THREE ESSAYS ON ASYMMETRIC INFORMATION AND PUBLIC POLICY: INFORMATION, THE ENVIRONMENT, AND THE PROVISON OF DEFENSE GOODS

by

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ABSTRACT

This dissertation provides a theoretical and empirical examination of the asymmetric information problem and its consequences in public policy. In particular, we explore the effects of asymmetric information on the environmental regulation, the environmental Kuznets curve, and the provision of defense goods, respectively.

The first chapter develops a positive theory of pollution tax under the assumptions of asymmetric information and regulator's rent-seeking. We find that politically determined pollution tax is different from the Pigouvian tax, in that many factors contribute to bias in environmental regulation. Votes held by the polluting industry, consumers' stake in industry, regulator's stake in industry, and information gap provide the regulator with motivation to set up a less stringent regulation.

The second chapter investigates the empirical relationship between information, freedom and the environment. We build our basic model by replicating Antweiler et al.'s (1998) model, and introduce six information indicators and the freedom variable to the basic model. Our estimates indicate that a 1% increase in freedom reduces the annual SO_2 concentration by approximately 0.05-0.12%, and a 1% increase in information results in approximately 0.001 to 0.05% decreases in SO_2 ambient. The environmental Kuznets curve gets flatter and shifts down after we introduce information and freedom to the basic replicated models.

The third chapter develops a political economic model of taxation in national defense under the assumptions of asymmetric information and representativeness, and draws its implications in the provision of defense goods. Our findings suggest

that: 1) the optimal supply of defense goods is not likely to be achieved even under the perfect information setting due to the regulator's rent-seeking and group interests, 2) the asymmetric information between the consumers and politician causes the problem of oversupply of defense goods, 3) but democracy alleviates the oversupply problem in defense by narrowing the information gap.

These results suggest that it is important for consumers to narrow information gap between the regulator and them, because the asymmetric information problem produces inefficient results in the environment and national security.

CHAPTER 1: A POLITICAL ECONOMIC MODEL OF ENVIRONMENTAL REGULATION: GROUP INTERESTS, ASYMMETRIC INFORMATION, REPRESENTATIVENESS, AND POLLUTION CONTROL

ABSTRACT

This paper develops a positive theory of pollution tax under the assumptions of asymmetric information and regulator's rent-seeking behavior. We find that politically determined pollution tax is different from the Pigouvian tax, in that many factors contribute to 'bias' in environmental regulation. Our findings suggest that toxicity, exposure, the number of votes in consumer group, future expected salary of a regulator, and representativeness are expected to contribute to a more stringent pollution tax. By contrast, votes held by the polluting industry, consumers' stake in industry, regulator's stake in industry, and information gap provide the regulator with motivation to set up a less stringent regulation.

Our theory is a more unified framework in that it reproduces the previous theoretical findings and incorporates them into a 'bigger picture'. Furthermore, some new features are added (for instance, consumers' stake and regulator's stake in polluting industry), and institutional variables such as an information gap between regulator and consumers and representativeness are included in the framework, which the previous literature did not touch.

1. INTRODUCTION

The regulator's motives in regulating externality have been in question for decades in the group interest theories of regulation. A normative theory suggests that the regulator is expected to impose a regulation on the party who causes the externality problem (polluter), so that he/she maximizes public welfare. The theoretical basis of this idea is the Pigouvian tax and it provides "the polluter pays principle". Positive theorists have challenged this traditional view, and they see regulators are not necessarily unselfish individuals. And at times, regulators may seek self-interest from the office using their authorities as a tool.

For the positive theorists, the direction of bias became a more important question; whom does the regulation protect? The first answer was "producer protection" or "capture theory", meaning that producers tend to capture regulations and accordingly, the government policies are biased in favor of producers (Mancur Olson, George Stigler). This view was too simplistic to explain the changeable characteristics of bias in regulation. The second answer came from Peltzman, who suggests that the bias is conditional; the motive of regulator is to earn majority votes, and the regulator balances the political support from multiple interest groups. The third view places more emphasis on 'wealth' than 'political support'. The regulator is interested in earning wealth, and a vote is merely an instrument to achieve this goal. Now, the government itself is another interest group who maximizes its own objective function by regulation. The direction of bias is determined not only by votes, but also by contribution, rents, or bribes.

The group interest theories of regulation have at least two limitations. First, regulation can be an outcome of an asymmetric information problem between consumers and the regulator, in that regulators may have more information on the externality than the consumers. If the members of a potential losing group are fully informed, and thus, are well aware of the possible loss from regulations, they may cause high political costs and then the regulator may not be able to achieve the intended outcome from regulations. Then, although the findings of current positive theories of regulation are possible under an asymmetric information case, existing research has paid little attention to the asymmetric information problem.

Second, along with the asymmetric information problem, political institutions must be a crucial factor that influences the government to determine the strength of regulations. The interest group theory of regulation has evolved from the Pigouvian tax, a pure economic consideration of externality regulation, to the positive theories, more complicated systems where political actors interact with each other to influence the outcome of regulation. Then, the political institutions should also be considered as a determinant of regulatory outcome in that the characteristics of political actors are shaped by it.

The purpose of this study is to incorporate these missing elements into a more unified framework. Introducing asymmetric information and representativeness in the 'wealth approach', we reproduce most of the previous theoretical findings, and we add new determinants of the stringency of regulation. In our framework, the regulator is assumed to be an incumbent whose objective is to maximize the present value of his wealth from the office. His wealth consists of current salary, current rents, and expected future income. The regulator's policy tool is a pollution tax, which transfers welfare from one interest group to another: to consumers from firm, or vice versa. Consumers suffer from a firm's pollution, and they determine the level of political support according to the regulator's tax setting. Votes will decide whether the incumbent will be reelected in the future and thus affect the incumbent's future income. The firm, the polluter, provides contribution or bribe to politicians to seek producer protection. Under this setting, we draw main previous findings under the full information case and extend the system into the asymmetric information case that is a more unified model of regulation.

In their paper on political economy of trade policy, Grossman and Helpman (1994) describe why free trade is rarely practiced in reality.

> When asked why free trade is so often preached and so rarely practiced, most international economists blame "politics". In representative democracies, governments shape trade policy in response not only to the concerns of the general electorate, but also to the pressures applied by special interests. Interest groups participate in the political process in order to influence policy outcomes. Politicians respond to the incentives they face, trading off the financial and other support that comes from heeding the interest groups' demands against the alienation of voters that may result from the implementation of socially costly policies (Grossman and Helpman, 1994: 833).

The efficiency of the Pigouvian tax is also widely accepted in environmental economics, but it is rarely applied to the real world. Examining this problem from a new perspective (asymmetric information, representativeness, and the regulator's wealth), we find that politically determined pollution tax is different from the Pigouvian tax, in that many factors contribute 'bias' in environmental regulation.

The paper is organized as follows: section 2 reviews the related literature, section 3 introduces a model of regulatory stringency and derives hypotheses, and section 4 presents conclusions and implications.

2. REVIEW OF LITERATURE

2.1 Protection of Single Interest Group

2.1.1 Normative theory: the Pigouvian tax and Consumer Protection

Modern normative analysis of pollution control originates from Pigou's *Economics of Welfare*, where he describes the externality problem and prescribes the solution. Pigou (1932) describes externality as follows:

> One person A, in the course of rendering some service, for which payment is made, to a second person B, incidentally also renders services or disservices to other persons (not producers of like services), or such a sort that payment cannot be exacted from the benefited parties or compensation enforced on behalf of the injured parties (Pigou, 1932: 183).

The externality problem causes difference between the private and social costs, and Pigou suggests that the party causing damages should be forced to compensate the victim (Coase, 1960). Since it is impossible to compensate every individual affected by pollution, the polluting parties should have to pay the state that will then decide how to allocate and distribute the resulting funds. This is known as 'the polluter pays principle'.

Based on the polluter pays principle, the "Pigouvian tax" is proposed for pollution problem that is defined as following.

> A tax levied on each unit of a polluter's output in an amount equal to the marginal damage that it inflicts at the efficient level of production. The goal is to set the tax so that the polluter incorporates the social cost (Cropper and Oates, 1992: 680).

In the Pigouvian tradition, Baumol (1972), Baumol and Oates (1971), and others supported the idea of using the Pigouvian taxes for reducing environmental externalities, because of its efficiency.

Cropper and Oates (1992) summarize the essence of the Pigouvian tax with a simple model. The basic relationships can be expressed in abbreviated form as:

$$U = U(X, Q) \tag{1}$$

$$X = X(L, E, Q) \tag{2}$$

$$Q = Q(E) \tag{3}$$

Where U is the utility of a representative consumer, X in equation (1) is consumption, Q is the level of pollution, X in equation 2 is a production function, L is input for producing X, and E is pollution results from waste emissions. The assumed signs of the partial derivatives are $U_X>0$, $U_Q<0$, $X_L>0$, $X_E>0$, $X_Q<0$, and $Q_E>0$. The utility of a representative consumer in equation 1 depends upon a vector of goods consumed X and upon the level of pollution Q. Pollution results from waste emissions E in the production of X, as in (2).

Maximization of utility subject to (2) and (3) produces a first order condition for a Pareto-efficient outcome;

$$\partial X/\partial E = -[\Sigma(\partial U/\partial Q\ \partial Q/\partial E)/(\partial U/\partial X) + \Sigma(\partial X/\partial Q\ \partial Q/\partial E)] \quad (4)$$

Equation (4) indicates that polluting firms should extend their waste discharges to the point at which the marginal product of these emissions equals the sum of the marginal damages that they impose on consumers and producers.

With this simple result, Cropper and Oates suggest such policy implications as following. "Polluting agents need to be confronted with a "price" equal to the marginal external cost of their polluting activities to induce them to internalize at the margin the full social costs of their pursuits. Such a price incentive can take the form of the familiar "Pigouvian tax," a levy on the polluting agent equal to marginal social damage" (Cropper and Oates, 1992: 680). They point out the tax results from the equation (4).

Although the notion of a Pigouvian tax is straightforward, there are shortcomings worth mentioning.[1] First, a Pigouvian tax is meaningful only when the regulator seeks to maximize public welfare. If the regulator's goal is to secure his/her own interest, the efficacy of a Pigouvian tax is seriously undermined. Second, in the framework of a Pigouvian tax, the consumers (victim) and producers (polluter) are assumed to be pure economic agents who do not wield their political forces to increase their group interests. Altogether, Oates' version of Pigouvian tax lacks

[1]Due to some problems, for instance, measurability problem, the Pigovian tax is rarely applied in practice.

interactions among social/economic agents that are important factors in determining the stringency of regulation.

2.1.2 Producer Protection: Positive Theory of Environmental Regulation

If regulators are rational and selfish, they may set up a regulation at the level where they can maximize their welfare (not the public's welfare), which is different from the perception of consumer protection. Economists and political scientists have asked whose interests are being protected by the regulation.

Mancur Olson (1965) states that relatively small sized groups are advantageous in group competition in that they are more homogeneous and can detect and punish the free riders. Accordingly, the producer groups are far better able to organize than are the consumer group, which implies that producers have higher chances in receiving protection from regulation.[2] Olson set forth a positive theory maintaining that the supply of public goods by interest groups would be sub-optimal (Mitchell and Munger, 1991).

Compared with Olson, the Chicago interest group theory of regulation introduced the government side that plays an important role in transferring wealth from one group to the other by regulation. In "Theory of Economic Regulation", Stigler (1971) provides a theoretical foundation of "producer protection view" (Peltzman, 1976), stating that regulation serves mainly for the producers, in

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[2] Olson didn't offer any views on government and regulation, which is said to be a drawback in his framework. See North (1979).

exchange for campaign contributions, votes, and future employment. This theory is known as the 'capture theory' of regulation, in that regulation tends to be captured by the producers. Moreover, similar to Olson, the industries with large numbers of producers have disadvantages in seeking group interest, because they have a free-rider's problem. Regulations by government could overcome Olson's free-rider problem as well as disguise the self-interest nature of that regulation.

A number of papers applied the "producer protection" to the environment and draws the conclusion that environmental regulations are biased in favor of the producers. Maloney and McCormick (1982) present empirical support for producer protection based on cotton dust standards and an air pollution ruling affecting smelters. They argue that the environmental quality regulation enhances the producer's wealth while it reduces the pollution problem by restricting access to common property at the same time. "Regulation not only corrects a resource misallocation, but it creates a scarcity rent as well" (Maloney and McCormick, 1982: 99).

