A System Dynamics Approach to the Environmental Problems in Taiwan

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Abstract

The rapid economic growth caused very serious environmental pollutions in Taiwan. This paper attempts to use the system dynamics methodology to construct a simple model to study the trade-offs between economic growth and environmental pollutions. The model is structured with feedback loops among three sectors: the government, the general public, and the industries. Environmental regulations with various implementation times and strengths are tested in the model to examine their effects on the smoothness of the economy and pollution changing pattern. The results show that a timely not-so-strict environmental regulation combined with an environmental education measure focused on lowering expectation on economic growth rate may be a better choice for Taiwan to go through the tough time more smoothly.

Introduction

Starting almost from "nothing", the government leaders and the people of the Republic of China on the island of Taiwan have produced world-acclaimed "miracle" of economic prosperity -- an average of around 9% steady growth of GNP for 30 years, and, by latest count, world's second-ranking holder of US$ 78.6 billion foreign exchange reserves. Many factors have contributed to this rapid growth. The most important ones are the industriousness of the people, their high propensity to save, and their dedicated pursuit of education. This was combined with a high interventionist policy mix implemented by the government since the 1950's, and was complemented by a stable socioeconomic order sustained by a form of martial law which was mostly symbolic yet effective (Ma 1990).

The "miracle", after all, can not be achieved without costs. The huge foreign exchange reserves have plunged the whole economy into a serious disequilibrium. Then the lifting of martial law in 1987 and the death of Present Chiang Ching-Kao in the following year marked the end of an area of strongman leadership. All kinds of long suppressed political and social energies began to emerge through every possible channel, the most notable being the environmental protection movements (Ma 1990).

Responding to these movements, the government set up the Environmental Protection Administration (EPA) to deal with environmental pollution. The pressure exerted by the environmental activists and the EPA are both growing. Industries can no longer get away with polluting the environment as easily as in previous years.

However, the environmental problems, along with many other social problems that were neglected during the economic runaway period, consume a huge amount of expenditures; which means that those actions will not be effective alone without the financial support from adequate economic growth. Thus, placing too great an emphasis on those actions might curb the economic growth, which will reversely affect those reforms. Owing to the very dynamic feature of this society, economy, still being the core of the structure, should not be slowed down too sharply on the course. How to take a proper pace of change so that Taiwan can go through this difficult transformation period will challenge both the government and the 20 million people on the island.

This paper attempts to use the system dynamics methodology to construct a simple model to study the trade-offs between economic growth and environmental pollutions. The model is structured with feedback loops among three sectors: the government, the general public, and the industries. Environmental regulations with various implementation times and strengths are tested in the model to examine their effects on the smoothness of the economy and pollution changing pattern.

Problem statement

In developing economies, industry is the engine to improve personal income. Mishan spoke about the growth ideology as the fundamental cause of environmental disasters and external costs of economic growth (Mishan 1967). When industry produces more, it pollutes its environment more. The more affluent the people are, the higher environmental quality they concern, that is the socioeconomic status effect (Fisher, et al. 1984, 29). In sum, industrialization leads to less supply and more demand of the environmental quality (Nijkamp 1980). It's exactly the situation now in Taiwan.

Environmental problems are not only to decrease the effluence of pollution but also to abate it from nature. It involves ecological, economical, social, and political considerations (Moffat 1985). To decrease the effluence of pollution, government must regulate firms from discharging pollutants exceeding acceptable levels. To abate pollution, the public sector must invest in pollution abatement. The more strict the environmental regulation standard is, the more money is invested to abate pollution, and the more improvement in environmental quality. Firms then must spend more money to abate pollution generated from the production process under this circumstances. This limits the resources of firms, since more resources are allocated to pollution abatement, thereby reducing the resources used to produce products. The personal income decreases, and people enjoy less material quality of life. The lowered personal incomes increases the desire for economic growth and lowers the need for environmental quality, which decreases the public pressure for improving environmental quality. Public policy then changes to focus on economic growth. Resources of the country are then allocated more to production and less to pollution control, which results in a reduction of environmental quality.

This chain of causal links shows the complexity of the environmental problems in Taiwan. The system dynamics methodology is thus employed to study the structure of those feedback interactions and to construct a simulation model to evaluate the effectiveness of some related policies.

