Evaluating The Policy of Stratospheric Ozone Protection: A System Dynamics Modeling Approach

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The Context of the Ozone Protection Policy

Environmental pollution and its protection have become significant yet controversial issues on the government agenda. The environmental pollution issue occurs mainly because individuals pursuing their own private interests may collectively generate public costs. Because of this market failure, governmental intervention to reduce the harmful impacts of private actions becomes inevitable. Policy implementation tools, such as regulation, are often the core of public intervention. Through the tools, the government attempts to change the behavior of the target population in favored directions.

The role of chlorofluorocarbons (CFCs) in depleting the stratospheric ozone layer that shields the earth from direct ultraviolet radiation has been modeled and debated since the results of a scientific research were reported in 1974. Four years later, the United States banned the use of CFCs as propellants in aerosol spray cans. With the rise of global ecological concerns, limiting emissions of CFCs became the first international environmental agreement, the Montreal Protocol in 1987. Due largely to technological breakthroughs on the development of less ozone-depleting substitute gases, the United States has officially announced the non-essential CFCs will no longer be produced in this country by the end of 1995. In this perspective, protecting the ozone layer by phasing out CFCs production illustrates a typical policy of what and how public intervention is used to deal with undesired private activity that leads to market failure. Moreover, despite the lack of a clear scientific consensus about the severity and magnitude of the ozone depletion, the two-decade story of phasing out CFCs is likely to be one of the rarely "effective" governmental intervention, especially in the environmental policy area.

Five primary policy stakeholders involved in the CFCs policy are: Environmental Protection Agency (EPA), CFCs producers, environmental groups, interest representatives of the CFCs firms in Congress, and CFCs consumers with cost minimizing preference. The EPA has been responsible for executing the policy of the ozone layer protection based on the Clean Air Act Amendments of 1990[1], in which Title VI provides with various phasing-out and comprehensive

[1] US Government Printing Office. *Clean Air Act Amendments of 1990.* Washington, DC. 1990.

regulatory programs. There are two categories of policy implementation tools the EPA has adopted, namely, preventive regulations and economic sanctions and rewards. Preventive tools include the punitive measures imposing on the CFCs producers if they violate the regulation of the EPA. Economic tools, in contrast, focus on stimulating firms to obey EPA regulations through market mechanisms, such as a pollution tax. In addition, environmental groups, such as the Natural Resources Defense Council (NRDC), play an important role in pushing the Act and awakening public concerns. At the same time, the CFCs producers have been striving to affect the EPA and Congress policy through lobbying.

Three Issues Under Study

Instead of focusing on the climatological phenomena associated with CFCs atmospheric pollution, the paper will aim at explanation and evaluation of the CFCs regulation policy, which has been exhibiting complicated and conflicting interactions among technological progress, governmental intervention, and the producers' interests. Attention will be placed, using the system dynamics modeling, on simulating the interaction between the EPA and the CFCs producers. Principal agent theory (agency theory)[2] is borrowed as the framework of analysis. In the ozone protection policy, EPA (the principal) delegated the CFCs producers (the agent) to achieve the CFCs production control (the contract).

First of all, the framework of the principal-agent model sketched like a systems archetype, is presented as the basis of further analysis (Figure 1).

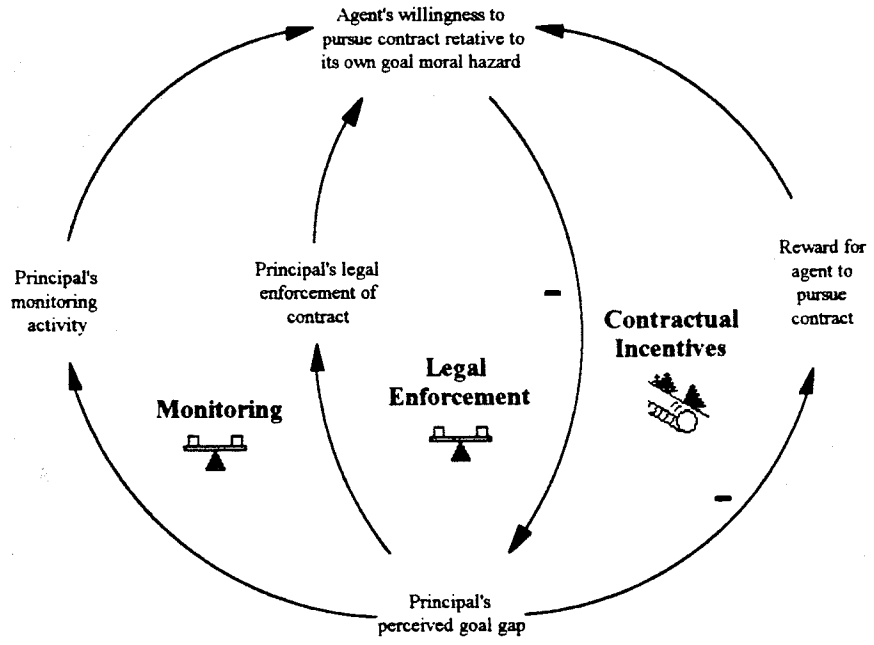

Figure 1: Principal-Agent Model as An Archetype

[2] Eisenhardt, Kathleen M. (1989). Agency Theory: An Assessment and Review. *Academy of Management Review*. 14(1): 57-74.