The producer protection theory or capture theory has limitations in that the theory predicts that the (environmental) regulation is biased in favor of producers only and that the consumers are assumed to be passive, not protesting their welfare loss. Moreover, the theory presupposes that the producers are always the winning group in competition.

2.2. More General Positive Theories of Environmental Regulation

Legislators may serve not only for a single interest group, but mediate several groups' welfare for the legislator's self-interest. Then, what is the legislator's benefit from regulation? There are two approaches regarding this question. One is the political support approach. This approach assumes that the regulator seeks political support by making regulation that will result in welfare transfer from a winning group to a loosing group. Thus, the winners will provide votes, and the probability of reelection will be increased. The other is the wealth approach where the regulator seeks increases in personal or party's wealth. Increases in wealth are achieved by bribery, contribution to a political party, or increases in salary from office. The way we distinguish the two approaches—the political support approach and the wealth approach, is whether the regulator's objective function explicitly includes wealth.

2.2.1 Political Support Approach

In "A More General Theory of Regulation," Peltzman (1976) argues that regulators balance political support from multiple interest groups (not necessarily producers) from regulation, and must respond to the demands of consumers as well as the regulated. Consumers faced with the welfare losses by regulation may become discontent and vote against incumbents. The major political problem for regulator is to design an efficient regulation that can determine where "votes gained per dollar of price increase exactly offset votes lost among consumers" (Mitchell and Munger, 1991: 515). Although Peltzman (1976) mentions that the legislators are interested not only in votes, but contributions as well, the regulator in his model maximizes only votes for reelection.

In Peltzman's model, the politician's objective function is written as follows:

$M=M(W_1, W_2)$, where W_1 = wealth of group i, and where $M_i>0$.

This is maximized subject to a constraint on total wealth (V):

$V = W_1 + W_2 = V(W_1, W_2)$, where $V_i>0$, but where $V_{12}<0$.

That is, the total wealth to be distributed is limited: market failures aside, one group's wealth can be increased only by decreasing the other's. A politician's role is to transfer the wealth of a group to the other in order to maximize votes.

The majority generating function is

$M=M(p, \pi)$

Where p = price of the goods, π= wealth of producers, $M_p<0$ and $M_\pi>0$.

The political returns to higher π or lower p are assumed to be diminishing ($M_{pp}<0$, $M_{\pi\pi}<0$). The relevant constraint is given by the cost and demand conditions summarized by the profit function, $\pi = f(p, c)$ where $c=c(Q)$ = production costs as a function of quantity (Q), and $f_p\geq 0$ and $f_{pp}<0$, and $f_c<0$. The formal problem for a successful regulator then is to maximize the Lagrangian,

$L= M(p, \pi) + \lambda(\pi - f(p, c))$,

With respect to p, π and λ, which yields

$-M_p/f_p = M_\pi = -\lambda$.

This means, "the marginal political product of a dollar of profit (M_{π}) must equal the marginal political product of a price cut ($-M_p$) that also costs a dollar of profits (f_p is the dollar profit loss per dollar price reduction)" (Peltzman, 1976: 223).

Peltzman's conclusion is that the vote-maximizing regulator's choice of price level is neither the profit maximizing level of price (pro-producer that allows monopoly) nor socially efficient price (pro-consumer that allows perfect competition). Instead, the optimal choice is a mid-point between the two cases. When certain conditions change, the direction of bias also changes. For instance, regulation will tend to be more heavily weighted toward "producer protection" in depressions and toward "consumer protection" in expansions.

The political support approach of regulation has been applied to the environment for some decades and brought more explanatory power in the formation of environmental regulation. Compared with the producer protection theory, the literature based on the political support approach shows that environmental legislations serve not only for a single interest group, but mediate several groups' self-interests for political support.

Pashigan (1985) deals with a multiple environmental standards problem in the U.S. He focuses on the policy of prevention of significant deterioration (PSD), the policy that prohibits areas with air quality superior to the minimum national standards from permitting a significant deterioration of local air quality by placing limits on economic development. While areas with unduly low air quality are ordered to improve the air quality and to attain the minimum standards, other areas with the air quality superior to the minimum standards must prevent a significant deterioration of air quality. Examining the votes in the House on PSD policy, Pashigan states that opposition to PSD policy comes from the South, the West, and rural locations such as areas with higher growth rates and with generally superior air quality. PSD policy is opposed in these areas because it places limits on growth. The strongest supporters of PSD policy are northern urban areas, many of which have lower air quality and are not directly affected by the PSD policy. He concludes that the vote evidence suggests that at least some parts of the environmental protection program have been shaped by areas' self-interest.

Hahn (1990) develops a positive theory of environmental regulation where the regulator chooses regulatory instruments (such as market oriented permits and emissions fees) when the preferences of environmentalists and industry are conflicting. He assumes that the environmentalists and industry have preferences over both the nature of instruments used and the overall level of environmental quality. Environmentalists want the regulator to implement emissions fees, which are believed to be more effective in pollution control, while the industry favors market oriented permits by which it can increase profits. The regulator in his model is assumed to choose the regulatory instruments and the pollution level to maximize a linear combination of the utilities of environmentalists and industry. He argues that an increase in industry influence will increase the market orientation of the instrument (pollution permits that industry prefers to emissions fees) and less stringent regulation (for instance, decrease in fees).

In an article on free trade and environment, Antweiler, et al. (2001) introduces two groups of consumers, one that cares about the environment greatly (Green) the other that cares less about the environment (Brown). Similar to Hahn's model (1990), the regulator in Antweiler, et al. decides the pollution tax level by which he/she maximizes a linear combination of the utilities of environmentalists (green) and industry (brown). The stringency of environmental regulation depends on the weight of the environment group, and other economic conditions and government type.

The political approach of regulation provides more sophisticated aspects of interrelationship among the regulator and regulated, and other competing interest groups in terms of vote maximization. However, a question can be raised on the notion of regulator. Like other interest groups such as consumers and industry, the legislator's ultimate goal can be wealth rather than majority votes, and accordingly, vote seeking can only be the regulator's instrumental and partial objective (Hirshleifer, 1976). McChesney (1997) points out that a regulator is another interest group and when the regulator transfers wealth from one group to another, the regulator may also have financial gains. If the regulator's objective is wealth, and majority vote is just an instrument to achieve that, the explanatory power of political approach on regulation must be insufficient.

2.2.2 Wealth Approach

While the political approach depicts the regulator as a passive individual who supplies legislation with an expectation of reelection, the wealth approach assumes politicians as more active rent-seekers who play the role of broker transferring wealth and extort rents by regulation. Accordingly, the regulator's objective is to increase his/her total wealth, rather then just increasing political support by regulation.

Rent is defined as "a return in excess of a resource owner's opportunity cost" (Tollison, 1982: 575). The origin of rent and rent-seeking studies dates back to Tullock (1967) and Ann Krueger (1974) (Mitchell and Munger, 1991: 523).

Based on these original works, there has been a large volume of papers on rent seeking in various directions such as strategic rent seeking (Tullock, 1980), and tariffs versus quotas as objects of rent seeking (Bhagwati and Srinivasan, 1980), etc. Mitchell and Munger (1991) summarize the basic propositions of rent-seeking theory as follows (Mitchell and Munger, 1991: 525).

1) The expenditure of resources to gain a transfer is itself a social cost.
2) The resulting market privileges or rents represent a welfare loss on consumers and taxpayers.
3) Legislations or policy instruments by which rents are created are designed to conceal the gains (for instance, subsidies, tax, and tariffs).

Grossman and Helpman (1994) develop a model in which special-interest groups make political contributions in order to influence an incumbent, the government's choice of trade policy. Politicians maximize their own welfare, which depends on the total contributions collected and on the welfare of voters. The government's objective function is $G= C(p) + aW(p), a\geq 0$, where C is the contributions from an interest group, W represents aggregate gross welfare, a is a weight, and p is a domestic price, the choice variable. Grossman and Helpman argue that the manner of campaign and party finance in many democratic nations creates powerful incentives for politicians to "peddle" their policy influence. Then the structure of trade protection is bound to reflect the outcome of a competition for political favors.

Influenced by Grossman and Helpman (1994), Fredriksson (1997) develops a model explaining the pollution tax policy outcomes in a small open economy. He assumes that a self-interested government cares not only for the aggregate welfare, but also political contributions received from lobby groups, which is the same assumption in Grossman and Helpman (1994). The weight is given to political donations in the government's objective functions, and the regulator maximizes the government's objective function (wealth) by deciding on the optimal level of pollution tax. Fredriksson shows that the pollution tax rate is increasing in the world market price, ambiguous in lobby group membership, and that the deviation from the optimal tax rate diminishes as the importance of lobbying activities is reduced.

2.3 Toward a More General Framework

Recently, a number of studies have dealt with asymmetric information problem (between voters and the government) and political institutions in the economics of environmental regulation.[3] Seldon and Terrones (1993) present a voting model of environmental legislation under the asymmetric information problem. They assume that voters are unable to observe the incumbent's "regulatory

[3] Laffont (1991, 1994) deals with asymmetric information between congress (principal) and the regulated industry, but we are more interested in asymmetry between voters and the regulators on the nature of externality.

zeal" (i.e., the level of regulation imposed by the incumbent), until the end of the period, when they observe the resulting environmental quality. They argue that if legislated abatement standards are more readily observable than their costs, the legislator will be motivated to set up an overly strict environmental legislation for election. On the other hand, if current consumption is more readily observable than the government's regulatory zeal, then the environmental regulation will be less stringent.

Seldon and Terrones' work falls into the 'political approach' in our category of positive theory, because the regulator maximizes votes by regulation. The limitation of their model is previously stated; the regulator's ultimate goal in office may be gaining personal wealth rather than vote maximization, and accordingly, the theory has insufficient explanatory power on the stringency of regulation.

On political institution and environmental regulation, Congleton (1992) introduces a median voter approach to the environment and argues that the stringency of environmental regulation depends on the political institution. The authoritarian ruler seeks self-interest, and tends to install a less stringent pollution control, while the counterpart in democracy favors a more stringent one, because he/she represents the median voter's preference. But, the problem of Congleton's model is that it is too simplistic. The regulators in democracy do not necessarily seek public (median voter) interest, as we have discussed so far, and by the same token, an authoritarian ruler may not always seek self-interest.

We present a model of environmental regulation, which incorporates asymmetric information among voters and regulator and political institution into the wealth approach of environmental regulation in the next section.

3. MODEL

In this section we present a simple model of interaction among three interest groups such as producers (polluter), consumers (sufferer), and a politician, within a rent-seeking context. This enables us to consider the effects of changes in the exogenous parameters of the model on the control variables.

3.1 Producers

Firms maximize profit by producing q in our model. q is the quantity of a good, and we assume that production of q generates r, a release of a byproduct. The total amount of byproduct r is a function of production level q, $r=r(q)$, where $\partial r/\partial q>0$.

The byproduct r may or may not be harmful to human body, and we denote z as the level of disamenity that r causes. The disamenity z is assumed to be a function of r, toxicity s, and the level of exposure a to pollutant, $z=z(r(q), s, a)$, where $s \geq 0$, $a \geq 0$, $\partial z/\partial r>0$, $\partial z/\partial a>0$, and $\partial z/\partial s>0$. In particular, we assume that z is a function of $asr(q)$, $z=z(asr(q))$. If s or a is 0, r has no local effects.

Given that s and a are positive numbers, production q decreases a third party's welfare, and the government imposes a pollution tax to the firm to reduce the externality. We denote the pollution tax as t, and a typical firm's profit function is π

$= kq - e(l, q) - tq$ where k is the unit price of q, e is the cost function of producing q, l is the vector of unit costs of inputs associated with production q where l is positively related to the cost function, and t is the pollution tax. The pollution tax, t, is the Pigouvian tax in that the externality is internalized according to 'the polluter pays principle'.[4] The purpose of pollution tax t is to increase the producer's production cost, so that it reduces z.

Firm's decision on q depends on price k, the vector of costs of inputs l, and the pollution tax rate t ($q=q(k, l, t)$, where $\partial q/\partial k>0$, $\partial q/\partial l<0$, and $\partial q/\partial t<0$).

3.2 Consumers

Assume that consumers constitute the largest group in an economy, and each consumer maximizes utility. Every consumer has well-behaved preferences and maximizes their utility. The consumers' utility is a function of consumption and environmental disamenity (Antweiler, Copeland, and Taylor, 2001).