Model descriptions

Figure 1 shows a simplified causal diagram of the feedback structure of the environmental system being studied. There are three main sectors in this model: industry, government, and the public. Firms try to maximize profits through efficient use of resources to produce products for sale and to make money for investments and capital accumulation. The more capital firms accumulates, the more products can be produced, and the more capital accumulates thereafter. If there are no other negative factors, production will grow exponentially. National income grows the same way as production (assuming that national income grows in proportion to industrial production). As national income grows, the demand for services will increase, which reduces the investments in the industrial sector. Because the ability of self-abatement of nature is limited by its carrying capacity, and when pollution effluence increases over the carrying capacity, the ability of self-abatement in nature will decay. Therefore, if pollution is generated more and more without investments in

pollution control, degradation of environmental quality will become more and more serious.

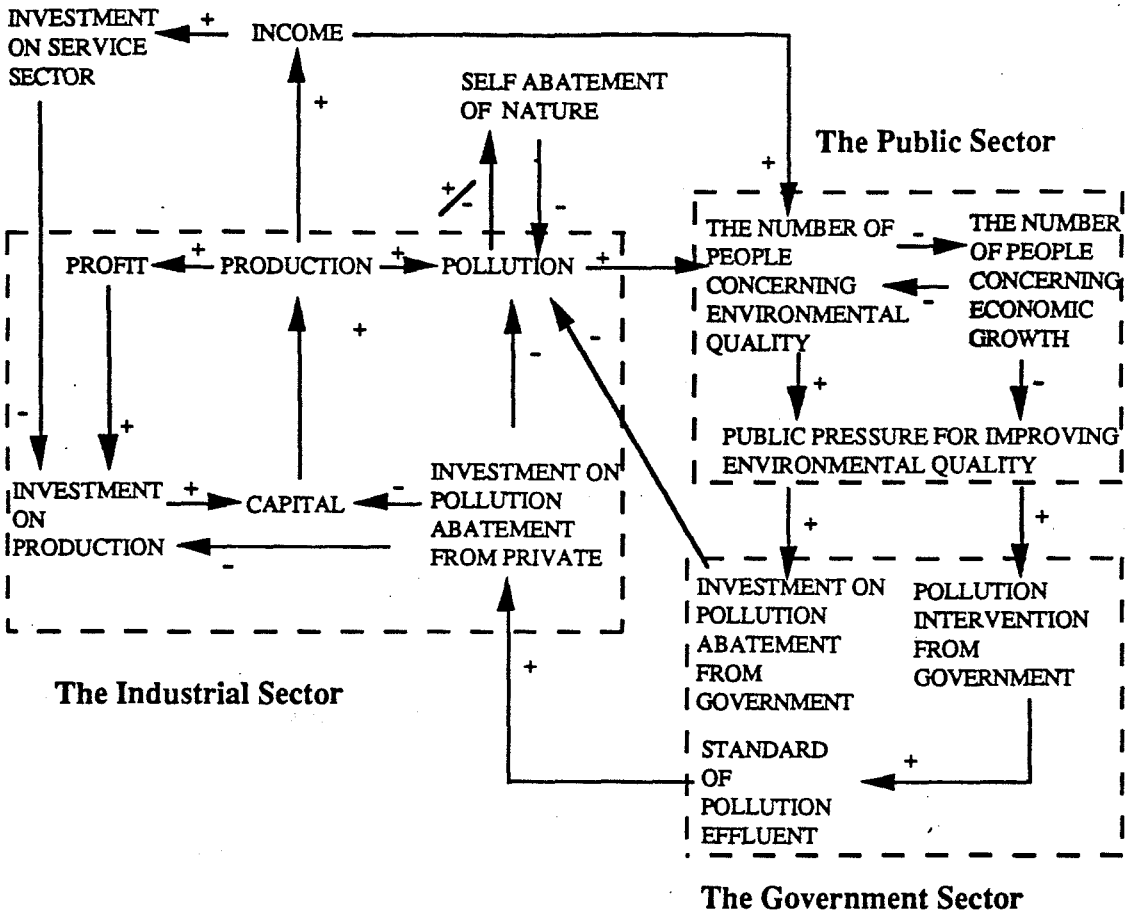

Figure 1: A Simplified Causal Diagram of the Model

The public searches not only for economic welfare but also environmental quality. When the national income increases coupled with decreasing environmental quality, the demand for environmental quality becomes higher. As the number of people concerned with environmental quality increases, the number of people concerned with economic growth decreases. The result is that the public will give more pressure to improve environmental quality. Alternatively, when the rate of economic growth decreases, the public will change their attitudes and concern more about the economic welfare as occurs in Taiwan recently. According to Hsiao, economic growth remains as the dominant objective in Taiwan until now

