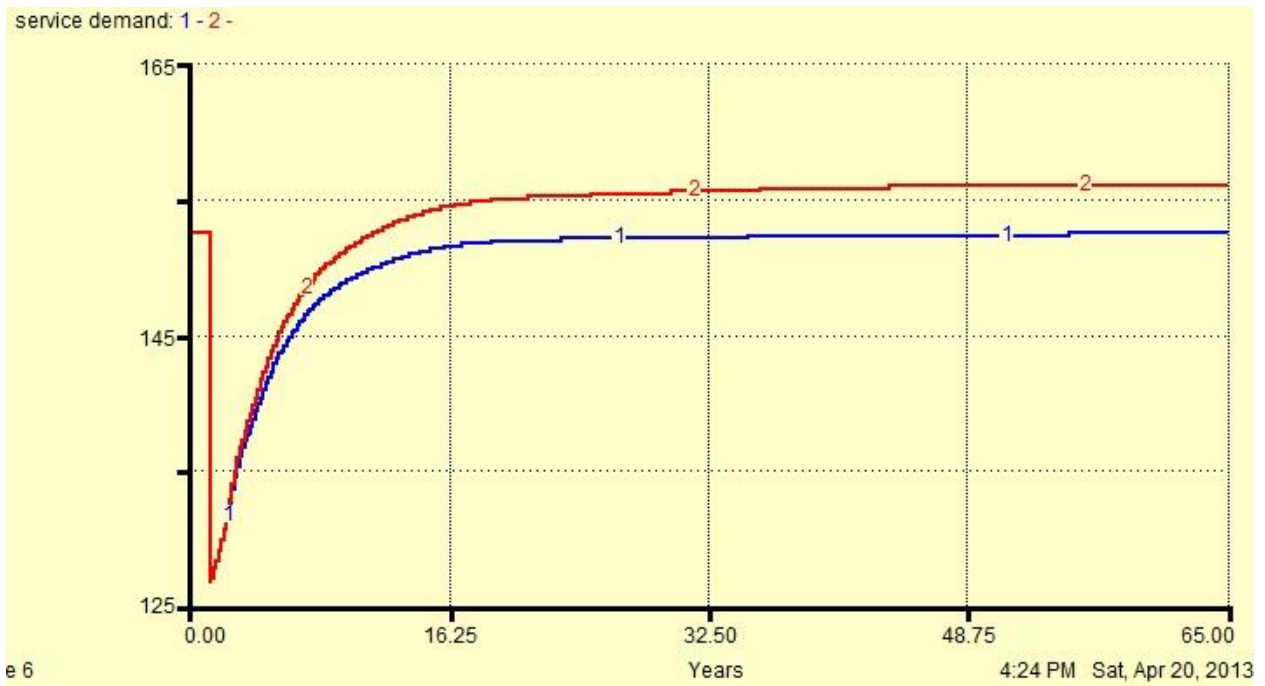


Figure 48: Service Demand (SSP)

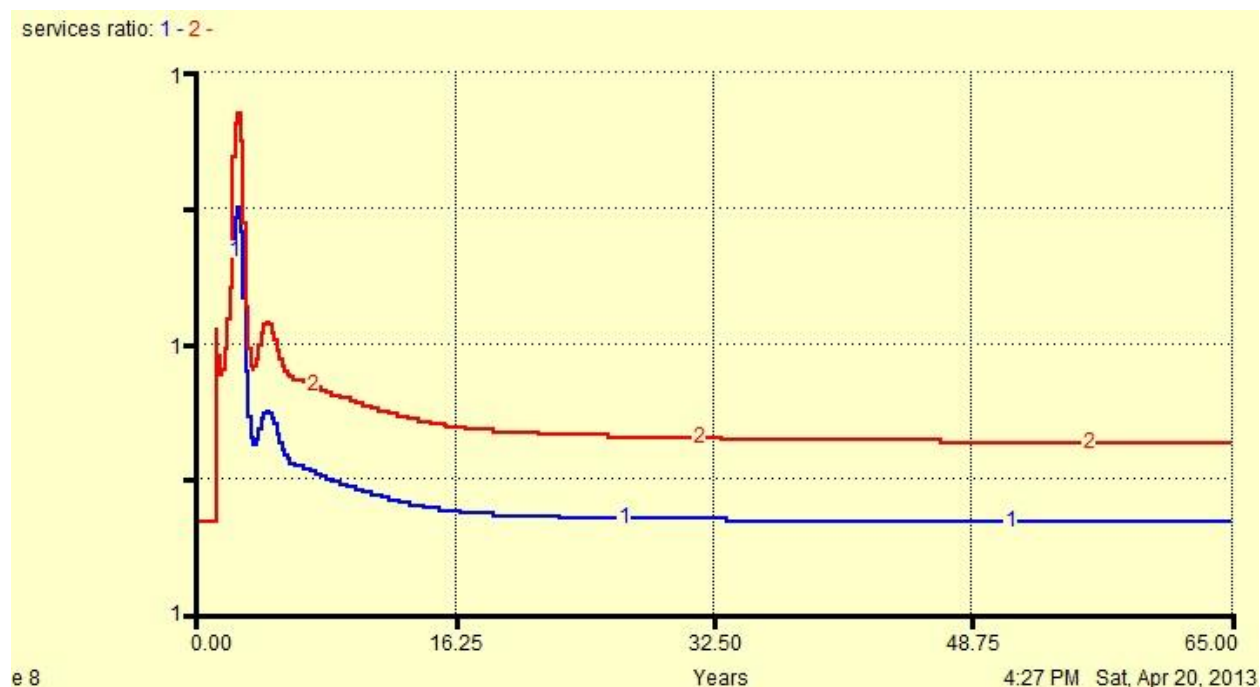


Figure 49: Services Ratio (SSP)

As shown in Figure 45 and 46, the service-supply policy results in a slight increase of the capital and workforce. At first, the service ratio significantly increases (Figure 49) due to an increase of Service Supply (Figure 47). However, as the time passes, the raise in workforce and capital will increase the Service Demand (Figure 48); therefore, minifies the increasing rate of the Service Ratio. Eventually, the Service Ratio will return to nearly one. As a result, the service-supply policy can only support the economic growth for a short amount of time.

In reality, the government can only implement this policy in short run due to limited budget. If the government is to implement this policy in long run, it would constantly require more money to maintain the constructed service supply. As a result, this policy is not sustainable, especially for Thai government.

Training Program Policy

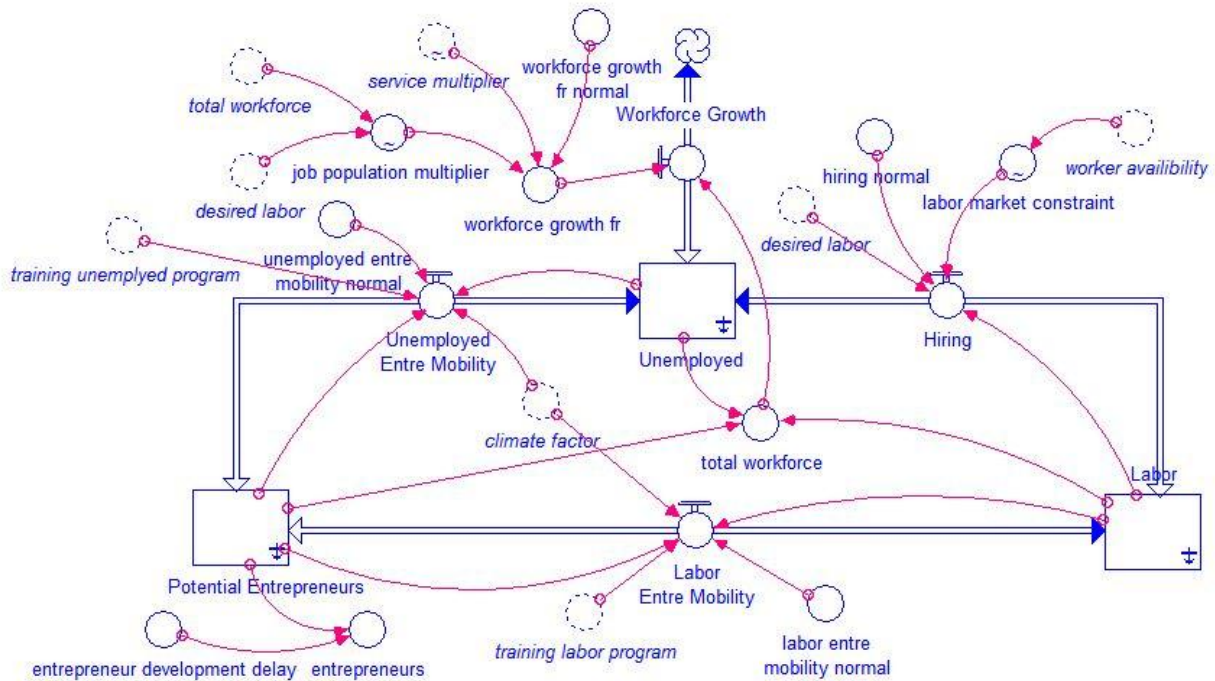


Figure 50: Training Program Policy (TPP)

The training program policies are implemented in order to encourage more people to become entrepreneurs. By having more entrepreneurs, more capital will be built and therefore fasten the recovery from the flood. The training program policies can be categorized in two categories: Labor Training Program and Unemployed Training Program. Both programs are represented in the model by directly increasing the Labor Entre Mobility and Unemployed Entre Mobility respectively.