$u = u(c, z)$, subject to $I=pc$

Where c is the consumption levels of goods and services, I is income, p is a price of consumption goods, and all income is spent on consumption, c. The utility function u is assumed to be concave in consumption $u_c>0$, $u_{cc}<0$. Environmental disamenity is negatively related to the utility function $\partial u/\partial z<0$.

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[4] Note that the pollution tax t is not imposed on the level of disamenity z, directly, but on the production level q. The disamenity z is determined not only by quantity $r(q)$, but also by quality s, and the regulator may not be able to impose pollution tax on z, because it has no unit. Cropper and Oates (1992) point out that the pollution tax should be imposed directly on the pollution activity and not on related activity such as output or input. However, they mention that indirect imposition of pollution tax to output is also the Pigovian tax.

In our setting, we assume that an average consumer is a stockholder of a polluting firm and the consumer's income consists of capital gain from investing in the polluting firm and other earnings. The capital gain is assumed to be a dividend of the polluting firm's profit, and other earnings are from other sources of income that are not related to the polluting firm, for instance, inheritance, government transfer, and consumer's wage or salary from non-polluting firm falls into this category.

Let g be the dividend of profit from the polluting firm, then $g\pi$ is the consumer's capital gain, where g is $0 \leq g \leq 1$. And let w be the consumer's other earnings that is exogenously given. The consumer's income I is $I = g\pi + w$, where g is $0 \leq g \leq 1$. This function indicates the level of consumer's economic dependency on the polluter's profit; if g is 0, the consumer's income is independent from the polluting firm, if g gets larger, the consumer has a higher stake in the polluting industry.

Now, the consumer's utility and budget constraint is,

$U=u(c, z)$ subject to $I=pc$, where $z = z(asr(q))$ and $I=g\pi+w$.

Then, consumption c is a function of price level p and income I, $c=c(I, p)=c(g\pi, w, p)$.

3.3 Regulator

3.3.1 Regulator's Wealth Maximization under Full Information: A Benchmark

Regulator's role in our model is to identify environmental risks and lessen them by implementing policy measures. The regulator is assumed to be an incumbent who seeks to maximize his welfare similar to the other interest groups in this economy.

In consumers' utility function, $u(c, z)$, z is the externality results from the firm's profit seeking, $\pi = kq - e(l, q) - tq$, where z is $z(sr(q))$, and the regulator sets pollution tax t to reduce the disamenity z. By doing so, the incumbent balances political support from each interest group and increases probability of reelection (Pelzman, 1976). In this section, we assume that consumers, firms, and the regulator have full information on the toxicity s.

Imposition of pollution tax t changes the firm's production level q (now q is $q(k, l, t)$), and we redefine the firm's profit function and consumer's utility in the regulator's perspective as follows.

$$\pi = kq(k, l, t) - e(l, q(k, l, t)) - tq(t, l, k) \quad (5)$$

$$u = u(c, z), \text{ where } c = c(I, p),\ I = g\pi + w,\ z = z(asr(q(k, l, t)) \quad (6)$$

We assume the consumers' political support for the incumbent depends on the changes in utility; an increase in utility leads to a greater political support, while a decrease in utility causes opposition to the politician. In equation (6) above, a pollution tax will decrease the firm's production q, and in turn, it will reduce r and z. Smaller z will increase the consumer's utility. However, smaller q will reduce the firm's profit, consumer's capital gain, and consumption, resulting in a decrease in utility. Consumer's net political support depends on the net change in utility: utility gain minus utility loss from taxation.

Similarly, the firms' political support for government is based on the change in profit; an increase (decrease) in profit leads to political support (opposition) for the politician.

Denote political support as μ that is an index between 0 and 1. 0 means no votes and 1 means that incumbent earns 100% support from the voters where voters include consumers and firms. We assume that μ is a function of political support from consumers L and that from producer F, meaning that incumbent seeks votes from both interest groups, as explained above. In turn, L and F are assumed to be the functions of consumers' utility and firms' profit, respectively, where $\mu=\mu(L(u), F(\pi))$, $\partial L/\partial u>0$, and $\partial F/\partial \pi>0$.

We assume that the regulator's wealth consists of salary and rent. While salary is the incumbent's remuneration for his office, and rent is assumed to be the regulator's stake in the polluting industry. We denote that the regulator's salary at period 0 (before the election) as y, and his salary at period 1 (after the election) as y_1. In addition, we denote G as the regulator's share of firm's profit, where G is $0 \leq G \leq 1$. The parameter G is the regulator's legal or illegal extractions from the firm's profit meaning it can be a reward from protecting the producer, which takes the form of political contribution or bribe. Or it can be the regulator's capital gain from investing in the polluting firm as a stockholder. The regulator's rent at period 0 is $G\pi$, and his rent at period 1 is $G\pi_1$. Then, the regulator's wealth at period 0 (before the election) is $y + G\pi$, while that at period 1 (after the election) is $y_1 + G\pi_1$. Since the result of reelection is uncertain at period 0, we introduce expectation $E[.]$, and the politician's expected wealth after election is $E[y_1 + G\pi_1]$.

We assume that $E[.]$ depends on the political support from consumers and firms (Appelbaum and Katz, 1987), and the incumbent maximizes net votes (votes from one interest group minus opposition from the other group, see Peltzman) by imposing a pollution tax on the firms. More votes increase the probability of reelection.

The politician's optimization problem is to maximize the wealth (W) by choosing t:

$$W = [y + G\pi(t)] + \beta\mu(t)[y_1 + G\pi_1]$$

Where y and y_1 are the politician's salary before and after the election; 1 denotes the term after the election.

G is the regulator's share of the firm's profit,

β is a discount factor,

$\mu = \mu(nL(u(c, z)), (N\text{-}n)F(\pi))$,

$c = c(p, I(g\pi, w))$,

$z = z(asr(q))$,

$\pi = kq - e(l, q) - tq$,

$q = q(t, l, k)$,

N is the number of voters in the society,

n is the number of voters in a consumer group.

The first order condition is,

$W_t = G\pi_t + \beta\mu_t[y_I + G\pi_I] = 0.$

Where $\pi_t = kq_t - e_q q_t - (q + tq_t),$

$\mu_t = n(g\mu_L L_u u_c c_\pi \pi_t + as\mu_L L_u u_z z_r r_q q_t) + (N\text{-}n)\mu_F F_\pi \pi_t.$

Note that π_t is non-positive ($\pi_t \leq 0$), which means the marginal effect of pollution tax to the firm's profit is negative or zero.

$\pi_t = kq_t - e_q q_t - (q + tq_t) = (k - l - t)q_t - q$, where l is an input price ($\partial e/\partial q = l \geq 0$). Because $(k - l - t)$ is positive or zero and q_t is negative, the π_t carries a non-positive sign ($\pi_t \leq 0$).

The term, $G\pi_t$, is the marginal decrease in the regulator's rent due to a pollution tax on the firm. There are three terms in μ_t, which represents net votes resulting from the pollution tax. The first and third terms of μ_t, $ng\mu_L L_u u_c c_\pi \pi_t$ and $(N\text{-}n)\mu_F F_\pi \pi_t$ are the marginal loss in political support from consumers and the firm by imposing the pollution tax. The second term $nas\mu_L L_u u_z z_r r_q q_t$ is the marginal increase in political support from the consumer group by taxation. Overall, W_t shows the marginal benefit and the cost of pollution tax that capture the changes in the regulator's expected income due to the changes in the net public support. The regulator's optimal policy balances the effects above.

The second order condition is,

$W_{tt} = G\pi_{tt} + \beta\mu_{tt}[y_I + G\pi_I] < 0$

Where $\pi_{tt} = kq_{tt} - e_q q_{tt} - (q_t + q_t + tq_{tt})$,

$\mu_{tt} = n[g\mu_L L_u u_c c_\pi \pi_{tt} + as\mu_L L_u uz_r r_q q_{tt}] + [(N-n)\mu_F F_\pi \pi_{tt}]$.

3.3.2. Comparative Statics: Full Information Case

In this section, we examine the effects of changes in various parameters on the control variable. The following results are obtained.

3.3.2. A. Toxicity, Exposure and the Stringency of Pollution Tax

$dt/ds = a\beta ny_1(\mu_L L_u u_z z_r r_q q_t)\lambda > 0$

$dt/da = s\beta ny_1(\mu_L L_u u_z z_r r_q q_t)\lambda > 0$

Where $\lambda = [-1/W_{tt}] > 0$.

A higher degree of toxicity will motivate the regulator to set up a more stringent pollution tax. If the toxicity of a pollutant increases, the political support from the consumer group will shrink, because the public welfare decreases. The regulator will seek more votes by imposing a more stringent pollution tax on the firm. This is the result that the Pigouvian tax suggests. Although the result is same with that of the normative theory, our result shows different interpretation; while the Pigouvian tax suggests that a regulator imposes a stringent regulation for public welfare, our theory shows that a regulator does it for his self-interest. Similarly, increased pollutant exposure to the public will lead to a stringent regulation in environment.

3.3.2.B. The Regulator's Stake in Polluting Firm

$dt/dG = [\pi_t + \beta\mu_t\pi_l]\lambda >=< 0,$

Where $\lambda = [-1/W_{tt}] > 0,$

$\pi_t = kq_t - e_q q_t - (q + tq_t) < 0,$

$\mu_t = n[g\mu_L L_u u_c c_\pi \pi_t + as\mu_L L_u u_z z_r r_q q_t] + [(N\text{-}n)\mu_F F_\pi \pi_t],$

$\pi_l > 0.$

The first term π_t is negative, while the second term $\beta\mu_t\pi_l$ is ambiguous. In the second term, μ_t is $n[g\mu_L L_u u_c c_\pi \pi_t + as\mu_L L_u u_z z_r r_q q_t] + [(N\text{-}n)\mu_F F_\pi \pi_t]$, and only $as\mu_L L_u u_z z_r r_q q_t$ is positive, while the rest are negative. The term $as\mu_L L_u u_z z_r r_q q_t$ is the marginal increase in political support from the consumer group by taxation, and if it is not high enough to offset the rest, the whole sign of dt/dG is negative. Hence, if the regulator has more stakes in the pollution industry, it will lead to a less stringent pollution control, in general. However, this result gets ambiguous when the consumers' political support gets responsive to the pollution tax level.

The parameter G is the regulator's legal or illegal extractions from the firm's profit. It represents the regulator's rent, political contribution from the industry, or the regulator's financial gain from investing in the polluting firm as a stockholder. In this sense, our comparative statics result (dt/dG is negative) is realistic. If the regulator's wealth is keenly related to the profit of polluting industry, he may not endeavor to set a stringent pollution tax that will decrease his wealth.

3.3.2.C. Consumer's Stakes in Polluting Industry

$dt/dg = [n\mu_L L_u u_c c_\pi \pi_t]\lambda < 0$, where $\lambda = [-1/W_{tt}] > 0$.

Higher consumers' stakes in the polluting industry cause a less stringent pollution tax. Compared to *dt/dG*, the result of *dt/dg* is more clear-cut. If the consumers are financially dependent on the polluting firm's profit, they will allow less stringent pollution regulation.

3.3.2. D. The Regulator's Salary after the Election and Pollution Tax

$dt/dy_1 = (\beta\mu_t)\lambda >=< 0$, where $\lambda = [-1/W_{tt}] > 0$.

The parameter β is positive by assumption, but μ_t is ambiguous. As explained above, μ_t is $n[g\mu_L L_u u_c c_\pi \pi_t + as\mu_L L_u u_c c_z z_r r_q q_t] + [(N-n)\mu_F F_\pi \pi_t]$ and the first and second terms of it are the consumer's marginal net support, while the third term is the firm's marginal support. The first and third terms are negative, in that they are the marginal loss of pollution tax. The only positive term in the equation is the second term, $as\mu_L L_u u_z z_r r_q q_t$ that is the marginal support from the consumer group.

If a pollution tax results in an increase in public support, both μ_t and dt/dy_1 is positive, which proves that higher salary motivates the regulator to set up a more stringent pollution policy. However, if μ_t is negative, meaning that a pollution tax results in a political loss, the sign of dt/dy_1 is negative. In this case, a higher future salary causes a less stringent regulation.