(Hsiao 1989). These relationships are assumed to be an S shaped curve.[1] In addition, the change in the attitudes of the public is assumed to take three years. The assumption is reasonable because the spread of information is quite soon on this small island, and people may change their attitudes more quickly. In addition, when pollution is higher, people can tolerate more pollution due to adaptation (Fisher, et al. 1984, 23-28). Some environmental education programs are thus designed to decrease the tolerance level of pollution or to lower the preference toward economic growth.

Under a democratic system, governments make public policy that include economic and environmental concerns to win votes, the same is in Taiwan, particularly after the the lifting of martial law in 1987. When public pressure to improve environmental quality increases, environmental regulation to abate pollution effluence are adopted in most countries (Downing 1984). Environmental regulation was enacted since the 1970's in Taiwan. But more strict and more punishment on firms starts about in 1983, because of public pressure for less pollution. As a result, the investment of pollution abatements in public and private sectors increase sharply since 1983. Pollution has been abated gradually recently. However, many firms were closed owing to the punishment of environmental regulation. This causal relationship between the public pressure for more environmental quality and the change of environmental policy occur after a time period, and is modeled as a smooth function. Environmental regulation is reset every five years, and is more strict gradually as observed in Taiwan and other developed countries.

The goal of firms is to maximize its profit through the most efficient use of resources. When the marginal cost of pollution control is assumed to be a diminishing marginal function of the concentration of pollution effluent, and is less than the cost of punishment, pollution control become necessary. Firms will invest less to production. Less profitable firms will be forced to withdraw from the industry. This results in a decrease in economic growth in Taiwan and a decline in the growth of national income. In the meantime, attitudes of the public may change if pollution decreases. Consequently, public policy may change in the same direction. It has been found that many petrochemical firms in Taiwan intend to withdraw their investment to other countries recently due to the public pressure for less pollution. In fact, economic growth declined since 1987 in Taiwan, partly because of more strict environmental regulation.

Since this study focuses on examining the smoothness of the changing patterns of economic growth and environmental pollution, lacking many of

[1] According to the empirical study by Bronson, ea al. (1988) S-shape curve is valid in the fundamental relationship between variables in macrosociological theory.

the quantitative data does not cause much trouble to us in building the model and testing the policies.

Model experiments

Reference run

The time-variant patterns generated by this model are shown in Figure 2. There are two reasons that long-term satisfactory economic growth rate equals 0.04 in the reference run. First, the economic growth rate in Taiwan was about 0.06 in 1989, and it is decreasing in 1990 based on the latest data. Second, the economic growth rate in developed countries maintain about 2%-6%. The simulation shows that, initially, production and pollution grow exponentially for about 20 years, which replicates the actual growth patterns in Taiwan from 1965 to 1985. The number of people concerned with environmental quality increases during the same period. However, social needs for environmental quality become stronger