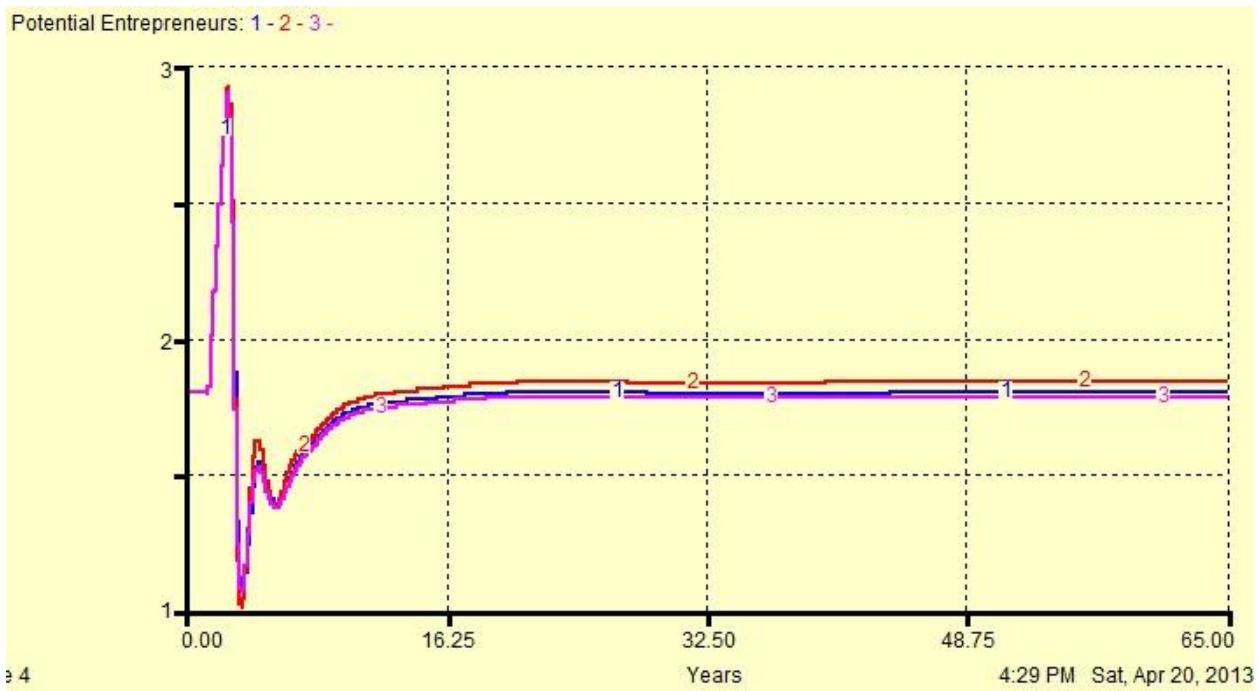


Figure 51: Potential Entrepreneurs (TPP)

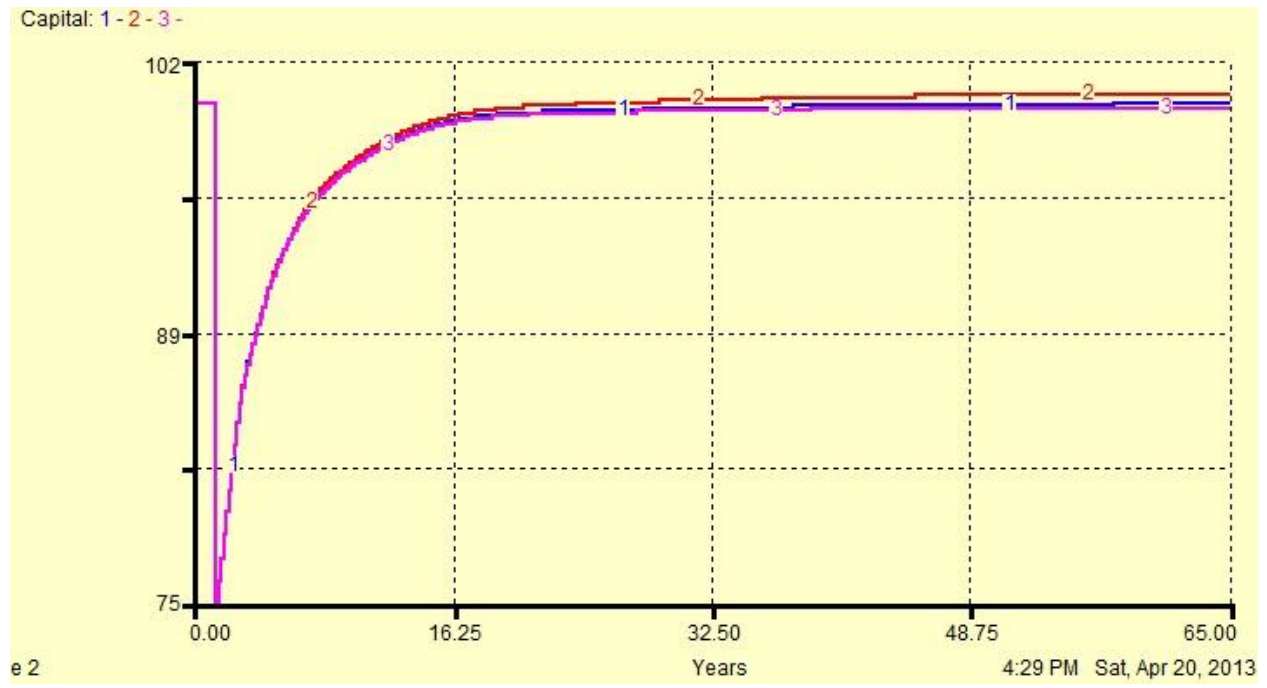


Figure 52: Total Capital (TTP)

The result shows that implementing the labor training program will slightly fasten the recovery. The number of entrepreneurs and capitals will also increase, as shown in line 2 of Figure 51 and 52. When labor is trained, more labors will become entrepreneurs; therefore

increase capital. In addition, the existing labor jobs will be freed. This will allow Unemployed to become Labor.

However, by implementing unemployed training program, the result (line 3) shows that the number of entrepreneurs and capital slightly decreases. This program has an opposite effect as intended. When unemployed training program is implemented, more Unemployed will initially become Potential Entrepreneurs. This will create an overshoot in Potential Entrepreneurs; therefore, a lot of Potential Entrepreneurs will exit the market. However, since the Potential Entrepreneurs are skilled individuals, they become Labor instead of Unemployed. The Worker Availability (ratio of Unemployed over Labor) will go down, resulting in an increase in Wage Rate which in return leads to a decrease in Climate Factor. As a result, entrepreneurs and capital will decrease respectively.

As shown in Figure 51 and 52, both training programs result in only a small change in entrepreneurs and capitals. This is because Potential Entrepreneurs, Labor and Unemployed are linked by flows. When the training program policy disturbs one of the flows, the other two flows change accordingly to adjust the model to initial equilibrium. It can be concluded that both training programs are not effective.

The unemployed training program was implemented by Thai government in 2009. The program called “Ton Kla Archeap” was designed to train unskilled-unemployed people. Three hundred million dollars was invested in the program to train approximately 400,000 people (Thairath, 2009). The program was discontinued in 2010 since the result of the program was not as successful as anticipated. The money invested in the program was too high while the program only helped a small group of people.

According to our model, the labor training program will be slightly better than the unemployed training program. However, it is also not as effective compared to the money that needed to be invested. In addition, the concept of implementing a labor training program is not very feasible. The government will not be able to justify training skilled labor while unemployed worker still exists.

Increase Wage Rate Policy

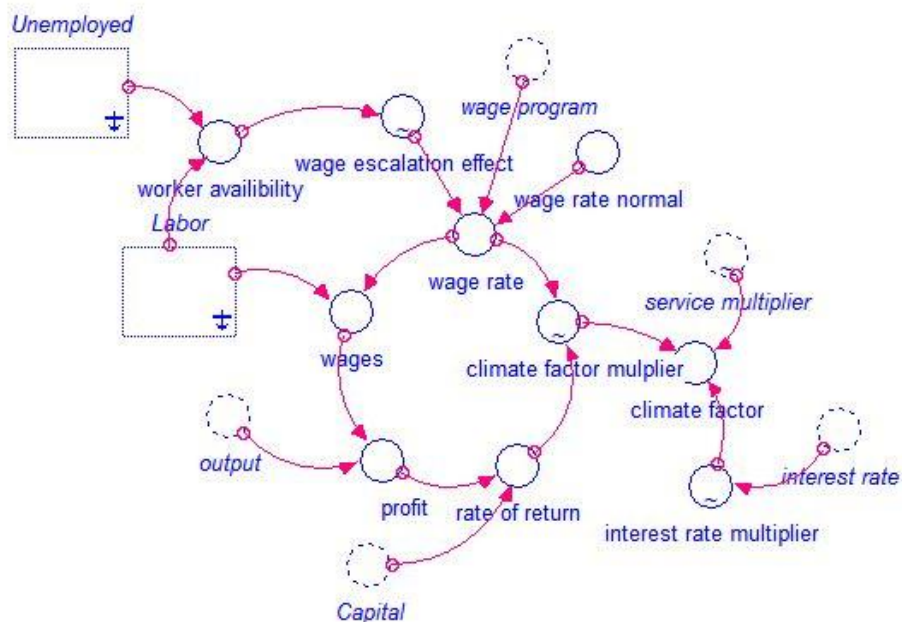


Figure 53: Increase Wage Rate Policy (IWRP)

The increase wage rate policy is intended to stimulate the economy by increasing the money supply – the household income. In addition, by increasing workers’ wage rate, they will have more money to rebuild their properties. This policy is implemented by adding step function “step(1, 2)” at the Wage Rate parameter.