In sum, if the regulator's salary after the election is high enough, the regulator is not likely to risk his job by setting a biased pollution tax. This tendency can be enhanced when the consumers' political support is more responsive to the utility loss from pollution. A previous study also draws the same findings. Appelbaum and Katz (1991) show that a higher salary motivates the regulator to avoid rent-seeking activities.

3.3.2.D. Votes in Consumer Group and Pollution Tax

$$dt/dn = \{\beta y_1(g\mu_L L_u u_c c_\pi \pi_t + as\mu_L L_u u_z z_r r_q q_t) - \beta y_1 \mu_F F_\pi \pi_t\}\lambda >=< 0$$

Where $\lambda = [-1/W_{tt}] > 0$ and $\pi_t < 0$.

The first term $\beta y_1(g\mu_L L_u u_c c_\pi \pi_t)$ is negative, and the second and third terms $\beta y_1(as\mu_L L_u u_z z_r r_q q_t)$ and $-\beta y_1(\mu_F F_\pi \pi_t)$ are positive. It is unclear whether more votes in the consumer group results in a more stringent regulation. If the marginal loss of consumers' votes from the pollution tax (the first term; $\beta g\mu_L L_u u_c c_\pi \pi_t$) is ignorable, dt/dn is positive. It means that if the number of consumers who are financially independent from the polluting industry increases, the pollution tax will be more stringent.

This result supports Mancur Olson's (1965) claim that more homogenous interest groups are advantageous in group competitions. If $\beta g\mu_L L_u u_c c_\pi \pi_t$ gets smaller, the consumer group will be more homogeneous in terms of stakes in the pollution industry, and then dt/dn is more positive. By contrast, if $\beta g\mu_L L_u u_c c_\pi \pi_t$ gets larger, the consumer group will be more heterogeneous, and then the sign of *dt/dn* gets ambiguous.

3.3.2.E. Votes in Polluting Industry

$$dt/d(N\text{-}n) = \beta y_1(\mu_F F_{\pi}\pi_t)\lambda < 0, \text{ where } \lambda = [-1/W_{tt}] > 0$$

More votes in the polluting industry will lead to a less stringent pollution control. Compared to *dt/dn*, the sign of *dt/d*(*N-n*) is clearly negative, which means that more votes in the polluting industry is more likely to result in a less stringent regulation. This result also supports Mancur Olson's (1965) argument that relatively small sized groups are advantageous in group competition because small groups are more homogeneous. The industry will (may) be smaller but more homogeneous than the consumer group, meaning votes from the industry will (may) be more effectively delivered to the regulator than votes from the consumer group.

Table 1.1 summarizes the comparative static results under the full information model and the comparison with previous theories. The findings of this paper are consistent with those in the previous literature.

Table 1.1: Findings and Comparisons in the Full Information Model

<table>
<tr><th>Determinants of stringency of regulation</th><th>Prediction of the previous theories</th><th>Prediction of this paper (A benchmark model)</th></tr>
<tr><td>Toxicity and Exposure</td><td>+
The Pigouvian Tax</td><td>+</td></tr>
<tr><td>Group size (number of votes in consumer group)</td><td rowspan="2">–
(Marginal effect of group size is negative)
Olson, Stigler</td><td>+
(Conditional)</td></tr>
<tr><td>Group size (number of votes in industry)</td><td>–</td></tr>
<tr><td>Consumers' stake in industry</td><td>NA</td><td>–</td></tr>
<tr><td>Future salary of the regulator</td><td>+
Appelbaum and Katz</td><td>+</td></tr>
<tr><td>Regulator's stake in industry</td><td>NA</td><td>– (Conditional)</td></tr>
</table>

3.3.3 Regulator's Wealth Maximization under Asymmetric Information

We assume that an asymmetric information problem may arise in the environmental risk analysis, in that the regulator has more information on the level of toxicity of pollutants than the consumers. The asymmetric information problem enables the regulator to seek self-interest by imposing biased pollution tax rates on the firm.

For the regulator, risk assessment is an important step to reduce pollution emissions. It is essential to find the correct value of s with scientific knowledge. Once the positive value of s is proven, the regulator sets a pollution tax rate and imposes it on the producer in order to lessen the externality that the firm caused.

There are two types of environmental risks that are associated with toxicity, one is the real risk s that is known to the regulator (and the polluter) only, and the other is the consumers' perceived risk s^P that is made public by the regulator. The hyper script P denotes the 'perceived' toxicity. While the first type is an objective risk that needs scientific analysis, the second type is what politicians' interest is added to the observation of the real risk.

Denote the amount of information that the regulator has as i^R and that of the consumers as i^C. The hyper scripts R and C denote the regulator and the consumers. The information gap between the incumbent and voters is defined as the i^R-i^C, and we denote it as i, where $i \geq 0$. We assume that the information gap contributes to the inaccuracy in the risk assessment of consumers, and that i is related to the deviation between s and s^P. Let s^d be s-s^P, and then s^d is an increasing function of i, $s^d = s^d(i)$,

$\partial s^d/\partial i>0$. The hyper script d represents the 'deviation' between s and s^p. More information gap causes less accurate risk assessment. If s^d is positive $s^d>0$, the risk is underestimated $s>s^p$, however, when it is negative $s^d<0$, the risk is overestimated $s<s^p$. When no information gap exists (i=0), s is equal to s^p and s^d is zero.

The information gap may be an endogenous variable, and we assume that representativeness is negatively related to the asymmetric information problem. Regarding this point, Payne (1995) argues, "In democracies, citizens are free to gather and disseminate environmental information and lobby their government, individually or collectively, for ecological purposes" (Payne, 1995: 43). Denote d as representativeness, and then i is an decreasing function of d, $i(d)$, where $\partial i/\partial d<0$. Then, s^d is $s^d(\phi i(d))$, where ϕ is a shift parameter of information gap.

Here, we examine the case of risk underestimation $s^d>0$.[5] If s^d is positive, $s^d>0$ and $s-s^p>0$, then the information gap i is positively related to s^d, where $s^d\geq 0$, $\partial s^d/\partial i>0$.

We need to replace toxicity s with perceived toxicity s^p in the vote maximization model of full information case.

Consumer's perceived toxicity; $s^p = s - s^d(\phi i(d))$

Firm's profit; $\pi = kq(k, l, t) - e(l, q(k, l, t)) - tq(t, l, k)$ (5)

Consumer's utility; $u=u(c, z)$ (6)'

where $c=c(I, p)$, $I = g\pi+w$, $z=z(as^p r(q(k, l, t))$, $s^P = s - s^d(\phi i(d))$.

The regulator's optimization problem is to maximize the wealth (W) by choosing t: $W = [y + G\pi(t)] + \beta\mu(t)[y_1 + G\pi_1]$,

Where y and y_1 are the politician's salary before and after the election, respectively,

G is the regulator's share of the firm's profit,

β is a discount factor,

μ is $\mu(nL(u(c, z)), (N\text{-}n)F(\pi))$,

c is $c(p, I(g\pi, w))$,

g is the consumers' share of firm's stock,

z is disamenity $z(as^p r(q))$,

$s^p = s - s^d(\phi i(d))$,

d is democracy,

π and π_1 are firm's profit before and after the election, respectively,

π is $kq - e(l, q) - tq$,

q is $q(t, l, k)$,

π_1 is given,

N is the number of votes in the society,

n is the number of votes in a consumer group.

The first order condition is,

$W_t = G\pi_t + \beta\mu_t[y_1 + G\pi_1] = 0$

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[5] Risk distortion is a zero-sum game, in that one party's gain results from another party's loss, and we

Where $\pi_t = kq_t - e_q q_t - (q + tq_t)$,

$\mu_t = n[g\mu_L L_u u_c c_\pi \pi_t + a(s\text{-}s^d(\phi i(d)))\mu_L L_u u_z z_r r_q q_t] + [(N\text{-}n)\mu_F F_\pi \pi_t]$.

The first term $G\pi_t$ is the marginal cost of pollution tax and it captures the decrease in the regulator's capital gain. The second term $\beta\mu_t[y+G\pi]$ is the marginal benefit of pollution tax that captures the increase in the regulator's expected income due to the increase in the net public support. (In μ_t, $n[g\mu_L L_u u_c c_\pi \pi_t + a(s\text{-}s^d(\phi i(d)))\mu_L L_u u_z z_r r_q q_t]$ is the marginal gain of votes from the consumer group, while $[(N\text{-}n)\mu_F F_\pi \pi_t]$ is the marginal loss of votes from the polluting industry.) The regulator's optimal policy balances these effects.

The second order condition is,

$W_{tt} = G\pi_{tt} + \beta\mu_{tt}[y_I+G\pi_I] < 0$

Where $\pi_{tt} = kq_{tt} - e_q q_{tt} - (q_t + q_t + tq_{tt})$,

$\mu_{tt} = n[g\mu_L L_u u_c c_\pi \pi_{tt} + (s\text{-}s^d(\phi i(d)))\mu_L L_u u z_r r_q q_{tt}] + [(N\text{-}n)\mu_F F_\pi \pi_{tt}]$.

3.3.4. Comparison: Benchmark Model and Incomplete Information Model

The main difference between the benchmark model and the asymmetric information model is the toxicity s (in the benchmark model) and the perceived toxicity s^p (in the asymmetric information model). We assumed that the perceived toxicity s^p is s - $s^d(\phi i(d))$, which means that s^p is smaller than s - $s^d(\phi i(d))$, if information gap between the regulator and consumers exists (in this case, i is

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only need to examine one case.

positive). This change results in a smaller μ_t in the first order condition of the asymmetric information model. The first order conditions of the two models are,

$W_t = G\pi_t + \beta\mu_t[y_1 + G\pi_1] = 0$

Where $\pi_t = kq_t - e_q q_t - (q + tq_t)$,

$\mu_t = n[g\mu_L L_u u_c c_\pi \pi_t + as\mu_L L_u u_z z_r r_q q_t] + [(N\text{-}n)\mu_F F_\pi \pi_t]$: Full Info Model

$\mu_t = n[g\mu_L L_u u_c c_\pi \pi_t + as^p \mu_L L_u u_z z_r r_q q_t] + [(N\text{-}n)\mu_F F_\pi \pi_t]$: Incomplete Info Model

$s^p = s - s^d(\phi i(d))$.

If other things are being equal, and if i is positive, μ_t is smaller in the incomplete information case than in the full information case, because s^p is smaller than $s - s^d(\phi i(d))$, and $as\mu_L L_u u_z z_r r_q q_t$ is positive. This result (smaller μ_t in the asymmetric information model) means that in the asymmetric information case, the political support from consumers on taxation will be less elastic, because the consumers have insufficient information on toxicity. In other words, the regulator will have less political support from taxation in the asymmetric information case than in the benchmark model. Then the regulator will have less motivation to set up a stringent environmental regulation under the asymmetric information case. In the next section, we examine the effects of changes in parameters on the control variable regarding the asymmetric information problem in detail. In particular, we will focus on the changes in the previous comparative statics (in the full information model) due to the addition of the information gap.

3.3.5. Comparative Statics: Asymmetric Information Case

3.3.5. A. Representativeness, Information Gap and Pollution Tax

$dt/dd = \beta\mu_{td}[y_1 + G\pi_1]\lambda > 0$

Where $\mu_{td} = n\phi(-s^d_{;i}i_d)(\mu_L L_u u_z z_r r_q q_t) > 0$, and $\lambda = [-1/W_{tt}] > 0$.

$dt/d\phi = \beta\mu_{t\phi}[y_1 + G\pi_1]\lambda < 0$

Where $\mu_{t\phi} = n(-s^d_{\phi})(\mu_L L_u u_z z_r r_q q_t) \leq 0$, and $\lambda = [-1/W_{tt}] > 0$.

Greater representativeness leads to a more stringent pollution policy. In particular, according to our theory, the representativeness decreases the information gap, a source of the regulator's rent-seeking motives, which in turn, allows a more stringent pollution control. In other words, more information gap on toxicity between the regulator and the consumers leads to a less stringent environmental regulation.

3.3.5. B. Number of Votes in Consumer Group: Comparison with the Benchmark Case

$dt/dn = \{\beta y_1(g\mu_L L_u u_c c_\pi \pi_t + as^p\mu_L L_u u_z z_r r_q q_t) - \beta y_1\mu_F F_\pi \pi_t\}\lambda >=< 0$

Where $\lambda = [-1/W_{tt}] > 0$, $\pi_t < 0$, and $s^p = s - s^d(\phi i(d))$.