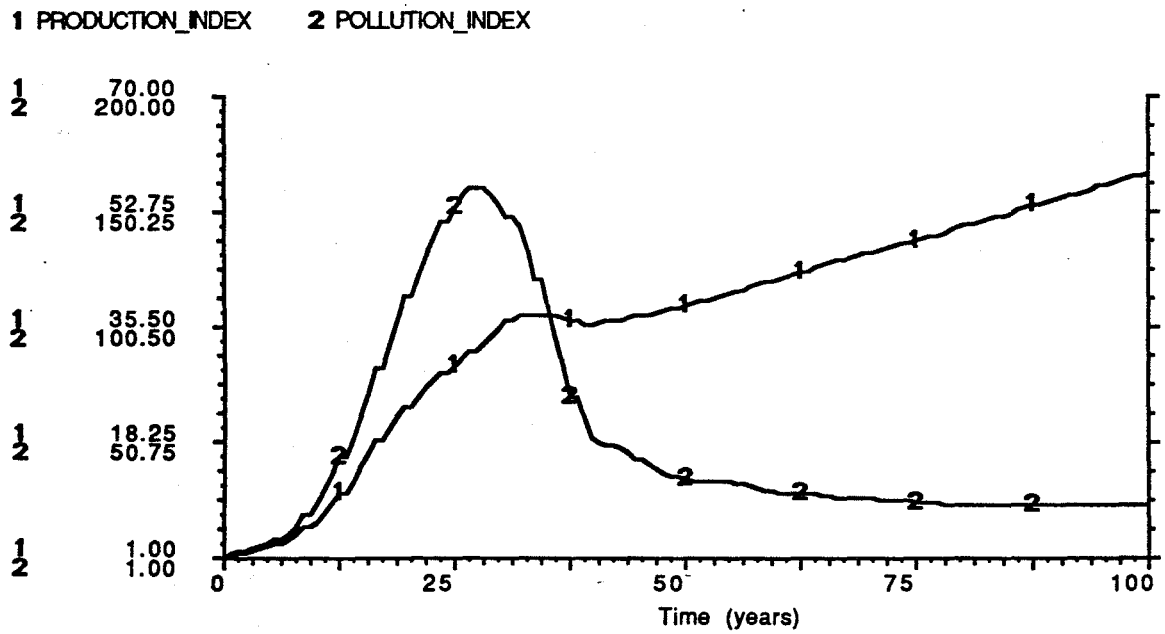

Figure 2. Simulation results of the reference run

because of higher income and lower environmental quality. The public pressure to abate pollution increases. Through the democratic system, the intervention in pollution control increases, and firms increase their

investment in pollution abatement. Pollution is decreased, and so is production.

Then, when the demand for environmental quality is satisfied to some extent, the number of people who searches for more income increases gradually, and the pressure from the public declines. Another stage of the system state results from the trade-off between environmental quality and economic growth starts. For the purpose of comparison, an "adjustment duration" is defined for the period from year 20 to year 50 to differentiate it from the long term period defined for the period after year 50.

Policy tests

There are six policies to be tested in this model, which are divided into three categories, policies 1, 2, and 3 are the pollution intervention policies; policies 4 and 5 are the environmental education policies; and policy 6 is the combination of policies 3 and 4. People often hope to solve environmental problem with most comfortable way (Fisher 1984), but the trade-offs between economic growth and environmental protection often exist. Therefore, a good policy may be that the pollution can be controlled at lower level without costing too much on economy and social harmony. In other words, the effectiveness of a policy is evaluated by its impact on the smoothness of the changing economy and pollution patterns.

Policy 1: More strict environmental regulation

The simulation results of more strict environmental regulation are shown in Figure 3. Though pollution can be controlled under a lower level in the long term, production whether in the "adjustment duration" or in the long term are all less than the reference case. Stagnation of economy is sustained about 15 years. It seems that the trasition is not so smooth.

Policy 2: Implementing the environmental regulation after pollution is more serious

The effects which government implements regulation after pollution becomes more serious can be observed from Figure 4. Production can be maintained at higher level with more serious stagnation than the reference case, and pollution is more serious too. It may be resulted from that regulation is implemented when economy is strong enough to bear the impact of the regulation. The trade-off between economy, environment,

and social harmony seems cost too much. In sum, because more pollution and stagnation of economy, there will have more conflicts in the society.