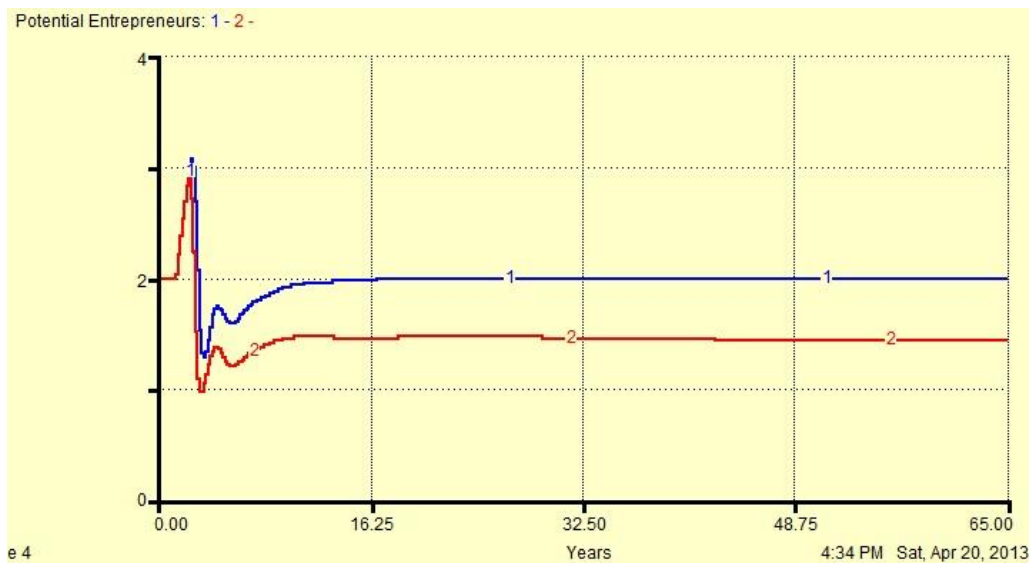


Figure 54: Potential Entrepreneurs (IWRP)

Labor: 1 - 2 -

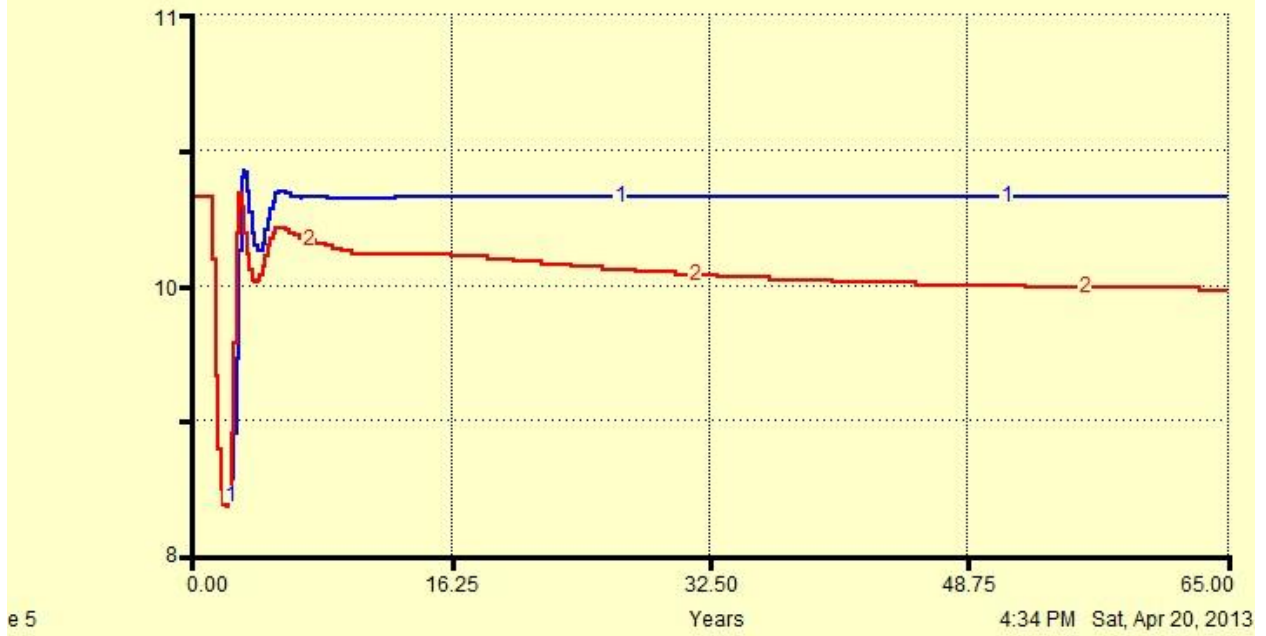


Figure 55: Labor (IWRP)

Unemployed: 1 - 2 -

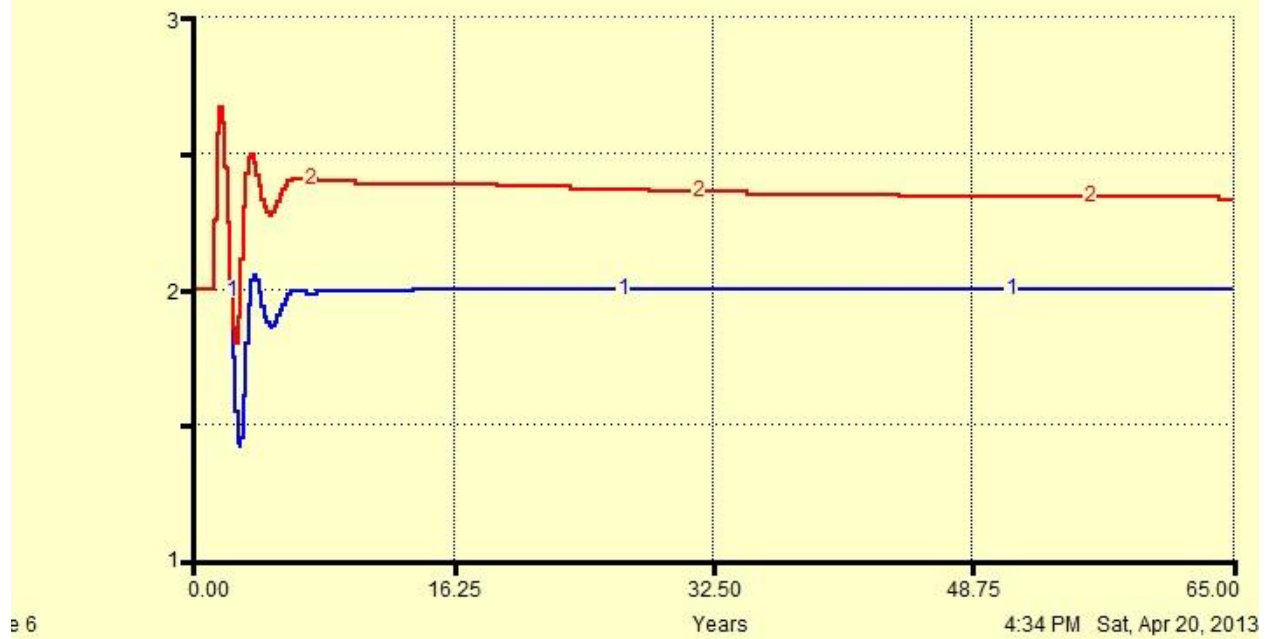


Figure 56: Unemployed (IWRP)

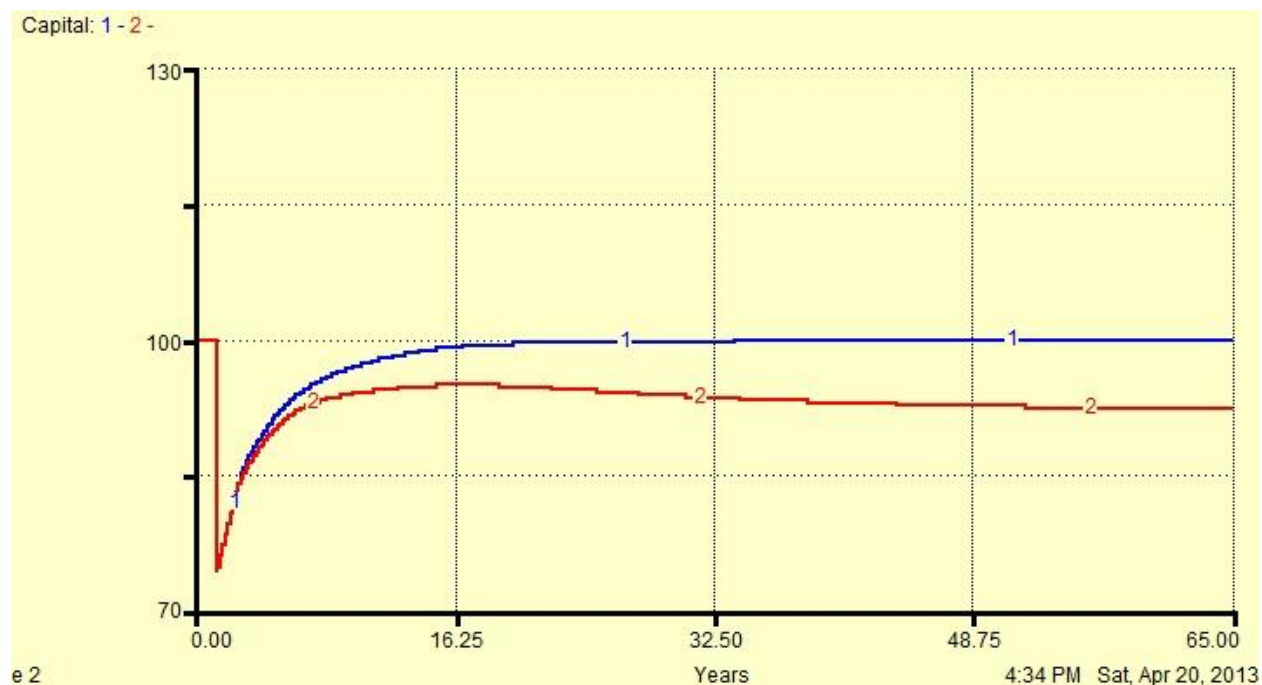


Figure 57: Total Capital (IWRP)

The outcome of this policy is not as intended. Table 6 shows that the numbers of entrepreneurs (Figure 54), labors (Figure 55), and capital decrease while the number of unemployed (Figure 56) increases significantly. With an increase in Wage Rate, the Climate Factor will go down. As a result Potential Entrepreneurs will decrease which lead to a decrease in capital (Figure 57).