As shown in the full information model, the sign of dt/dn is ambiguous, again. The first term $\beta y_1(g\mu_L L_u u_c c_\pi \pi_t)$ is negative, and the second and third terms, $\beta y_1(as\mu_L L_u u_z z_r r_q q_t)$ and $-\beta y_1(\mu_F F_\pi \pi_t)$, are both positive. If the marginal loss of consumers' votes from the pollution tax (the first term; $\beta g\mu_L L_u u_c c_\pi \pi_t$) is ignorable, then dt/dn is positive. However, note that the term, $as^p\mu_L L_u u_z z_r r_q q_t$, was

$as\mu_L L_u u_z z_r r_q q_t$ in the full information model. The term $as^P\mu_L L_u u_z z_r r_q q_t$ is smaller than $as\mu_L L_u u_z z_r r_q q_t$, which means that the whole sign of dt/dn is less likely to be positive in the asymmetric information case than in the benchmark model.

This result can be interpreted as; more votes in the consumer group do not necessarily lead to a more stringent environmental regulation, especially when the asymmetric information problem exists. If the consumer group is more homogeneous (lower $g\mu_L L_u u_c c_\pi \pi_t$), more votes will result in more stringent pollution tax ($dt/dn > 0$). This coincides with Mancur Olson's (1965) claim that more homogenous interest groups are advantageous in group competitions. In addition, we find that the asymmetric information problem (higher $as^P\mu_L L_u u_z z_r r_q q_t$) will make dt/dn more ambiguous.

3.3.5. C. The Regulator's Stake in Polluting Firm: Comparison with the Benchmark Case

$dt/dG = [\pi_t + \beta\mu_t\pi_1]\lambda >=< 0$

Where $\lambda = [-1/W_{tt}] > 0$,

$\pi_t = kq_t - e_q q_t - (q + tq_t) < 0$,

$\mu_t = n[g\mu_L L_u u_c c_\pi \pi_t + as^P\mu_L L_u u_z z_r r_q q_t] + [(N\text{-}n)\mu_F F_\pi \pi_t]$,

$\pi_1 > 0$.

The first term π_t is negative, while the second term $\beta\mu_t\pi_1$ is ambiguous. In the second term, μ_t is $n[g\mu_L L_u u_c c_\pi \pi_t + as\mu_L L_u u_z z_r r_q q_t] + [(N\text{-}n)\mu_F F_\pi \pi_t]$, and only

$as\mu_L L_u u_z z_r r_q q_t$ is positive, while the rest are negative. The term $as^p\mu_L L_u u_z z_r r_q q_t$ is the marginal increase in political support from the consumer group by taxation, and if it is not high enough to offset the rest, the whole sign of *dt/dG* is negative. Hence, if the regulator has more stakes in the pollution industry, it will lead to a less stringent pollution control, in general. However, this result gets ambiguous when the consumers' political support gets responsive to the pollution tax level.

As explained in *dt/dn*, the term $as^p\mu_L L_u u_z z_r r_q q_t$ (in the asymmetric information case) is smaller than $as\mu_L L_u u_z z_r r_q q_t$ (in the full information model). Compared to the full information model, the only positive term, $as^p\mu_L L_u u_z z_r r_q q_t$, gets smaller in the asymmetric information model. Hence, the sign of *dt/dG* is more likely to be negative under the asymmetric information model than the full information model. This means that the regulator's stake in the industry will result in a less stringent regulation, and this tendency will be enhanced when the asymmetric information problem exists.

Table 1.2 summarizes the comparative static results under the asymmetric information model and the comparison with the full information case and the previous theories. This paper not only reproduces the main results of the previous literature, but also extends the system to the asymmetric information and representativeness.

Table 1.2: Comparative Static Results for Alternative Regulatory Models

Determinants of stringency of regulation	Prediction of the previous theories	Prediction of this paper	
		A benchmark model	Asymmetric information model
Toxicity and Exposure	+ The Pigouvian Tax	+	+
Group size (number of votes in consumer group)	– (Marginal effect of group size is negative) Olson, Stigler	+ (Conditional)	+* (Conditional)
Group size (number of votes in industry)		–	–
Consumers' stake in industry	NA	–	–
Future salary of the regulator	+ Appelbaum and Katz	+	+
Regulator's stake in industry	NA	– (Conditional)	–** (Conditional)
Information gap	– Seldon and Terrones	NA	–
Representativeness	+ Congleton, Frederiksson et al.	NA	+

* The effect is weaker in asymmetric information case than in full information case.
** The effect is stronger in asymmetric information case than in full information case.

4. CONCLUSIONS AND IMPLICATIONS

In this paper, we develop a positive theory of pollution tax under the assumptions of asymmetric information and the regulator's rent seeking motives. We find that the politically determined pollution tax is different from the Pigovian tax, in that many factors contribute 'bias' in environmental regulation. Our theory is a more unified framework in that it reproduces most of the previous findings and incorporates them into a 'bigger picture'. Furthermore, some new features are added (for instance, the consumers' stake and regulator's stake in the polluting industry), and the institution variables such as information gap and representativeness are systematically included in the framework, which the previous literature was lacking.

Toxicity, exposure, number of votes in a consumer group, future salary of a regulator, and representativeness are expected to contribute to a more stringent regulation. By contrast, votes in the polluting industry, consumers' stake in the industry, regulator's stake in the industry, and information gap provides motivation for the regulator to set up a less stringent regulation.

These findings guide us to several policy implications to narrow the gap between the ideal Pigouvian tax and the regulation in the real world. First, as previously pointed out, an increase in the salary of the regulator will help reduce the intensity of regulator's rent-seeking motives, and then the regulation will be closer to a socially optimum level (Appelbaum and Katz, 1987). Second, the regulator's remuneration should not be linked with the polluting firm's profit. Otherwise, the regulation will tend to be more producer-protective. Third, similarly, the consumers' reliance on the polluting industry in terms of welfare should be reduced. Encouraging the service sector rather than the pollution producing industry will help lessen the consumers' financial dependence upon 'dirty industry'. Fourth, regarding the number of votes in the polluting industry, the government should provide firms with incentives to adopt labor saving technologies, so that the firms' profit can be increased, and the votes against environment-friendly policies can be decreased. Last, but not least, information-sharing devices are very important for a society to formulate an unbiased regulation. Emphasis should be placed on both software side and hardware side of information-sharing. Software-side of information means consumers' information acquisition, which is closely related to the education level or civil society. More educated or better-connected consumers may have more capacity to obtain relevant information and interpret it properly. Hardware-side is information sharing tools for communication such as telephone, Internet, newspaper, television, radio, etc. As we pointed out in our model section, section 3, these information variables are related to a political regime, in that the authoritarian regime controls information acquisition and information sharing devices for the regime's stability. Then, we end up with the 'Al Gore' type of policy implication; propagating democracy will be helpful for the global environment.[6]

The limitation of this study should not be ignored. So far, we have pointed out that the regulator's self-interest is a source of problems in achieving a socially desired level of regulation. However, a lot of policy implications mentioned above put an emphasis on the role of regulator to correct socio-economic causes of rent-seeking motives and biased regulation. It seems that after we criticized the Pigouvian tax system we go back to seek an unselfish politician to solve the problem. In this sense, most of the policy implications we draw above are not only for the regulator, but also for all the societal members such as the consumers, producers, and regulators.

The policy implications above are more meaningful only when our theory-based predictions are proven in empirical tests. The next chapter addresses this concern.

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[6] See Al Gore, *Earth in the Balance*, 1993.

CHAPTER 2: AN EMPIRICAL STUDY ON INFORMATION AND THE ENVIRONMENT

ABSTRACT

This paper investigates the empirical relationship between information, freedom and the environment. We build our basic model by replicating Antweiler et al.'s (1998) model, and introduce six information indicators and the freedom variable to the basic model. Our estimates indicate that a 1% increase in freedom reduces the annual SO_2 concentration by approximately 0.05-0.12%, and a 1% increase in information results in approximately 0.001 to 0.05% decreases in SO_2 ambient. Although the elasticity is different from the information indicators we selected, all information and freedom are significantly negative at 1% level and other main variables such as scale, composition, technique, and trade remain significant and carry the right signs. Furthermore, the EKC of the full models is flatter and the income turning points (ITP) are higher than those in the basic replicated models. The income turning points (ITP) range from US$3,240 to US$4,300 in the basic models and from US$2,800 to US$4,950 (1985 US dollar rate) in the full models. Higher ITP does not necessarily mean that the higher maximum pollution levels; more freedom and information shift the EKC down, which brings lower maximum pollution levels than those of the basic models do.

1. INTRODUCTION

Recent empirical findings suggest that some pollutants follow an inverted U-shaped curve with respect to per capita income, which is called an environmental Kuznets curve (Grossman and Krueger, 1991, 1995; Seldon and Song, 1994, hereafter called EKC). While earlier empirical papers on this subject introduced a few economic indicators to a simple reduced regression model to show the existence of the EKC, recent works tend to include more various socio-economic covariates that might explain the linkage between the income and pollution level. For instance, income per capita and lagged income per capita (Grossman and Krueger, 1995), population density (Selden and Song, 1994), GDP per area and steel exports per GDP (Kaufman, 1998), trade intensity and other covariates (Antweiler et al., 1998, 2001), policy indicators (Panayotou, 1997), inequality and literacy (Torras and Boyce, 1998), and democracy (Barrett and Graddy, 2000) are added to the income-environment relations model.

There seems to be one more important covariate that determines the level of pollution which previous literature has ignored; information. Information sharing may play a pivotal role in the recovery of once deteriorated environment in which well-informed citizens will not accept the excessive pollution level that the producers cause or that the government oversees. Quantity and quality of information may be determined by the income level and political regime, and accordingly, information may affect the environment. In this sense (if this is true), information seems to induce a new income-inducing effect on pollution that bridges income, political regime, and the environment.

This paper investigates the empirical relationship between information, freedom and the environment. We build our basic model by replicating Antweiler et al.'s (1998) model— one of the most comprehensive empirical frameworks that exists, and then added information and freedom variables to the basic model to see if our hypothetical variables are significant and meaningful. In addition, we checked to see if other covariates and system are not weakened, at the same time. We have selected 6 information indicators such as telephone mainlines per 10 people, school enrollments, number of years of education, television sets per 10 people, international telecom (out going traffic, minutes per subscriber), and newspapers per 10 people.

Our estimates indicate that a 1% increase in freedom reduces the annual SO_2 concentration by approximately 0.05-0.12%, and a 1% increase in information results in approximately 0.001 to 0.05% decreases in SO_2 ambient. Information and freedom variables are significantly negative at 1% level and other main variables such as scale, composition, technique, and trade are still significant and hold the right signs. The income turning points (ITP) range from US$3,240 to US$4,300 in the basic models while US$2,800 to US$4,950 was recorded (1985 dollar rate) in the full models. These figures are very close to the ITPs of previous studies (Grossman and Krueger 1995, Torras and Boyce 1998, Panayotou 1997, and Barrett and Graddy, 2000). The EKC of the full models is flatter and their ITPs higher when compared to the basic replicated models. Higher ITP does not necessarily mean that higher maximum pollution levels, meaning more freedom and information, shift the EKC down and in turn creating a lower maximum pollution level when compared to those of the basic models.

The paper is organized as follows: section 2 reviews the related literature, section 3 introduces an empirical model and data, section 4 summarizes empirical results, and section 5 presents conclusion.

2. REVIEW OF LITERATURE

In this section, we will review some of the empirical research on the relationship between the environment and socio-economic covariates.[7]

2.1 Economic growth and the environment: the EKC and related debates

In early 1990s, a series of empirical findings suggested that some pollutants follow an inverted U-shaped curve with respect to per capita income (Grossman and Krueger, 1991, 1995; Seldon and Song, 1994). The inverted U-shaped relationship between income and pollution has been coined as the environmental Kuznets curve, which posits that the environmental conditions tend to worsen in the early stage of industrialization and later improve with respect to the economic growth. Since then, the empirical analyses of the EKC mostly focused on two critical topics: whether a

[7] There are numerous literatures on income and the environment, and we selectively included the most common and widely cited ones in each category. Moreover, we want to focus on the works that used SO_2 as a dependent variable, which is the dependent variable in this paper.

given indicator of environmental degradation displays an inverted-*U* relationship with the levels of per capita income; and the calculation of the threshold where the environmental quality improves with rising per capita income (Barbier, 1997).