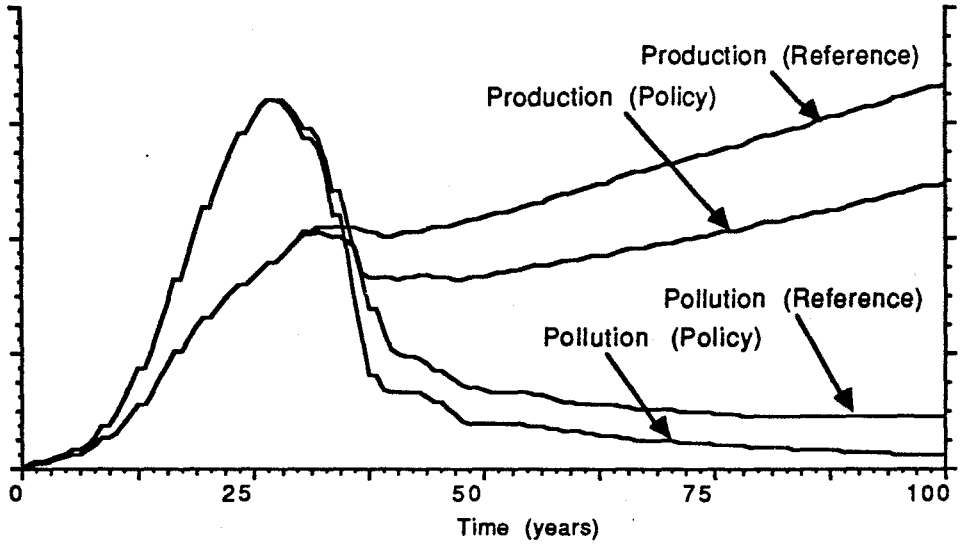

Figure 3. Simulation results of policy 1 compared with the reference case

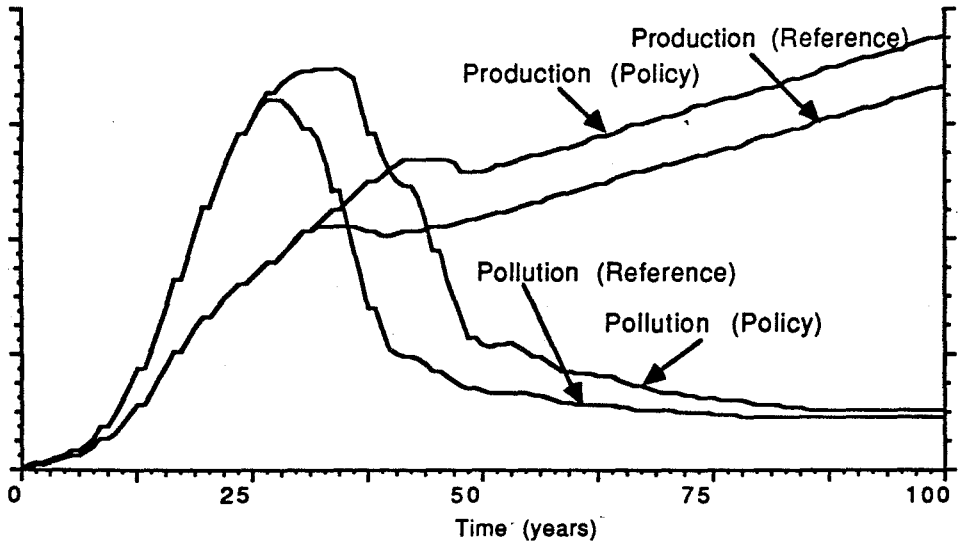

Figure 4. Simulation results of policy 2 compared with the reference case

Policy 3: Timely implementing environmental regulation

The effects which government implements environmental regulation as soon as the pollution becomes more serious are illustrated in Figure 5.

Production is lower than that the reference case during the "adjustment duration". Pollution is lower than the reference case during "adjustment duration", but it does not occur in the long term. Further, the changing pattern of production and pollution are more smooth. Nevertheless, long-term problem still exists.