Thai government implemented the increase wage rate policy in 2012. The policy intended to help individuals with low income. However, the policy was not as successful as expected. By increasing Wage Rate, a large amount of labors was laid off since the business owners (entrepreneurs) were not able to afford hiring the same amount of workers. Not long after the laid off, a lot of business – especially small businesses – were closed down (Matichon, 2013). The result of this policy is the same as the prediction from our model. It is likely that capital will continue to decrease and more people will be unemployed until the government discontinues the policy.

Old Capital Demolition Policy

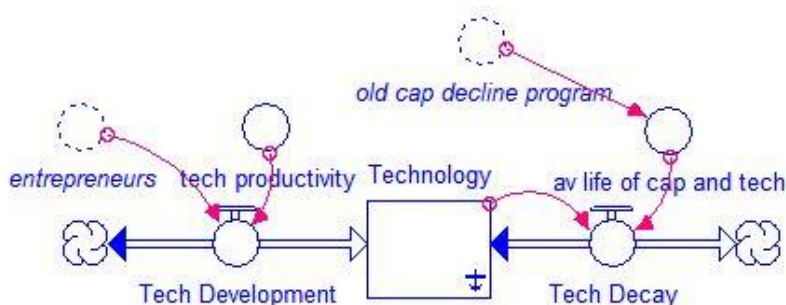


Figure 58: Old Capital Demolition Policy (OCDP)

From previous section, we found that New Capital Construction Policy and Decrease Interest Rate Policy were effective alleviation policies. However, we also found that, for both policies, the level of New Capital is low compared to the Old Capital. Therefore, we decide to free up the occupied land by destroying Old Capitals, hence simulating Proactive Creative Destruction. In this sector we will illustrate the result of pairing Old Capital Demolition Policy with New Capital Construction Policy and Decrease Interest Rate Policy.

The old capital demolition policy is implemented in the model by decreasing the Average Life of Capital and Technology by 2, from 10 to 8 years.

Combine decrease interest policy with capital demolition policy

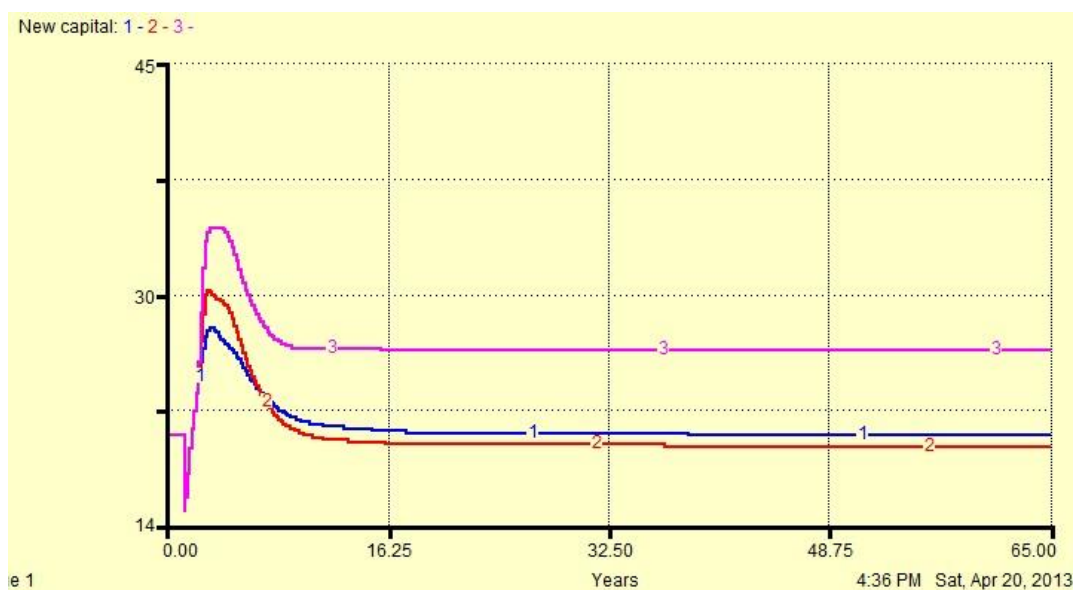


Figure 59: New Capital (DIRP&CDP)

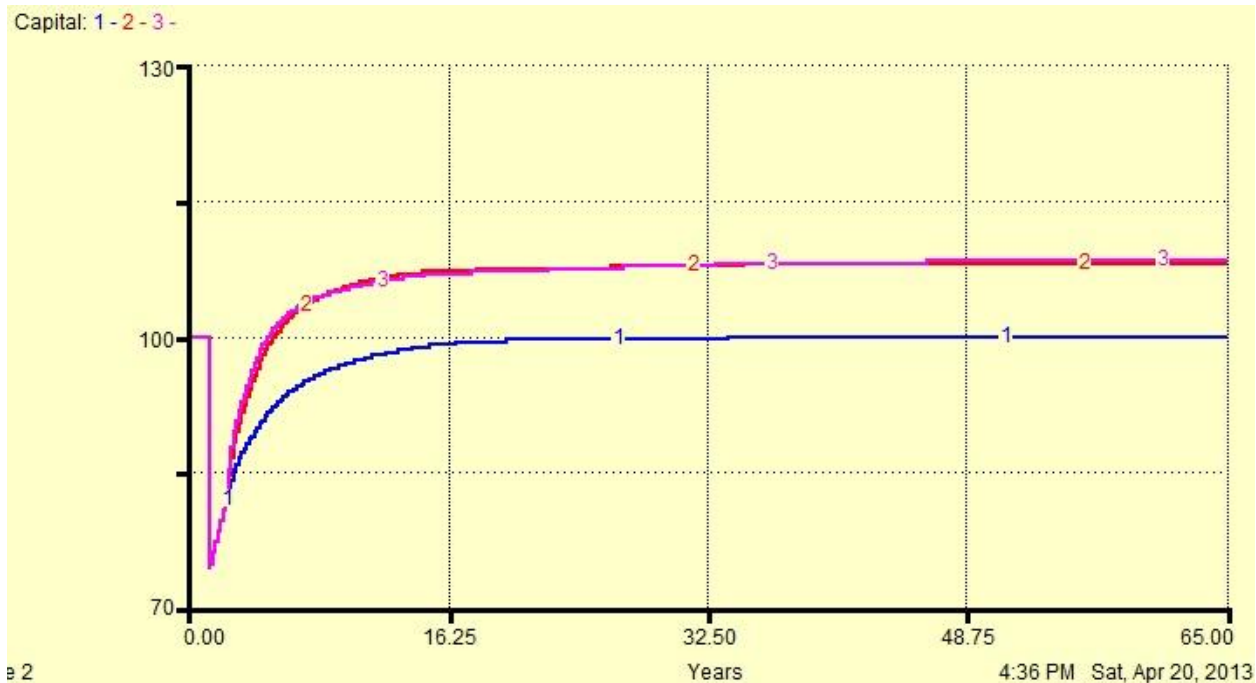


Figure 60: Total Capital (DIRP&CDP)

Comparing line 2 and line 3, the combined policy (line 3) increases the level of new capital (Figure 59), whereas the level of total capital remains almost the same (Figure 60). By decreasing the average life of capital and technology, the outflow of old capital increases; therefore, more fraction of land will be available for constructing new capital infrastructures.

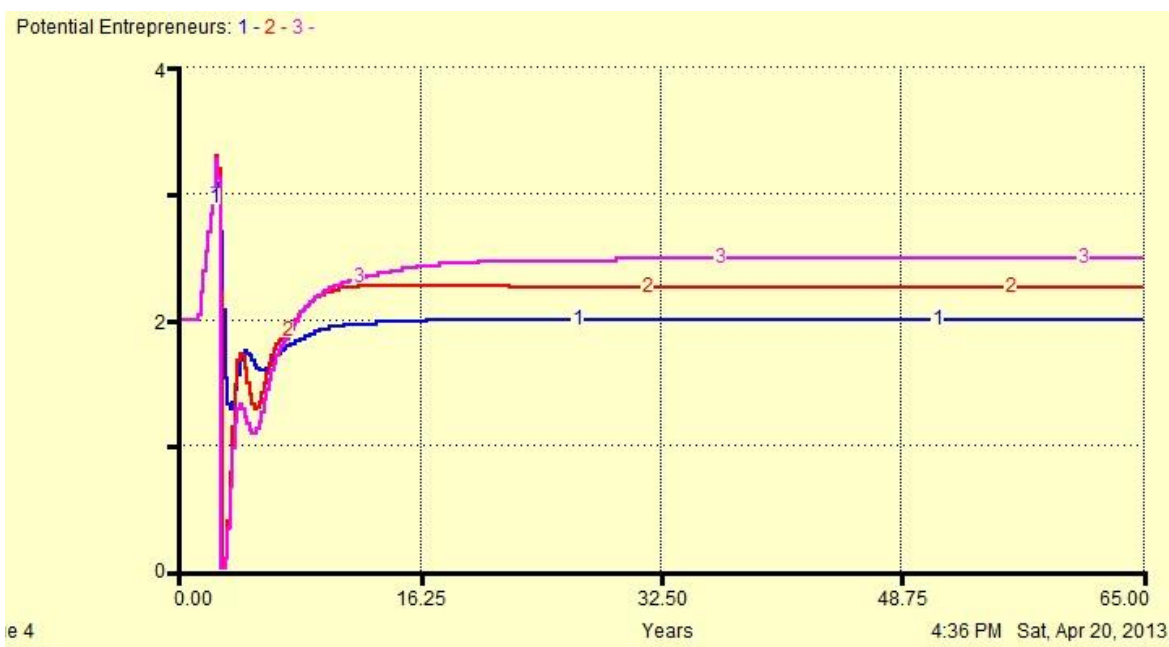


Figure 61: Potential Entrepreneurs (DIRP&CDP)