The paper then focuses on the three mutually related issues: 1) how EPA, in hope of the CFCs producers' following the regulation, executed incentive and monitoring activities, e.g., inspection, subject to cost constraint, 2) how the producers decided the extent to which they followed the EPA's regulation based on their self-interested goal pursuing behavior, and 3) what eventually contributed to the policy of non-essential CFCs production control.

1. How did EPA implement the ozone protection policy?

As described in the preceding context, two categories of policy tools, the preventive ("stick") and economic ("carrot") tools have been adopted. The stick is reflected in two forms: EPA's monitoring activities and legal enforcement, as shown in the two goal-seeking loops "Monitoring" and "Legal Enforcement" in Figure 1. The carrot is designed as the incentives for the CFCs producers, as shown in the self-enforcing "Contractual Incentives" loop in the figure.

Comparing the effects of EPA's monitoring and regulation (preventive tool) and EPA's production tax (economic tool), it seems that the former presents more effective policy outcomes. Nevertheless, the study tentatively argues that, in the ozone protection policy, the effects of the preventive and economic implementation tools cannot be adequately evaluated since the lurking factors, the market mechanism and the producers' technological advance as detailed later in the third issue, has dominated the effects of both tools and caused possible spuriousness in evaluating the implementation tools.

2. How did the CFCs producers behave based on their self interests?

In 1987, the EPA initially announced a CFC phase-out schedule to regulate that the producers decrease their non-essential CFCs production year by year and eventually stop non-essential CFCs production by 2000. Surprisingly, the producers chose to support and even advocate an accelerated schedule that totally prohibited non-essential CFCs production by 1995. Did the EPA's regulation itself, such as legal enforcement and monitoring, make this progress? One might tend to argue that the CFCs production policy was successful because the producers were regulated and monitored by EPA based on the law. However, many cases in the public regulation policy area show that public intervention is not always effective.

Accordingly, the ground on which the CFCs producers' behavior is based becomes a critical issue. The principal-agent model, as shown in Figure 1, implies a decision lever for the CFCs producers - "Agent's willingness to pursue contract relative to its own goal." The paper proposes that whether the producers obey (or even accelerate) the regulation policy depends on their perception of relative importance of EPA's regulation and its own profit-maximizing goal, which is initially assumed conflicting with the regulation. As explicated in the archetype, the resource allocation decision incorporates three aspects of concerns from EPA's legal enforcement power, EPA's monitoring capacity, and the reward accompanying the regulatory policy.

3. What eventually contributed to the policy of non-essential CFCs production control?

System dynamics modeling further helps to identify the dominant structures underlying the ozone protection policy: Initially EPA's regulation on non-essential CFCs production did result in profit loss and resistance of the producers. The resistance is reflected, as described earlier, in the top element "Agent's willingness to pursue contract relative to its own goal" in Figure 1. When the reward to follow EPA's regulation cannot offset the profit loss, the producers may choose to remain producing excessive non-essential CFCs and risk violating EPA's regulation unless EPA improved its monitoring capacity and intensified the legal enforcement. The phenomenon is actually the moral hazard in the literature of agency theory. While EPA's monitoring and legal enforcement culminated, the producers had to, though reluctantly, decrease non-essential CFCs production and adjust their assembly lines to produce CFCs substitutes.

However, the reluctant behavior cannot alone explain the development of the CFCs production control policy. In the progress of the policy implementation, consumers' increasing demand for CFCs substitutes and the producers' decreasing cost to produce CFCs substitutes based on technological advance had been gradually leading to the producers' net profit. The CFCs producers turned to be happy to cooperate with the EPA's regulation for non-essential CFCs production and adjust their assembly lines to produce more profitable CFCs substitutes. The positive feedback loop "Contractual Incentives" at this point actively enforces the producers' willingness to follow EPA's regulation. More crucially, the dominant "Reward for agent to pursue contract" in this situation is not the EPA's economic implementation tool, such as tax deduction, as specified in the first issue. Rather, it is the CFCs producers' profitability that drives their willingness to accelerate the production control.

In this sense, the whole CFCs regulatory policy seems like that EPA just initiated the policy. In a short term, the CFCs producers would resist the production control due to the profit loss (moral hazard) and EPA had to implement the policy by monitoring and legal enforcement. Nevertheless, when the producers perceived producing CFCs substitute is more profitable than non-essential CFCs, they would allocate more resources to produce CFCs substitute and eventually followed EPA's regulation.

As a result, in the long run self-interested incentives of the CFCs producers, superior to EPA's regulation and monitoring, mostly contributes to the "successful" CFCs regulatory policy. In this perspective, the paper would hesitate to conclude that the ozone policy is truly effective because the cost burden to protect the ozone layer largely imposes on the consumers of CFCs and their substitutes.