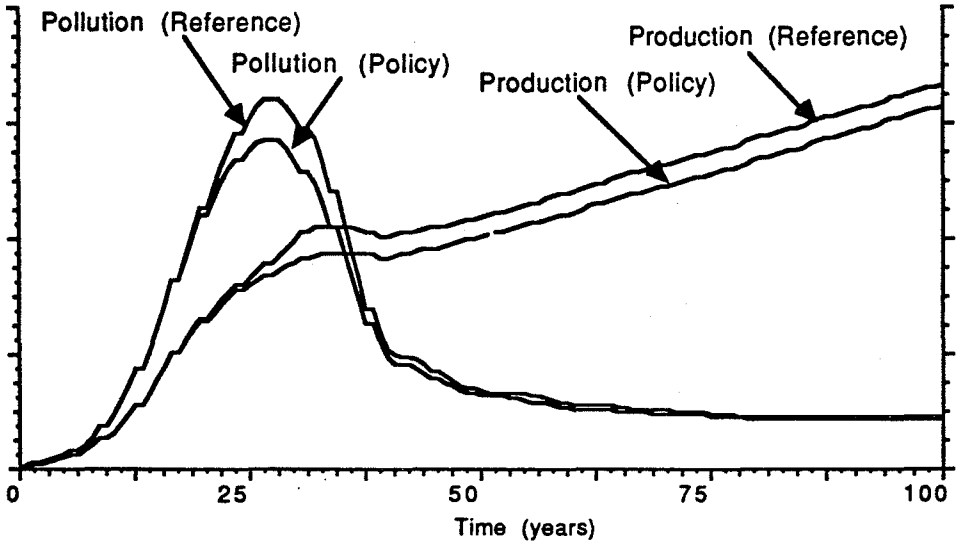

Figure 5. Simulation results of policy 3 compared with the reference case

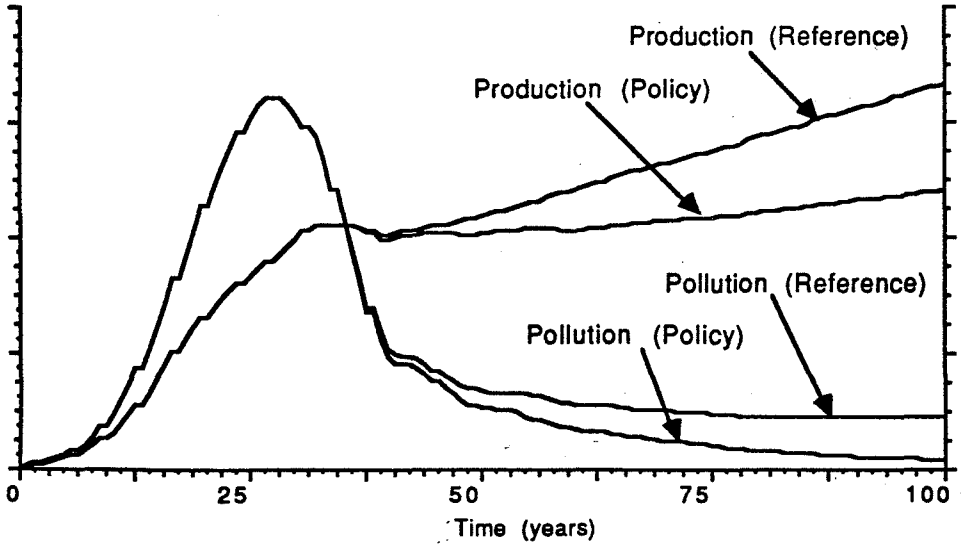

Figure 6. Simulation results of policy 4 compared with the reference case

Policy 4: Environmental education program for lowering the expectation on economic growth rate

The effects of environmental education program for lowering the expectation on economic growth rate are shown in Figure 6. The satisfactory economic growth rate equals 0.01. The effect in the "adjustment duration" is about the same as the reference case, because environmental education is a long-term policy for this problem. Both the production and the pollution are less than the reference case in the long run. It implies that sustainable economic growth is possible through environmental education program for lowering the expectation on economic growth rate, then pollution can be controlled at a lower level in the long term. But people still face a tough time during the "adjustment duration".

Policy 5: Environmental education program for lowering the level of pollution tolerance

The effects of environmental education program for lowering the level of pollution tolerance are shown in Figure 7. It seems that the policy does not work effectively. Production and pollution are all slightly less than the reference case, but it is not significant.