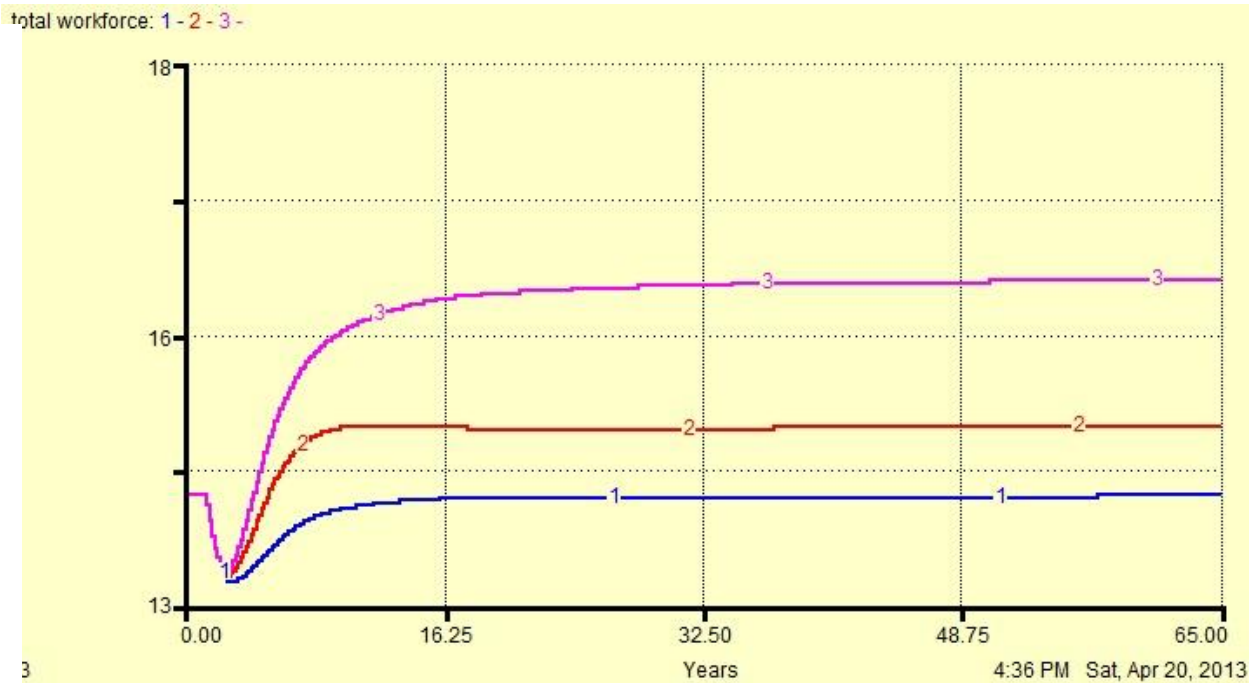


Figure 62: Total Workforce (DIRP&CDP)

According to Figure 61 and Figure 62, the level of workforce and entrepreneurs also increase from line 2 to line 3. This is because, even though the amount of total capital is the same, new capital creates more jobs than old capital. More people will move into the city, meaning entrepreneurs will also increase proportionally.

Combine new capital construction policy with old capital demolition policy

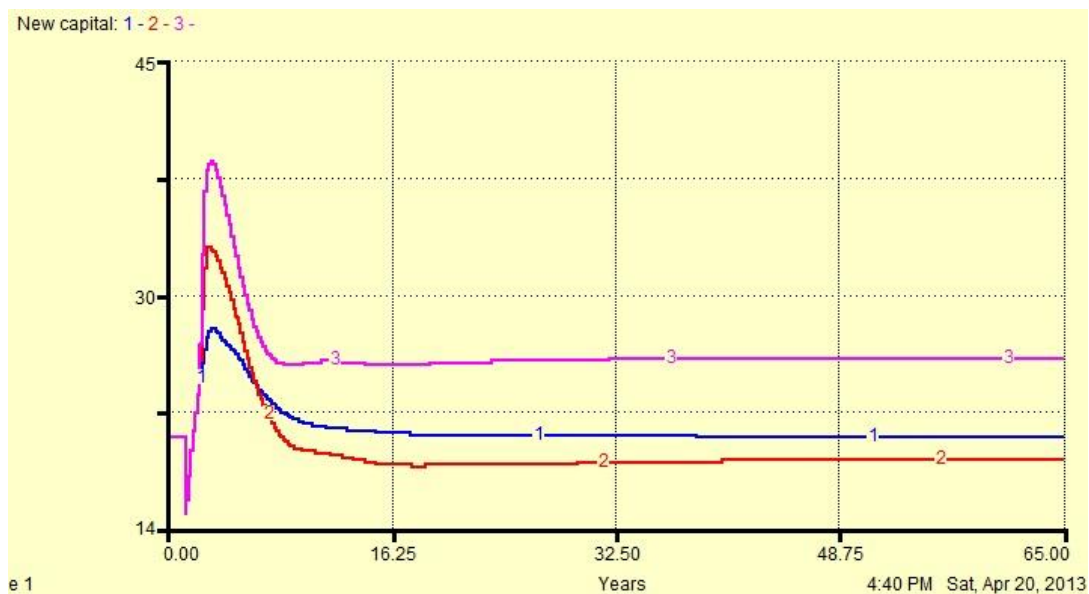


Figure 63: New Capital (NCCP&CDP)

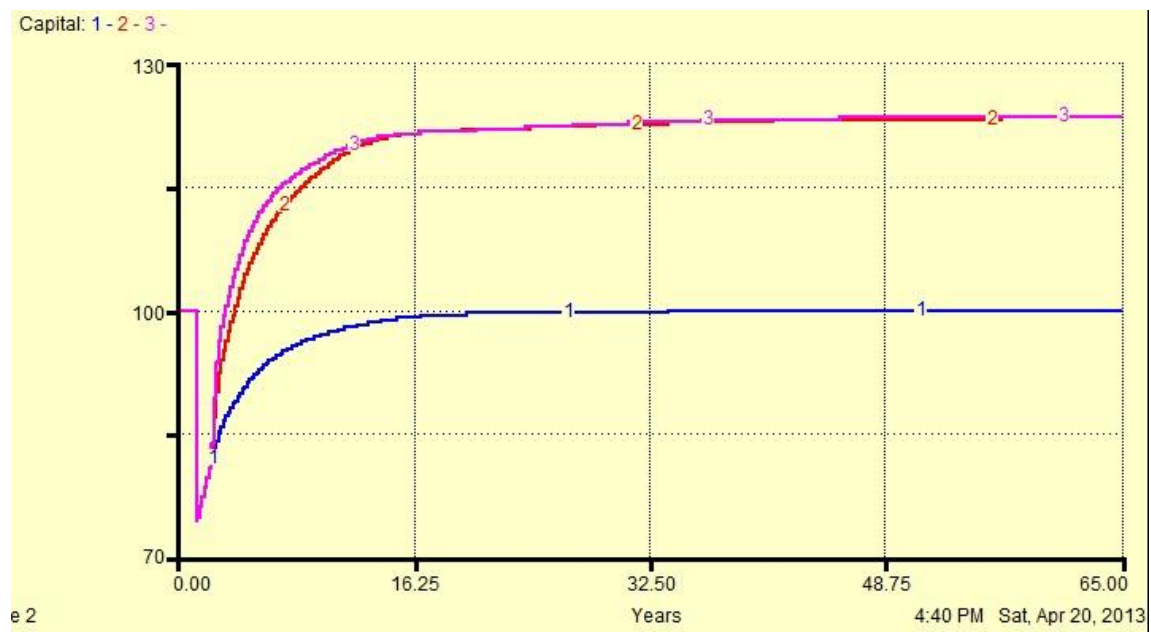


Figure 64: Total Capital (NCCP&CDP)

The result of using both Old Capital Demolition Policy and New Capital Construction Policy is similar to previous combination's. New capital increases from line 2 to line 3 (Figure 63) while total capital remains the same (Figure 64). This is because decreasing the average life of capital and technology increases the outflow of old capital; therefore, more land will be available for new capital construction.

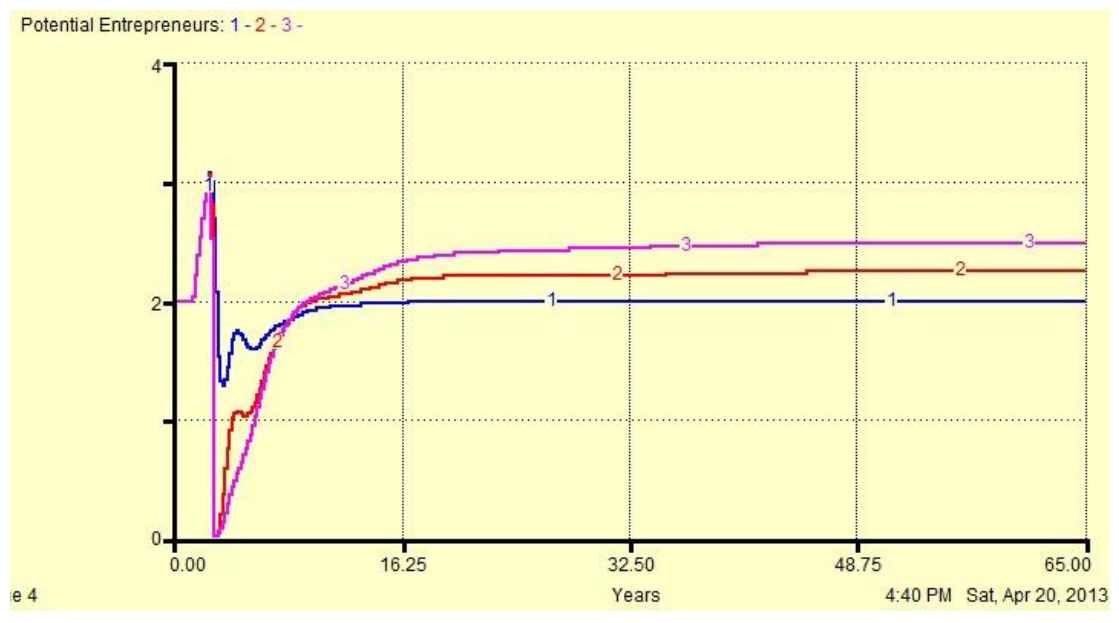


Figure 65: Potential Entrepreneurs (NCCP&CDP)