Grossman and Krueger's (1991, 1995) works are among the most carefully done and widely cited on the relationship between economic growth and the environment (Harbaugh et al., 2002). They regress the following model with the air and water pollutants data for the period from 1977 to 1988 obtained from GEMS/AIRS and GEMS/WATER.

$$ln(E_{it}) = \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 Y_{it}^3 + \alpha_4 \underline{Y}_{it-} + \alpha_5 \underline{Y}_{it-}^2 + \alpha_6 \underline{Y}_{it-}^3 + \alpha_7 X_{it}' + \varepsilon_{it}$$

Where E_{it} is the median concentration of air and water pollution in station i in year t, Y_{it} is GDP per capita in year t in the country in which station i is located, $\underline{Y}_{it-}$ is the average GDP per capita over the previous three years, X_{it} is a vector of other covariates, and ε_{it} is an error term. The α's are parameters to be estimated.

Showing that α_2 and α_5 are significantly negative and α_1 and α_4 are significantly positive in most pollutants in their model, Grossman and Krueger (1995, p. 370) provide the finding that some pollutants follow an inverted U-shaped curve with respect to per capita income. They conclude that "Contrary to the alarmist cries of some environmental groups, we find no evidence that economic growth does unavoidable harm to the natural habitat. The turning points in these inverted U-shaped relationships vary for the different pollutants, but in almost every case they occur at an income of less than US$8,000 (1985 dollar rate)" (Grossman and

Krueger, 1995: 370).[8] In the case of SO_2, the peak is reached when per capita GDP is US$4,053 (1985 dollar rate).

Selden and Song (1994) also drew the same inverted-U shaped curve in air pollution and per capita income by using the pollution emission data drawn from World Resources Institute. Their air pollution data documents the average emissions of SO_2, SPM, NOx, and CO for the periods 1973-1975, 1979-1981, and 1982-1984. They include population density of countries in the basic income-pollution model. Their estimation results suggest that the income turning points of SO_2 and SPM range from US$8,000 to US$10,000 (1985 dollar rate), while those of CO are around US$11,000-US$17,800 (1985 dollar rate).

These premiere works on the EKC brought two streams of related researches on the environment and socio-economic studies; one side confirms the existence of the EKC and tries to explain the black box of the reduced income-pollution relations, while the other side doubts the robustness of findings on the EKC. We will review the EKC supporting literature first, and then turn to the skeptics.

2.2 Explanations: Economic Aspects

Because the empirical findings in the income-environment relations are based on a reduced form regression, it is unclear why economic growth results in a favorable environment in the later stage of development. In their earlier work,

[8] The turning points of Grossman and Krueger's (1995) paper range from $4,000 to $5,000 in 1985 U.S. dollars. According to Yandle et al. (2002) these turning points are equivalent to approximately $6,200 to $8,200 in 2001 U.S. dollars.

Grossman and Krueger (1991) provided a possible causal linkage between per capita income and the environmental quality, which guided what kinds of economic variables should be included in the later empirical works on the EKC. According to them, there are at least three income-induced effects on the environment; scale, composition, and technique. Scale effect is the notion that expansion of economic activity caused by trade or investment liberalization will result in environmental degradation. Composition effect means that the change of the composition of output among sectors (for instance, structural transformation from a manufacture-reliant economy to more service oriented one) contributes to environmental recovery. The technique effect particularly means the impact of technological advances assisting producers to adopt environment-friendly production process. According to Grossman and Krueger (1991), the quality of environment could improve with income, if the scale effect can be eclipsed by both composition and technique effect.

Analysts have tried to increase the explanatory power of empirical models by adding the indicators that represent scale, composition, and technique effects.

With panel data of SO_2 concentration for 23 countries between 1974 and 1989, Kaufmann et al. (1998) provides another evidence that an inverted U-shaped curve exists, and in addition, they show that along with income, scale and composition of economic activity are also important determinants of SO_2 concentrations. They add GDP/area, $(GDP/area)^2$, and (steel export)/(nominal GDP) terms to the environment-income relations model, and show that the estimated coefficient of $(GDP/area)^2$ are significantly negative and that of (steel export)/(nominal GDP) is significantly positive. GDP/area terms measure the scale effect and steel export/nominal GDP term estimates the composition effect. Their result suggests that the relations between the spatial intensity of economic activity and SO_2 concentration are inverted U-shaped and the portion of polluting industry out of nominal GDP positively contributes to the SO_2 concentrations.

The most comprehensive empirical work existing on the environment and socio-economic covariates is Antweiler et al.'s (1998, 2001) recent works. To examine whether trade is good for the environment they first build a simple empirical model that includes the basic determinants of SO_2 pollution level such as the scale effect term (economic intensity of a city, GDP/km^2), the composition effect term (capital abundance, K/L), the technique effect term (lagged per capita income and lagged per capital income squared), and other country specific and monitoring site specific terms such as communist country dummy, suburban or rural area dummy, average temperature, and precipitation variation. The dependent variable is the log of annual median concentrations of SO_2 in GEMS/AIRS data. In this basic model, all the estimated coefficients are significant and hold right signs; the scale and composition effects are positive while the technique effect is negative.[9] Thereafter, they introduce the trade intensity variable and interaction terms of trade-capital abundance and trade-income. In this full model, they draw the result that all the important variables remain significant with the right signs, and that not only the

[9] See Antweiler et al. (1998), pp. 28-29.

trade intensity negatively related to pollution, but also the trade induced composition effects which are measured by the trade related interaction terms (trade×relative capital abundance, for instance) are not jointly zero. They conclude that a 1% increase in openness results in a 1% decrease in SO_2 concentration in an average country. Antweiler et al. do not mention the EKC regarding their empirical result, but their model indicates that the EKC exists not only in the basic model without trade, but also remain significant in the full model including trade intensity; the coefficient estimates (of income and income squared terms) regarding the EKC are significant with the right signs.[10]

2.3 Explanations: Institutional Aspects

The economic aspect of income-environment relations must be one of the most important explanations of the EKC, but this must not be the only pathway that economic growth results in improvement of the environment. Political and socio-economic aspects of income-induced effects are also important, in that the long-run economic development changes social and political conditions, which may affect the country level and its environmental quality. Lipset (1959) hypothesizes that economic growth is conducive to democratization. Inglehart (1997) also claims that social value shifts from materialistic to a more postmodern with respect to the economic growth.

[10] Antweiler et al. (1998, 2001) do not mention the income turning points either, but our calculation based on their estimation results (the fixed effect model) indicates that the income turning point of SO_2 is about US$5,000 (in 1995 dollar rate).

With panel data of SO_2 emissions in 30 developing and advanced countries for the period between 1982-94, Panayotou (1997) built a basic model that includes GDP per capita, GDP per capita squared, GDP per capita cubed, population density, population density squared, and population density cubed. Afterwards he shows that the basic model conforms the EKC pattern. Then, he introduces GDP growth rate and policy variables to the basic model, and draws the result that GDP growth rate is positively related to the pollution level, while the policy variable is negatively affecting the dependent variable, SO_2 emissions. His policy variables are proxies for institutions such as enforcement of contracts, efficiency of bureaucracy, the efficacy of the rules of law, the extent of government corruption and the risk of appropriation obtained from Knack and Keefer (1995). Based on his estimation result, Panayotou (1997) argues that better policy results in the lower environmental Kuznets curve. The income turning point of Panayotou's analysis is under US$5,000 in 1985 dollar rate.

Torras and Boyce (1998) introduce income inequality, literacy, and political rights to Grossman and Krueger's GEMS data as additional explanatory variables. They find that a more equitable income distribution (higher GINI ratio), higher literacy, and more political rights contribute to a better environment. Their result confirms the EKC, and in the case of SO_2 concentration, the peak pollution level is reached when per capita income is approximately US$3890 in 1985 dollar rate. However, they caution that there is a trough in a very high-income level, US$14,000-$15,000, in the case of SO_2 concentrations.

Replicating Grossman and Krueger's (1995) initial model with the same data that Grossman and Krueger used, Barrett and Graddy (2000) show that political right and civil liberty are significantly negative to air and water pollutants. The income turning point of SO_2 concentration is reached when per capita income is approximately US$4,000 in 1985 dollar rate.

2.4 Skeptics

There have been skeptical viewpoints on the robustness and consistency of the EKC findings (Arrow et al., 1995; Stern and common, 2001; Harbaugh et al., 2002). Stern and Common (2001) claim that the majority of existing estimates of the EKC (for SO_2) use the data of high-income countries only, which accordingly tend to underestimate the income turning point than those using the world data. With global SO_2 emission data for 1960-90 obtained from A.S.L. and Associates (1997), Stern and Common (2001) ran panel regressions for three different groups of countries; the world, OECD members, and non-OECD members. Their regression for the OECD member country group is almost replica of Seldon and Song's (1994) estimation result in that the income turning points of two regressions are very close; around US$9,200 in the fixed effects models in both analyses. However, regressions for the world and non-OECD member groups suggest too high income turning points that look unrealistic for the less developed countries to reach; US$101,166 in the world group, while US$908,178 in the non-OECD member group.[11]

Harbaugh et al. (2002) question the sensitivity and functional form of the EKC studies. They attempt to replicate Grossman and Kruger's (1995) premier model with AIRS EXEC dataset that is the GEMS data maintained and distributed by the U.S. EPA. Even if they use the same explanatory variables, the observations, and specifications, they are unable to replicate Grossman and Krueger's work especially for SO_2. Although there are some minor differences between Harbaugh et al.'s data and Grossman and Krueger's[12], their estimation result is considerably different from Grossman and Krueger's in terms of the magnitude and significance of coefficient estimation. With the replicated model, Harbaugh et al. show that inclusion of more recent data or adding more explanatory variables such as trade intensity, democracy index, and/or relative GDP weakens the functional form of the widely accepted EKC. While Grossman and Krueger report that the turning point and trough of SO_2 are about US$4,000 and US$13,000 (in 1985 dollar rate), Harbaugh et al's replicated model with the same cities and years that Grossman and Krueger used are US$13,741 and US$7,145, and those of the replicated model with all years (up to 1998) are US$20,081 and US$9,142, and those of the replicated model with more

[11] The turning points presented here are the results of fixed effects models. As Hausman tests indicate that the random effect models are inconsistent in Stern and Common's (2001) model, we present only turning points of fixed effects here.

[12] Harbaugh et al. (2002) use the annual mean of pollutant concentrations, while Grossman and Krueger (1995) use the annual median of pollutant concentrations. According to Harbaugh et al, this

explanatory variables (democracy index, trade intensity, relative GDP, investment) are US$39,700 and US$5,650. Note that the turning point is in the lower income level than that of the trough in Grossman and Krueger's EKC, which is not the case in Harbaugh et al's estimation results.

Harbaugh et al.'s conclusion is that there is insufficient empirical evidence for the existence of an inverted-U-shaped "environmental Kuznets curve". However, they qualify their conclusion by pointing out, "Monitoring stations measurements may be inaccurate. Furthermore, pollution around a given monitoring station is almost certainly related to local economic activity and pollution density, neither of which we measured." (Harbaugh et al., 2002: 549). The last point suggests that more site-specific data such as temperature, precipitation, and economic intensity of city are needed.[13]

2.5 Evaluation

A problem of current empirical studies is that they have not included one probable linkage between income and the environment as well as information and the environment. To date, the literature on environmental Kuznets curves or other empirical studies on the environment has not addressed the relationship between information and the environment. We view that information is an important tool for

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difference may be disregarded because their estimations using mean and median SO_2 produced not significantly different results.

[13] Antweiler et al.'s (2001) model includes not only site-specific variables such as temperature, precipitation variation, and economic intensity of a city, but also other major determinants of SO_2 like capital abundance, trade, relative income, etc.

social actors to reduce social pollution level; citizens' demand on the government for improved environment can be activated with information sharing. By including the information variable to the existing framework of the EKC, we may be able to capture the new income-inducing effect on the environment. While the conventional income-induced effects such as scale, composition, technique, trade, and institution effects estimate the impact of economic and political changes to the environment, information effect will represent the social actors' 'cognitive' changes to the environment, which is followed by the income growth.