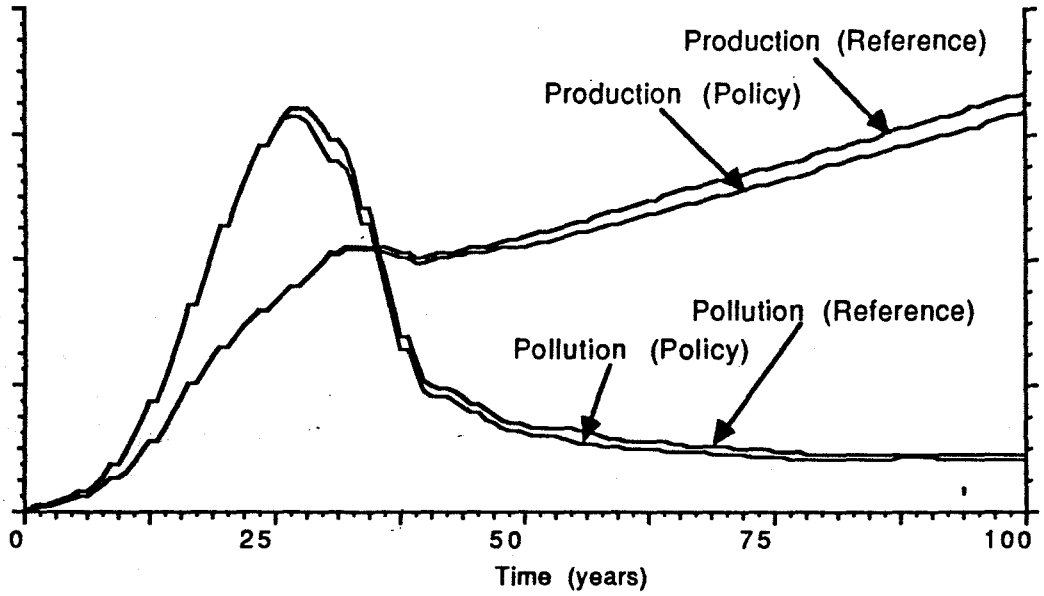

Figure 7. Simulation results of policy 5 compared with the reference case

Policy 6: Combination of policy 3 and policy 4

The effects of the combination policy of policies 3 and 4 are shown in Figure 8. Both the production and pollution are lower than those in the reference case during the "adjustment duration" and in the long term. Besides, the changing pattern of production and pollution during the "adjustment duration" are more smooth. The combination policy seems better than the others.

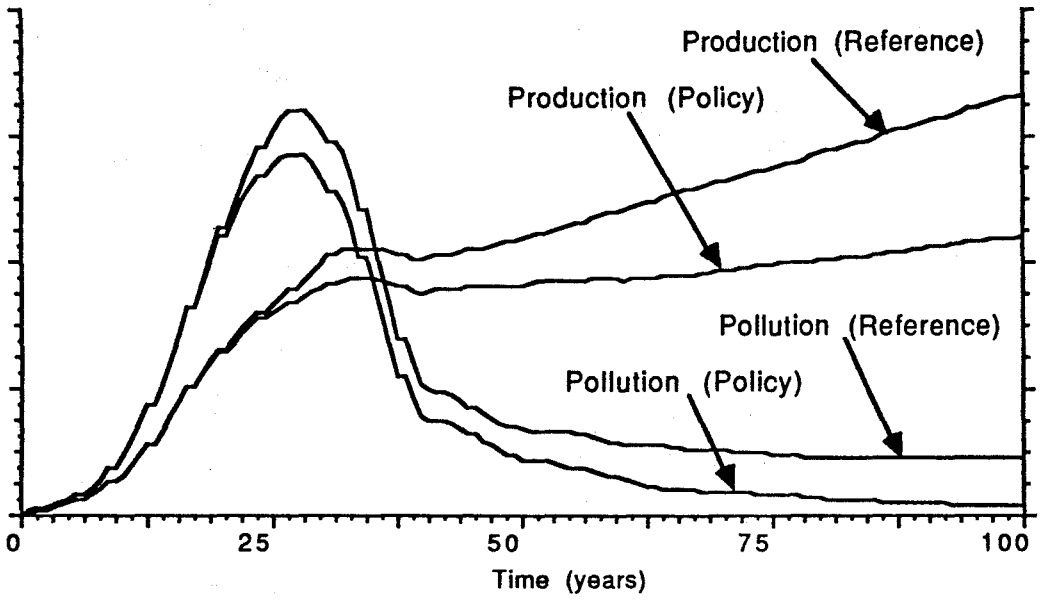

Figure 8. Simulation results of policy 6 compared with the reference case

Summary and conclusion

The rapid economic growth caused very serious environmental pollutions in Taiwan. This paper attempts to use the system dynamics methodology to construct a simple model to study the trade-offs between economic growth and environmental pollutions. Some feedback loops are identified among the government, the general public, and the industries to form the main structure of the simulation model. The effects of three pollution intervention policies and two environmental education policies are then tested. The simulation results indicate that more strict regulation seems to have short-term effect but not so good for the long term. The policy that environmental regulation is implemented after environmental problems are serious will lead to more serious situation in the long term. The policy that environmental regulation is implemented as soon as environmental problems occurred seems good during the "adjustment duration", but the

long-term pollution is the same. Environmental education program works well in the long term, and should take more emphasis on lowering the expectation of economic growth rate. Maybe the policy which implementing environmental regulation as soon as environmental problems occurred combined with environmental education program focusing on lowering the expectation of economic growth rate is a better choice for Taiwan. A broad-base consensus should be reached to allow some compromise between economic growth and environmental protection so that the tough time can be gone through more smoothly.

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