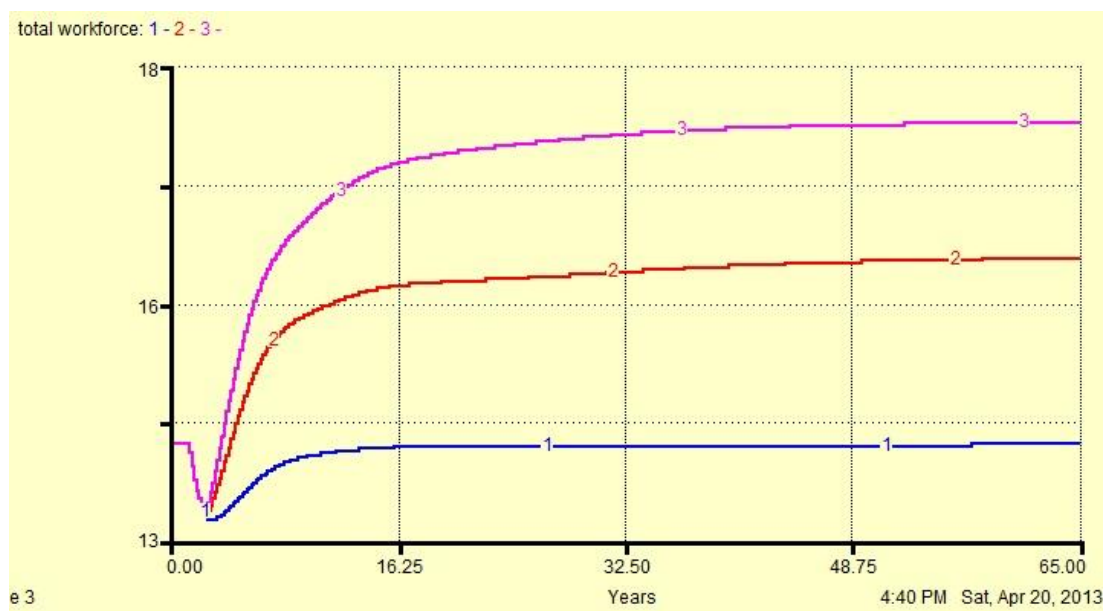


Figure 66: Total Workforce (NCCP&CDP)

As illustrated in Figure 65 and Figure 66, total workforce and entrepreneurs increase from line 2 to line 3. By freeing up land with the Old Capital Demolition Policy, the amount of new capital increases. Since new capital requires more workers than old capital, more jobs will be available. More people will move into the city; therefore, proportionately increase the number of entrepreneurs.

In conclusion, combining Old Capitals Demolition Policy with Decrease Interest Rate Policy or New Capital Construction Policy will significantly fasten the alleviation. Without applying Creative Destruction – destroying old capital – the economic recovery will not be as effective. In reality, the Old Capital Demolition policy can be implemented by establishing tax structure that provides incentive for removal of aging structures (Forrester, 1969). The tax will encourage entrepreneurs to replace old capital with new capital.

Policy Discussion

Variable	Base Run	NCCP	DIRP	ITP	SSP	LTPP	UTPP	IWRP	DIRP + OCDP	NCCP + OCDP
Total Capital	0	23.50	8.23	3.44	2.40	0.46	-0.18	-7.79	8.33	23.62
New Capital	0	-7.56	-3.88	-1.49	2.25	0.03	0.13	-0.22	28.11	26.37
Total Workforce	0	14.14	4.59	1.95	2.35	0.32	-0.09	-5.48	14.27	24.43
Potential Entrepreneurs	0	12.76	12.85	1.71	3.14	2.02	-0.85	-28.66	24.44	24.51
Ratio of New Capital to Old Capital	0	-40.20	-20.12	-9.09	-0.29	-0.84	0.62	17.87	44.67	4.54
Ratio of Potential Entrepreneurs to Total Workforce	0	-1.24	7.86	-0.26	0.74	1.66	-0.79	-24.55	8.87	0.04
Ratio of Unemployed to Total Workforce	0	0.98	-7.44	0.15	-0.77	-1.28	-0.81	23.38	-8.38	-0.15
Service Ratio	0	-6.70	-1.37	-1.24	4.43	0.18	0.08	-2.74	6.25	0.57

Figure 67: Comparison Results of All Policies to Base Run in Percentage

In this section, we select five policies for comparison. Increase Wage Rate Policy and Unemployed Training Program were selected because Thai government had implemented these programs in the past. Service Supply Policy was selected because, at the time this paper is written, Thai government is about to implement this policy. Decrease Interest Rate Policy, which generated the same result as New Capital Construction Policy, was selected as a representation of the most effective policy without proactive creative destruction. Finally, the combination of

Old Capital Demolition Policy and Capital Construction Policy was selected as a best policy (with proactive creative destruction).