Regarding the debate on the consistency of the EKC, most empirical models need more site-specific regressors that represent the characteristics of monitoring sites rather than national level data, for instance, population density of a city, temperature and precipitation (Harbaugh et al. 2002). This is not the only issue that the skeptics raise questions about when referring to the fragility of the EKC, but more site-specific covariates will be helpful in building a better empirical model and to draw more meaningful implications from the EKC studies.

3. MODEL AND DATA

3.1 Empirical Strategy

Our empirical strategy has two steps. We first estimate a conventional EKC model without the freedom and information variables to check whether the main determinants of pollution are meaningful in our basic model. Next, we add the freedom variable and several indicators of 'information' or 'information gap' to the basic model, and determine whether the freedom and information indicators turn-out significant along with the right signs and whether other covariates remain significant, as well.

For the first step, we replicate Antweiler et al.'s (1998) empirical model where they deal with the relationship between trade and the environment. Their framework seems to be one of the most comprehensive structures that contain main determinants of SO_2 such as scale, composition, technique, and trade effects along with other site-specific covariates. In the second step, we will add the freedom and information variables to the replicated model of Antweiler et al., and see the results.

Our replica model of Antweiler et al.'s (1998) model is,

$SO_2 = f(S, K/L, (K/L)^2, I, I^2, COM, COM\times I, COM\times I^2, T, T\times RK/L, T\times(RK/L)^2, T\times RI, T\times(RI)^2, SUB, RUR, TEMP, PREC, TIME)$.

Where *S* denotes scale, *K/L*- capital abundance, *I*- lagged per capita income, *T*- trade intensity, *COM*- communist country dummy, *SUB*- suburban area dummy, *RUR*- rural area dummy, *TEMP*- average temperature, *PREC*- precipitation variation, and *TIME* is time trend.

When the freedom and information variables are added, our model stands as,

$SO_2 = f(S, K/L, (K/L)^2, I, I^2, COM, COM\times I, COM\times I^2, T, T\times RK/L, T\times(RK/L)^2, T\times RI, T\times(RI)^2, SUB, RUR, TEMP, PREC, TIME, FREEDOM, INFO)$, where FREEDOM and INFO denote freedom and information, respectively.

3.2 Data

Following our empirical strategy, we use the same data that Antweiler et al. had used. However, we are sometimes forced to steer away from the data due to its unavailability.

3.2.1 Dependent variable

We use the log of annual mean concentrations of SO_2 as a dependent variable. EPA maintains and releases the GEMS/AIR data by AIRS Executive International Database (hereafter called AIRS EXEC) that is accessible at EPA's website, http://www.epa.gov/airs/aexec.html. The annual means concentrations of SO_2 are available in AIRS EXEC system which we extracted the data, and took log transformation. Because Antweiler et al. used the annual median concentrations for the dependent variable, our estimation result is expected to be more or less different from Antweiler et al.'s result in terms of the magnitude of coefficient estimates.[14]

The original source of AIRS EXEC comes from the Global Environment Monitoring System (GEMS) which monitors urban air quality of different cities in developing and advanced countries. Comparability and reliability are the core aims

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[14] We contacted the U.S. EPA to obtain the annual median concentration of SO_2 data monitored by GEMS/AIR – the same data Antweiler et al. used, but the data provided by the EPA was incomplete, due to missing SO_2 observations made in some of the countries such as Spain, Colombia, Sweden, Denmark, Indonesia, and Philippines. However, other data, which EPA had directly provided was very helpful to identify each monitoring site locations in terms of longitude and latitude. Based on this information on location, we tracked down the site-specific characteristics of each site such as local population density, temperature, and precipitation. We would like to express our gratitude to Ms. Ambrose of the US-EPA for providing the GEMS/Air International Data that contained the annual percentile concentration levels of SO_2 in international cities.

of the effort by GEMS, a joint project of the World Health Organization and the Untied Nations Environmental Programme. The GEMS/Air has been monitoring SO_2 concentrations in major urban areas from the early 1970's up to 1994, globally. Our data set consists of 2,600 observations from 273 observation sites located in 109 cities representing 43 countries from 1971 to 1996.

3.2.2 Explanatory variables

3.2.2. A. Indicators of information and freedom

For information data, we introduce five proxies; telephone mainlines (per 10 people), number of years of education, school enrollment (secondary, % of gross),[15] television sets (per 10 people), international telecom (out going traffic, minutes per subscriber), and newspapers (per 10 people).

We obtained the years of education from Barrow/Lee data set which is open to the public at the NBER website, http://www.nber.org/pub.[16] Data for other information indicators are taken from World Development Indicators CD-ROM (World Bank, 2000). Freedom data is drawn from the Freedom House, which provides measures for political rights and civil liberty. In this source, about 150

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[15] We tried other education indicators such as primary schooling and literacy rate, also, but statistics are scarce in these variables, so we selected only years of education and secondary schooling as our variables.

[16] The education years of Barrow/Lee data are presented for the years 1960-1985, and for the recent missing years, we simply extended the latest observations up to 1990's. In addition, we found that education years of China were also missing, and we applied the average education years of the East Asian countries to China. These countries are South Korea, Taiwan, Hong Kong, Japan, and Philippines.

countries are categorized into "free", "partly free", and "non-free", and we coded 1 for non-free, 2 for partly free, and 3 for free nations.[17]

3.2.2.B. Economic data

Our economic data are obtained from Penn World Table (Mark 5.6a).[18] The economic data include real per capita GDP, capital abundance (K/L), trade intensity, relative capital abundance, and relative per capita income. All monetary figures in PWT 5.6a are in 1985 U.S. dollar rate. Note that Antweiler et al. (1998) used the same PWT 5.6, but extended and adjusted their economic variables into 1995 U.S. dollar rate. We simply used the economic indicators in PWT 5.6a as they are, because adjustments of income related data might result in unnecessary deviations from the intended replication. Moreover, the majority of the existing EKC papers used income data from PWT 5.6 in 1985 U.S. dollar rate, which allows us to compare our empirical results to the previous works, directly.

For capital abundance data, we use KapW variable in PWT 5.6a. However, capital abundance (K/L) data is not available for some countries such as China, Brazil, Malaysia, and Egypt, therefore we ran a simple regression, $K/L = f($per capita

[17] The Freedom House also provides political rights and civil liberties measured in scale of 1 to 7 where 1 denotes free and 7 non-free, but because they are highly correlated with income and information, we used less correlated variable in 1-3 scale that is described above.

[18] More recent version of PWT 6.0 is also available, but we used 5.6 version, because some countries are no longer included in 6.0 such as Czechoslovakia, Yugoslavia, and Iraq. More importantly, capital abundance data does not exist in PWT 6.0.

GDP) and then applied the estimation result to create K/L for those countries[19] without capital abundance data. Lagged per capita GDP is the three-year average of lagged GDP per capita, $I_t = (Y_{t-1} + Y_{t-2} + Y_{t-3})/3$ as defined in Antweiler et al. (1998, 2001).[20] Trade intensity is defined by (export+import)/GDP in %, and we used *OPEN* variable in PWT 5.6a. Relative income is lagged per capita GDP divided by the corresponding world average for the given year, where the world average is defined by all the countries in the PWT 5.6a. Similarly, relative K/L is K/L divided by the corresponding average for the given year, where the world average is defined by all countries in the PWT 5.6a.

3.2.3. C. Other covariates

We define scale variable as the economic intensity of a city that is obtained by multiplying per capita GDP by population density of a city. For city level population density, we draw population density in each grid cell of 1° (longitude) ×1° (latitude) in the year 1990 for each country that is from Global Population Distribution Database provided by Consortium for the International Earth Science Information Network (CIESIN). We matched GEMS monitoring sites to corresponding grids in CIESIN dataset based on the latitude and longitude information. However, the latitude and longitude of GEMS sites are sometimes

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[19] The estimation result is K/L = 186.882+2.381×(per capita GDP).

[20] See Antweiler et al. (1998, 2001).

inaccurate resulting in incorrect matches of GEMS sites and CIESIN's units of population distribution.[21]

Average temperature and precipitation data are from the Global Historical Climatology Network. We matched GEMS/AIR monitoring locations to the nearest observation stations of temperature and precipitation. These are the same data that Antweiler et al. used, but there must be differences in the definition of precipitation variation in our data and that of Antweiler et al.'s. They mention that their precipitation variation variable is precipitation "coefficient" of variation, but did not explain in details what the coefficient means. We simply used the annual average precipitation data.

3.3 Methodology

Due to the unbalanced panel characteristics of the international pollution data, most of existing literatures apply the Generalized Least Squares procedure (GLS) to the EKC study. We also ran GLS regressions for our empirical model.

4. EMPIRICAL RESULTS

4.1 Summary and Comparison of Statistics

Table 2.1 summarizes the statistics of our dataset and compares them with those of Antweiler et al. (1998).

[21] Antweiler et al. (1998, 2001) also mention that the latitude and longitude information on each monitoring sites are sometimes inaccurate, and they had to corrected them case-by-case. We also noticed this problem, and we followed the same procedure.

Table 2.1: Summary and Comparison of Statistics

Variable	Dimension	Obs	Mean	Std. Dev.	Min	Max
Log of mean SO2 (Log of median SO2)	ppm	2268 (2621)	-1.88884 (-2.102)	0.381507 (0.48)	-3.52288	-0.35174
City Economic Intensity	$m per km^2	2263 (2621)	7.638952 (7.729)	13.09029 (8.733)	0.015243	77.62612
Capital Abundance (Adjusted K/L)	$k	2260 (2621)	21.38542 (31.496)	12.0518 (17.775)	1.123	54.388
GDP per capita, 3yrs avg.	$k	2256 (2621)	9.34152 (14.114)	5.726687 (8.372)	0.779	17.953
Trade Intensity	%	2265 (2621)	39.4917 (41.054)	26.61073 (31.859)	8.84	156.45
Relative Income	World=1	2265 (2621)	2.181713 (2.468)	1.30291 (1.388)	0.18528	4.050948
Relative Capital Abundance (Adjusted RKL)	World=1	2260 (2621)	1.382166 (2.224)	0.75057 (1.198)	0.86698	4.03352
Communist Country	1, 0	2268 (2621)	0.150353 (0.147)	0.357496 (0.354)	0	1
C.C × Income	$k	341 (385)	2.204765 (3.699)	1.450407 (2.403)	0.891333	5.021333
Avg. Temperature	C	2268 (2621)	15.11236 (14.602)	5.655406 (5.556)	2.172727	29.37273
Avg. Precipitation (Precipitation Variation)	mm (NA)	2268 (2621)	0.007985 (0.011)	0.004278 (0.006)	0	0.028383
Freedom	1, 2, 3 Free=3	2415	2.59	0.72	1	3
Telephone mainlines	NA	2308	2.80	2.09	0.022	6.61
School enrollment	%	2241	75.38	24.19	13.3	120.7
Education years	NA	2422	7.96	3.09	1.32	12.14
TV sets	Per 10 person	2303	3.64	2.34	0.008	7.72
Telecom	NA	2089	39.83	33.5	1.17	242.4
Newspaper	Per 10 person	2127	2.245	1.55	0.008	7.51

1. Parentheses are Antweiler et al.'s (1998) variables and statistics.
2. Monetary figures of this paper are in 1985 dollars, while those of Antweiler et al. are in 1995 U.S. dollars.

Due to the data availability problem, there are differences between our data and that Antweiler et al. used, which may result in differences in the estimation results. The main differences are in the dependent variables (log of mean SO_2 vs. log of median SO_2), monetary figures (1985 U.S. dollar rate vs. 1995 U.S. dollar rate), and several data adjustments (K/L up to 1992 vs. extended K/L up to 1996). Note that statistics of our dataset (shown in Table 2.1) are, in general, smaller than that of Antweiler et al. The average log of mean SO_2 in our sample is –1.89, while that of log of median SO_2 in Antweiler et al' dataset is –2.10. This tendency results from the difference between the mean and median SO_2 concentrations. Furthermore, the averages of economic variables in our dataset such as per capita GDP (3 years), capital abundance, relative income, and relative capital abundance are smaller than what Antweiler et al. used. In addition, while our monetary figures are in 1985 U.S. dollar rate, Antweiler et al.'s are in 1995 dollar rate.

4.2 The Estimation Results

Tables 2.2 to 2.7 present Antweiler et al.'s (1998) model, our basic (replicated) model, and the full model (with information). Because Hausman test results indicate that random effect models are inconsistent, we only present the fixed effect models. We compare our basic replicated model and Antweiler et al's (1998) model, first, and then we examine the findings in our full models.