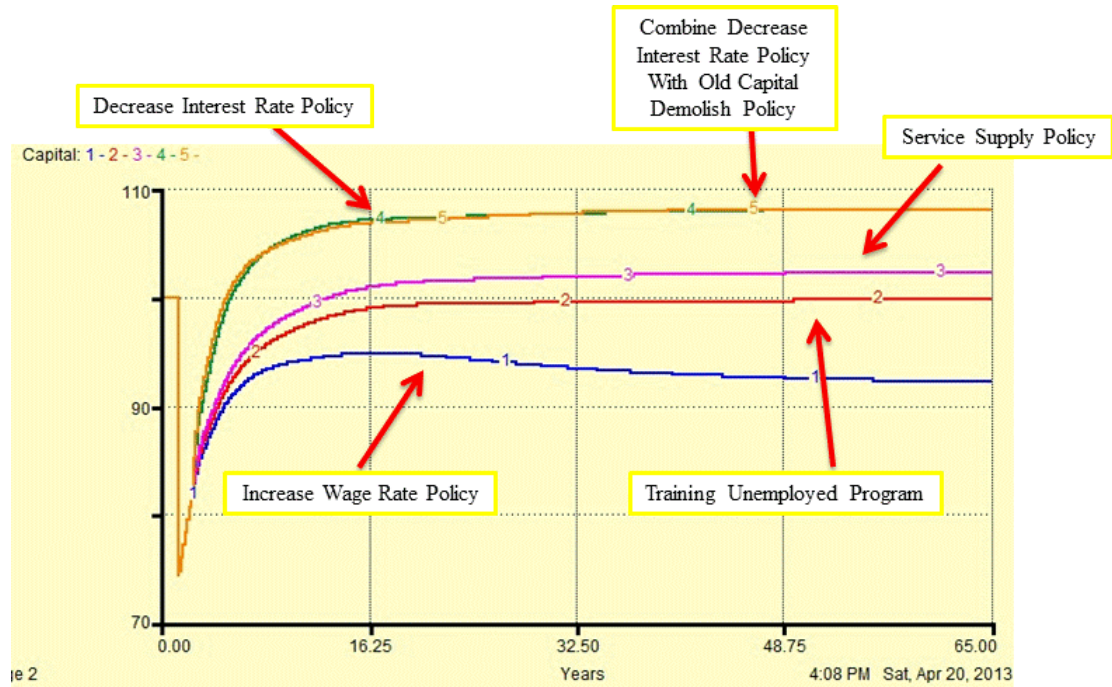


Figure 68: Graph Comparing the Amount of Capital

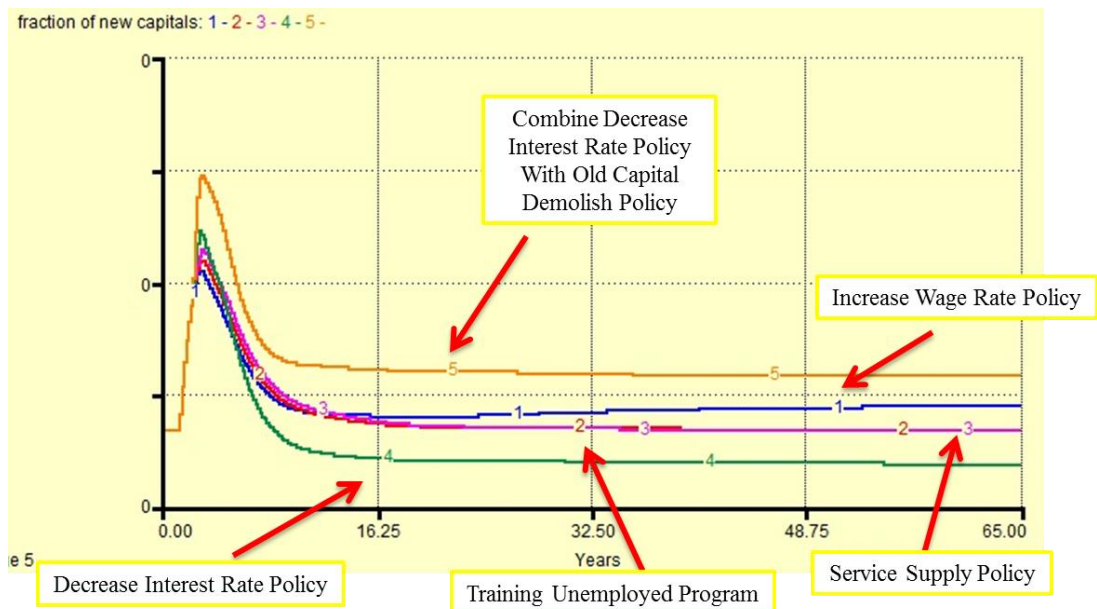


Figure 69: Graph Comparing the Fraction of New Capital

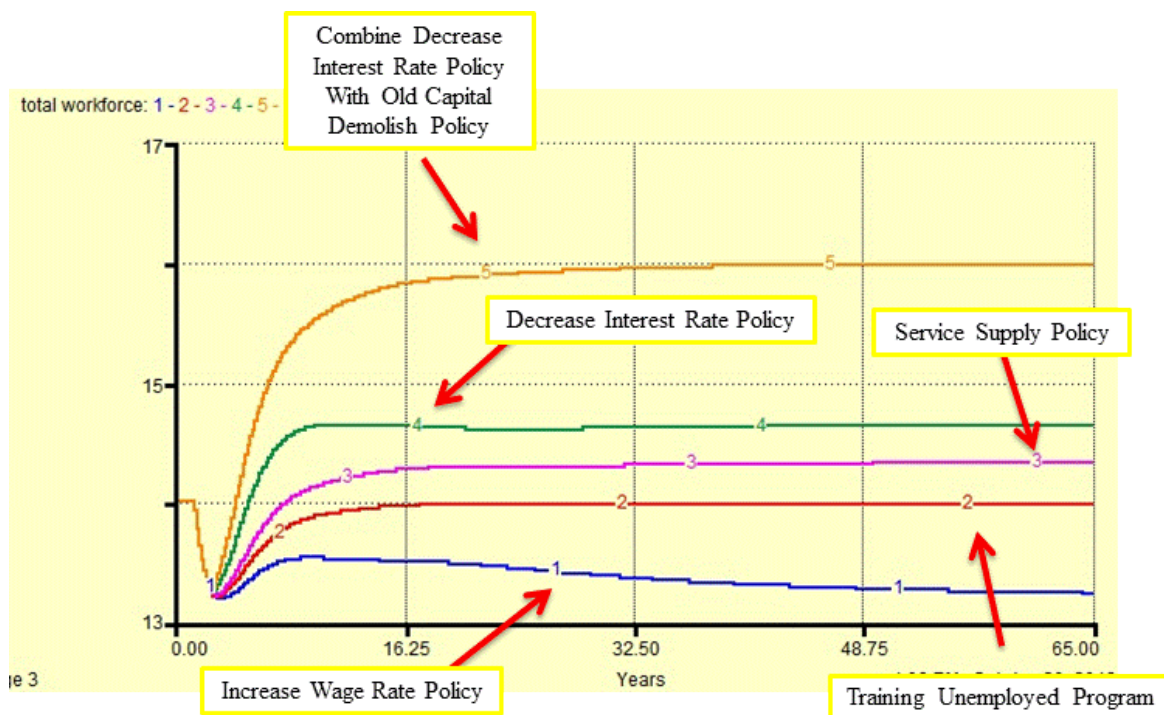


Figure 70: Graph Comparing the Amount of Total Workforce

Policies that Thai government had implemented were not as effective as anticipated. Increase Wage Rate Policy and Training Unemployed Policy result in a decrease of Capital (Figure 68) and Total Workforce (Figure 70). Service Supply Policy, which the government is about to implement, generate a positive outcome, however, only by a small amount. It only slightly increases the Capital (Figure 68) and Total Workforce (Figure 70). According to our studies, we found that Decrease Interest Rate Policy (and New Capital Construction Policy) is an effective policy for economic recovery. It significantly increases the amount of Capital (Figure 68) and Total Workforce (Figure 70). However, Decrease Interest Rate Policy decreases the fraction of New Capital (Figure 69). To further improve the result, Decrease Interest Rate Policy is combined with Old Capital Demolition Policy, which represents proactive Creative Destruction. As a result, Capital (Figure 68) significantly increases with a high Fraction of New Capital (Figure 69). In order to fasten the economic recovery from 2011 flood, we would like to suggest Thai government to apply Decrease Interest Rate Policy together with Old Capital Demolition Policy.

Conclusion

In 2011, Thailand was flooded for five months. The flood severely damaged not only infrastructures but also the economy. It has been almost 2 years since the flood; however, the economy has not fully recovered. The goal of our project is to use system dynamic to simulate the impact of flood on Thai economy and alleviation policies. Since most of Thailand economic activities are located in the capital, we decided to set the boundary of our study to only Bangkok, where most of the economic damage occurred.

We created our model by combining Forrester's Urban Dynamics model with Saeed's Creative Destruction model (concept by Schumpeter). We used Saeed's model as a base model then add the following structures from Forrester's to Saeed's: third-order-aging capitals, land constraint, job sector, and service sector. After the combination, the model was set to equilibrium in order to simulate the flood and alleviation policies.

We studied the alleviation policies from both literature and Thai government's. Increase New Capital Policy, Decrease Interest Rate Policy, Import Technology Policy, and Service-Supply Policy are drawn from the literature while Training Program Policy and Wage Rate Policy were implemented by Thai government in 2009 and 2012 respectively. After the analysis, we found that only Increase New Capital Policy and Decrease Interest Rate Policy are effective. Both policies generated positive outcomes: increases in entrepreneurs, total workforce, and total capital. However, we noticed that, due to the land constraint, higher portion of existing capital is old capital instead of new.

Since the high proportion of old capital is the obstacle that impede the alleviation, we decided to destroy old capital so more land will be available for new capital construction. We paired the old capital demolition policy with both new capital construction policy and decrease interest rate policy. With these combinations, the alleviation rate of the initial policies will increase significantly. As a result, we can conclude that, in combination with alleviation policy, Creative Destruction is a crucial factor for economic recovery.

Our project can be improved by taking into account of the economic damage from agriculture sector, which is located in the rural areas. Even though the damage is small compared

to the industry sector in Bangkok, simulating the impact of agriculture sector will better represent Thai economy.

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Appendix

Model Parameters at Equilibrium

Labor(t) = Labor(t - dt) + (Hiring - Labor__Entre_Mobility) * dt

INIT Labor = 10

INFLOWS:

Hiring = ((desired_labor-Labor)*hiring_normal)*labor_market_constraint

OUTFLOWS:

Labor__Entre_Mobility = (Labor*.05*climate_factor*(1+training_labor_program)-
Potential_Entrepreneurs*.25/climate_factor)*labor_entre__mobility_normal

Mature_capital(t) = Mature_capital(t - dt) + (New_capital__to_Mature_capital -
Mature_capital__to_Old_capital - mature_capital__destroyed) * dt

INIT Mature_capital = 30

INFLOWS:

New_capital__to_Mature_capital =

decline_multiplier__of_New_capital__to_Mature_capital*New_capital/avg_life__of_New_capital

OUTFLOWS:

Mature_capital__to_Old_capital =

decline_multiplier_of_Mature_capital_to_Old_capital*Mature_capital/avg_life_of_Mature_capital

mature_capital__destroyed = Mature_capital*mature_capital__decay_normal*flood_program

New_capital(t) = New_capital(t - dt) + (Investment - New_capital__to_Mature_capital -
new_capital__destroyed) * dt

INIT New_capital = 20

INFLOWS:

Investment =

(autonomous_investment+induced__investment)*capital_construct_multiplier*(1+new_cap__construct_program)

OUTFLOWS:

New_capital__to_Mature_capital =

decline_multiplier__of_New_capital__to_Mature_capital*New_capital/avg_life__of_New_capital

new_capital__destroyed = New_capital*new_capital__decay_normal*flood_program

Old_capital(t) = Old_capital(t - dt) + (Mature_capital__to_Old_capital - Cap_Decay -
old_capital__destroyed) * dt

INIT Old_capital = 50

INFLOWS:

Mature_capital__to_Old_capital =

decline_multiplier_of_Mature_capital_to_Old_capital*Mature_capital/avg_life_of_Mature_capital

OUTFLOWS:

Cap_Decay = demolition__multiplier_of_Old_capital*Old_capital/avg_life_of_Old_capital

old_capital__destroyed = Old_capital*old_capital__decay_normal*flood_program

Potential_Entrepreneurs(t) = Potential_Entrepreneurs(t - dt) + (Labor__Entre_Mobility + Unemployed__Entre_Mobility) * dt

INIT Potential_Entrepreneurs = 2

INFLOWS:

Labor__Entre_Mobility = (Labor*.05*climate_factor*(1+training_labor_program)- Potential_Entrepreneurs*.25/climate_factor)*labor_entre__mobility_normal

Unemployed__Entre_Mobility =

(Unemployed*0.1*climate_factor*(1+training_unemployed_program)-

Potential_Entrepreneurs*0.1)*unemployed_entre__mobility_normal

Technology(t) = Technology(t - dt) + (Tech_Development - Tech_Decay) * dt

INIT Technology = 100

INFLOWS:

Tech_Development = entrepreneurs*tech_productivity

OUTFLOWS:

Tech_Decay = Technology/av_life_of_cap_and_tech

Unemployed(t) = Unemployed(t - dt) + (Workforce_Growth - Unemployed__Entre_Mobility - Hiring) * dt

INIT Unemployed = 2

INFLOWS:

Workforce_Growth = total_workforce*workforce_growth_fr

OUTFLOWS:

Unemployed__Entre_Mobility =

(Unemployed*0.1*climate_factor*(1+training_unemployed_program)-

Potential_Entrepreneurs*0.1)*unemployed_entre__mobility_normal

Hiring = ((desired_labor-Labor)*hiring_normal)*labor_market_constraint

Unspent_Saving(t) = Unspent_Saving(t - dt) + (Saving_Up - Resources) * dt

INIT Unspent_Saving = 20

INFLOWS:

Saving_Up = output*fr_output_saved*interest_rate/.1

OUTFLOWS:

Resources = entrepreneurs*fr_saving_mobilized_per_entrepreneur*Unspent_Saving

area = 100

autonomous_investment =

Resources^.5*(Technology/10)^.5*(autonomous__investment_normal_1)^.5-

Saving_Up*autonomous__investment_normal_2

autonomous__investment_normal_1 = 1

autonomous__investment_normal_2 = 1

avg_life_of_Mature_capital = 3

avg_life_of_Old_capital = av_life_of_cap_and_tech-avg_life__of_New_capital-

avg_life_of_Mature_capital

avg_life__of_New_capital = 2

av_life_of_cap_and_tech = 10+old_cap_decline_program

```

Capital = Mature_capital+New_capital+Old_capital
capital_construct_multiplier = capital_land_multiplier*service_multiplier
capital_tax_collection =
Old_capital*old_capital__tax_rate+Mature_capital*mature_capital__tax_rate+New_capital*new_ca
pital__tax_rate
climate_factor = climate_factor_mulplier*service_multiplier*interest_rate_multiplier
demolition__multiplier_of_Old_capital =
declining_capital_enterprise_multiplier*declining_capital_land_multiplier
desired_capital = desired_new_capital+desired_mature_capital+desired_old_capital
desired_labor =
New_capital/new_capital_labor_ratio+Mature_capital/mature_capital_labor_ratio+Old_capital/old_c
apital_labor_ratio
desired_mature_capital = mature_capital_output*mature_capital_output_ratio
desired_new_capital = new_capital_output*new_capital_output_ratio
desired_old_capital = old_capital_output*old_capital_output_ratio
entrepreneurs = SMTH3(Potential_Entrepreneurs,entrepreneur_development_delay)
entrepreneur_development_delay = 5
flood_policy = PULSE(.3,1,10000)
flood_program = flood_program_switch*flood_policy
flood_program_switch = 0
fr_output_saved = .2
fr_saving_mobilized_per_entrepreneur = .25
hiring_normal = 2
import_tech_policy = step(1,2)
import_tech_program = import_tech_policy*import_tech_program_switch
import_tech_program_switch = 0
induced_investment__normal = 1/2
induced__investment = (desired_capital-Capital)*induced_investment__normal+Cap_Decay
interest_policy = step(-0.05,2)
interest_program = interest_policy*interest_program_switch
interest_program_switch = 0
interest_rate = .1+interest_program
labor_entre__mobility_normal = 1
labor_tax_rate = 7.5
land_fr_occupied = Capital*land_per_capital/area
land_per_capital = .7
mature_capital_labor_ratio = 1/.11
mature_capital_output = Mature_capital/mature_capital_output_ratio
mature_capital_output_ratio = 2
mature_capital__decay_normal = 1
mature_capital__tax_rate = .5
new_capital_labor_ratio = 1/.16

```

```

new_capital_output = New_capital/new_capital_output_ratio
new_capital_output_ratio = 4/3
new_capital__decay_normal = 1
new_capital__tax_rate = 1
new_cap_construct_policy = step(1.12,2)
new_cap_construct_program_switch = 0
new_cap__construct_program = new_cap_construct_policy*new_cap_construct_program_switch
old_capital_labor_ratio = 1/.07
old_capital_output = Old_capital/old_capital_output_ratio
old_capital_output_ratio = 2.5
old_capital__decay_normal = 1
old_capital__tax_rate = .25
old_cap_decline_policy = step(-2,2)
old_cap_decline_program = old_cap_decline_policy*old_cap_decline_program_switch
old_cap_decline_program_switch = 0
output = (new_capital_output+mature_capital_output+old_capital_output)*labor_constraint
population_tax_collection =
Unemployed*unemployed_tax_rate+Labor*labor_tax_rate+Potential_Entrepreneurs*potential_entrepreneurs__tax_rate
potential_entrepreneurs__tax_rate = 15
profit = output-wages
rate_of_return = profit/Capital
services_ratio = service_supply/service_demand
service_demand = Capital*service_demand__per_cap+total_workforce*service_demand__per_pop
service_demand__per_cap = 1
service_demand__per_pop = 3.75
service_per_unit_tax = 1
service_supply = service_per_unit_tax*total_tax_collection+service_supply_program
service_supply_policy = step(6.75,2)
service_supply_program = service_supply_policy*service_supply_program_switch
service_supply_program_switch = 0
tech_productivity = 5+import_tech_program
total_tax_collection = capital_tax_collection+population_tax_collection
total_workforce = Labor+Potential_Entrepreneurs+Unemployed
training_labor_policy = step(0.2,2)
training_labor_program = training_labor_program_switch*training_labor_policy
training_labor_program_switch = 0
training_unemployed_policy = step(0.4,2)
training_unemployed_program = training_unemployed_program_switch*training_unemployed_policy
training_unemployed_program_switch = 0
unemployed_entre__mobility_normal = 1
unemployed_tax_rate = 0

```



```

wages = Labor*wage_rate
wage_policy = step(1,2)
wage_program = wage_program_switch*wage_policy
wage_program_switch = 0
wage_rate = wage_rate_normal*wage_escalation_effect+wage_program
wage_rate_normal = 3
worker_availability = (Unemployed/Labor)/(2/10)
workforce_growth_fr =
workforce_growth_fr_normal*job_population_multiplier*service_multiplier
workforce_growth_fr_normal = 0.1
capital_land_multiplier = GRAPH(land_fr_occupied)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.45), (0.5, 1.40), (0.6, 1.30), (0.7, 1.00), (0.8,
0.7), (0.9, 0.4), (1, 0.00)
climate_factor_multiplier = GRAPH(((rate_of_return/.2)/(wage_rate/3)))
(0.00, 0.001), (0.2, 0.06), (0.4, 0.18), (0.6, 0.35), (0.8, 0.67), (1.00, 1.00), (1.20, 1.49), (1.40, 1.75),
(1.60, 1.89), (1.80, 1.96), (2.00, 2.00)
decline_multiplier_of_Mature_capital_to_Old_capital =
GRAPH(LOG10(capital_construct_multiplier)/LOG10(2))
(-3.00, 2.00), (-2.00, 1.80), (-1.00, 1.50), (0.00, 1.00), (1.00, 0.7), (2.00, 0.5), (3.00, 0.5)
decline_multiplier_of_New_capital_to_Mature_capital =
GRAPH(LOG10(capital_construct_multiplier)/LOG10(2))
(-3.00, 2.00), (-2.00, 1.80), (-1.00, 1.50), (0.00, 1.00), (1.00, 0.7), (2.00, 0.5), (3.00, 0.5)
declining_capital_enterprise_multiplier = GRAPH(LOG10(capital_construct_multiplier)/LOG10(2))
(-3.00, 0.4), (-2.00, 0.5), (-1.00, 0.7), (0.00, 1.00), (1.00, 1.60), (2.00, 2.40), (3.00, 4.00)
declining_capital_land_multiplier = GRAPH(land_fr_occupied)
(0.8, 1.00), (0.85, 1.20), (0.9, 1.60), (0.95, 2.20), (1.00, 6.00)
interest_rate_multiplier = GRAPH(interest_rate)
(0.00, 2.00), (0.025, 1.90), (0.05, 1.73), (0.075, 1.41), (0.1, 1.00), (0.125, 0.51), (0.15, 0.24), (0.175,
0.06), (0.2, 0.00)
job_population_multiplier = GRAPH((desired_labor/10)/(total_workforce/14))
(0.00, -1.58), (0.2, -1.54), (0.4, -1.36), (0.6, -1.04), (0.8, -0.58), (1.00, 0.00), (1.20, 0.58), (1.40,
1.04), (1.60, 1.36), (1.80, 1.54), (2.00, 1.58)
labor_constraint = GRAPH(Labor/desired_labor)
(0.00, 0.00), (0.2, 0.45), (0.4, 0.69), (0.6, 0.83), (0.8, 0.92), (1.00, 1.00), (1.20, 1.06), (1.40, 1.11),
(1.60, 1.14), (1.80, 1.17), (2.00, 1.19)
labor_market_constraint = GRAPH(worker_availability)
(0.00, 0.00), (0.1, 0.435), (0.2, 0.655), (0.3, 0.765), (0.4, 0.85), (0.5, 0.895), (0.6, 0.935), (0.7, 0.96),
(0.8, 0.975), (0.9, 0.995), (1, 1.00)
service_multiplier = GRAPH(LOG10(services_ratio)/LOG10(2))
(-2.00, 0.3), (-1.00, 0.5), (0.00, 1.00), (1.00, 1.80), (2.00, 2.80), (3.00, 3.60), (4.00, 4.00)
wage_escalation_effect = GRAPH(worker_availability)

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(0.00, 4.00), (0.2, 2.76), (0.4, 2.04), (0.6, 1.62), (0.8, 1.28), (1.00, 1.00), (1.20, 0.74), (1.40, 0.54),
 (1.60, 0.4), (1.80, 0.28), (2.00, 0.22)

Model Parameters' Changes for Polices Implementation

Policy	Parameter Name	Changed Value
Flood Simulation	flood policy	PULSE(.3,1,10000)
New Capital Construction Policy	new cap construct policy	step(1.12,2)
Decrease Interest Rate Policy	interest policy	step(-0.05,2)
Import Technology Policy	import tech policy	step(1,2)
Service Supply Policy	service supply policy	step(6.75,2)
Labor Training Program Policy	training unemployed policy	step(0.2,2)
Unemployed Training Program Policy	training labor policy	step(0.4,2)
Increase Wage Rate Policy	wage policy	step(1,2)
Old Capital Demolition Policy	old cap decline policy	step(-2,2)