Most of variables in the replicated model are statistically significant at least at 10% level and the signs are same with those of Antweiler et al's model. Especially, all the main variables that capture scale, composition, technique, and trade effects are supporting the right signs and significant at least at 5% level. However, the magnitude of estimates in our model is smaller, which might have resulted from the difference between the dependent variables and economic indicators. Moreover, r-squares of replicated models are smaller than the original model. One possible explanation for our lower r-squares is that some GEMS location information is inaccurate, and accordingly, some site-specific covariates of GEMS monitoring points might be mismatched. In fact, the significances of city economic intensity, temperature, and precipitation variables in our models are consistently different from Antweiler et al's results. Our city economic intensity tends to be less significant, while precipitation variable tends to be more significant. The significance of temperature varies. We conclude that our basic models are not closely replicated in terms of r-square and magnitudes, but they are still meaningful, because the significance and signs of estimates are almost same as the targeted model.

Generally speaking, our full models are enhanced since the freedom and information variables are added. R-squares are considerably increased after the inclusion of those variables to the basic models. Especially, the r-square (overall) of the full model with the newspaper variable increased from 0.0474 to 0.2071.

More importantly, all freedom and information variables are negative and significant at 1 % level except Model 5 where we included the freedom and telecom variables. Freedom is significant at 10% level, while telecom is significant at 1% level.

Table 2.2: Model 1 (Telephone Mainlines, Fixed Effects)

	Antweiler et al. (1998)	Replicates Antweiler et al. (1998)	Full model
Dependent variable	Log (median SO_2)	Log (mean SO_2)	Log (mean SO_2)
Constant	-3.66165***	-1.56395***	-1.3826***
City Economic Intensity	0.04263***	0.010313**	0.013774***
K/L	0.11915***	0.049518***	0.046672***
$(K/L)^2$	-0.00149***	-0.00082***	-0.00087***
I	-0.31075***	-0.11485***	-0.08138***
I^2	0.0074***	0.004724***	0.003583***
CC×I	1.15287***	0.800613***	0.617327***
CC×I^2	-0.008355***	-0.0792***	-0.0587***
Trade intensity	-0.02293***	-0.00643***	-0.00546**
T×relative K/L	-0.003054***	-0.02075***	-0.01989***
T×relative $(K/L)^2$	0.00592***	0.006889***	0.006928***
T×relative I	0.03438***	0.009184***	0.007273***
T×relative I^2	-0.00523***	-0.00145***	-0.00122***
Temperature	-0.05924**	-0.01956***	-0.01412*
Precipitation	7.9698	4.277941*	4.59851**
Time trend	-0.03838***	-0.02594***	-0.02074***
Freedom			-0.1146***
Phone			-0.04720***
Phone squared			0.00742***
Observations / Groups R^2 (overall) R^2 (within)	2621 / 293 0.137 -	2247 / 261 0.0802 0.1938	2247 / 261 0.1044 0.2101
ITP		$4,325	$4,950

* p<0.10, ** p<0.05, *** p<0.01

Table 2.3: Model 2(School Enrollment, Fixed Effects)

	Antweiler et al. (1998)	Replicates Antweiler et al. (1998)	Full model
Dependent variable	Log (median SO_2)	Log (mean SO_2)	Log (mean SO_2)
Constant	-3.66165***	-1.77902***	-1.343006***
City Economic Intensity	0.04263***	0.009945**	0.011206**
K/L	0.11915***	0.06061***	0.0514058***
$(K/L)^2$	-0.00149***	-0.00091***	-0.000817***
I	-0.31075***	-0.12169***	-0.0740282***
I^2	0.0074***	0.004674***	0.0025827***
CC×I	1.15287***	0.860987***	0.7273262***
CC×I^2	-0.008355***	-0.0898***	-0.0761893***
Trade intensity	-0.02293***	-0.00541**	-0.0052292**
T×relative K/L	-0.003054***	-0.01874***	-0.0153267***
T×relative $(K/L)^2$	0.00592***	0.006111***	0.0053628***
T×relative I	0.03438***	0.008847***	0.0072251***
T×relative I^2	-0.00523***	-0.00136***	-0.0011884***
Temperature	-0.05924**	-0.01612**	-0.014667**
Precipitation	7.9698	4.496096**	4.033084*
Time trend	-0.03838***	-0.02811***	-0.0165728***
Freedom			-0.0676349***
School Enrollment			-0.0051267***
Observations / Groups R^2 (overall) R^2 (within)	2621 / 293 0.137 -	2185 / 262 0.0659 0.1755	2185 / 262 0.0971 0.1871
ITP		$3,745	$4,427

* $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 2.4: Model 3 (Education Years, Fixed Effects)

	Antweiler et al. (1998)	Replicates Antweiler et al. (1998)	Full model
Dependent variable	Log (median SO_2)	Log (mean SO_2)	Log (mean SO_2)
Constant	-3.66165***	-1.597688***	-1.200927***
City Economic Intensity	0.04263***	0.0095229**	0.0120372***
K/L	0.11915***	0.053794***	0.0593448***
$(K/L)^2$	-0.00149***	-0.0008654***	-0.0010315***
I	-0.31075***	-0.1206053***	-0.085655***
I^2	0.0074***	0.0048963***	0.0039048***
CC×I	1.15287***	0.8650035***	0.7448582***
CC×I^2	-0.008355***	-0.0857726***	-0.0733855***
Trade intensity	-0.02293***	-0.0062736***	-0.0060373**
T×relative K/L	-0.003054***	-0.0212348***	-0.0186369***
T×relative $(K/L)^2$	0.00592***	0.0069442***	0.0065841***
T×relative I	0.03438***	0.0095977***	0.0075605***
T×relative I^2	-0.00523***	-0.0015005***	-0.0013369***
Temperature	-0.05924**	-0.0196798***	-0.0179013**
Precipitation	7.9698	4.385387*	4.176407*
Time trend	-0.03838***	-0.0270911***	-0.0206004***
Freedom			-0.1130707***
Education years			-0.0445176***
Observations / Groups R^2 (overall) R^2 (within)	2621 / 293 0.137 -	2214 / 255 0.0641 0.1964	2214 / 255 0.1126 0.2115
ITP		$4,311	$4,773

* p<0.10, ** p<0.05, *** p<0.01

Table 2.5: Model 4 (Television Sets, Fixed Effects)

	Antweiler et al. (1998)	Replicates Antweiler et al.(1998)	Full model
Dependent variable	Log (median SO_2)	Log (mean SO_2)	Log (mean SO_2)
Constant	-3.66165***	-1.911472***	-1.790513***
City Economic Intensity	0.04263***	0.0086509*	0.0112698**
K/L	0.11915***	0.0660684***	0.0698807***
$(K/L)^2$	-0.00149***	-0.0010587***	-0.0011607***
I	-0.31075***	-0.1096627***	-0.0973739***
I^2	0.0074***	0.0047437***	0.0048678***
CC×I	1.15287***	0.8836734***	0.9062248***
CC×I^2	-0.008355***	-0.0925118***	-0.0961187***
Trade intensity	-0.02293***	-0.0065635***	-0.005004**
T×relative K/L	-0.003054***	-0.0185047***	-0.018412***
T×relative $(K/L)^2$	0.00592***	0.0062113***	0.0063616***
T×relative I	0.03438***	0.0088061***	0.0073155***
T×relative I^2	-0.00523***	-0.0013661***	-0.0011441***
Temperature	-0.05924**	-0.0162619**	-0.0145635*
Precipitation	7.9698	4.906582**	5.225168**
Time trend	-0.03838***	-0.0287682***	-0.0231949***
Freedom			-0.0669535***
TV			-0.04872***
Observations / Groups R^2 (overall) R^2 (within)	2621 / 293 0.137 -	2133 / 251 0.0503 0.1878	2133 / 251 0.0662 0.1942
ITP		$4,268	$4,379

* p<0.10, ** p<0.05, *** p<0.01

Table 2.6: Model 5 (Telecom, Fixed Effects)

	Antweiler et al. (1998)	Replicates Antweiler et al. (1998)	Full model
Dependent variable	Log (median SO_2)	Log (mean SO_2)	Log (mean SO_2)
Constant	-3.66165***	-1.890754***	-1.783066***
City Economic Intensity	0.04263***	0.0092708*	0.0082956*
K/L	0.11915***	0.0785826***	0.0776931***
$(K/L)^2$	-0.00149***	-0.0011865***	-0.0011922***
I	-0.31075***	-0.1414481***	-0.1383018***
I^2	0.0074***	0.005586***	0.0057163***
CC×I	1.15287***	0.7917934***	0.8094895***
CC×I^2	-0.008355***	-0.0756725***	-0.0759498***
Trade intensity	-0.02293***	-0.0050042*	-0.0048736*
T×relative K/L	-0.003054***	-0.0205665***	-0.023881***
T×relative $(K/L)^2$	0.00592***	0.0068988***	0.0077971***
T×relative I	0.03438***	0.0087024***	0.0113571***
T×relative I^2	-0.00523***	-0.0012845***	-0.0017566***
Temperature	-0.05924**	-0.0176343**	-0.0173256**
Precipitation	7.9698	5.152955**	4.743094**
Time trend	-0.03838***	-0.0314594***	-0.0256586***
Freedom			-0.0479514*
Telecom			-0.0012979***
Observations / Groups R^2 (overall) R^2 (within)	2621 / 293 0.137 -	1984/244 0.0586 0.1897	1984/244 0.0609 0.2000
ITP		$3,294	$4,582

* p<0.10, ** p<0.05, *** p<0.01

Table 2.7: Model 6 (Newspapers, Fixed Effects)

	Antweiler et al. (1998)	Replicates Antweiler et al. (1998)	Full model
Dependent variable	Log (median SO_2)	Log (mean SO_2)	Log (mean SO_2)
Constant	-3.66165***	-1.706479***	-1.013003***
City Economic Intensity	0.04263***	0.008352*	0.011188**
K/L	0.11915***	0.0572566***	0.040622***
$(K/L)^2$	-0.00149***	-0.0008915***	-0.0008792***
I	-0.31075***	-0.1070751***	-0.107886***
I^2	0.0074***	0.0042365***	0.0049107***
CC×I	1.15287***	0.5837097**	0.3980622*
CC×I^2	-0.008355***	-0.0578279**	-0.032242
Trade intensity	-0.02293***	-0.0054571**	-0.0051745**
T×relative K/L	-0.003054***	-0.0182807***	-0.0166864***
T×relative $(K/L)^2$	0.00592***	0.0060794***	0.0060374***
T×relative I	0.03438***	0.0084425***	0.0068085***
T×relative I^2	-0.00523***	-0.0013131***	-0.0011478***
Temperature	-0.05924**	-0.0174401**	-0.0146733**
Precipitation	7.9698	3.324213	2.547776
Time trend	-0.03838***	-0.0262299***	-0.0175343***
Freedom			-0.0911357***
Newspaper			-0.37407***
Newspaper squared			0.08555***
Observations / Groups R^2 (overall) R^2 (within)	2621 / 293 0.137 -	2086 / 260 0.0474 0.1795	2086 / 260 0.2071 0.2091
ITP		$3,940	$2,818

* p<0.10, ** p<0.05, *** p<0.01

One interesting finding is the non-linear U shaped-relationships in telephone-SO_2 and newspapers-SO_2. The effect of telephone on SO_2 concentration is negative when telephone mainlines per 10 people is less than 3.1, however, later a positive relationship appears. Because the mean of telephone lines in our sample is 2.8 (minimum is 0.02, while maximum is 6.61), the negative impact is stronger in the lower income countries, while it marginally decreases with respect to the spread of telephone. A similar tendency is found in newspapers. The negative relationship between newspapers and SO_2 ends around 2.186 newspapers per 10 people (minimum is 0.008, while maximum is 7.5), and later positive relations appear. When we consider the mean of newspapers, it stands at 2.245. The newspapers seem to have stronger effects in the earlier stages of development, again. We need to caution regarding the positive relationships between telephone, newspapers and SO_2 in highly developed societies. The positive relationship may result from the trend that newspapers and telephone lines are replaced by other new hi-tech information sharing tools such as Internet and mobile phones, etc, in high income countries rather than actual positive correlations between these tools and SO_2 ambient.

Table 2.8 displays the elasticity of freedom and information variables in each model. Our estimates indicate that a 1% increase in freedom reduces the annual SO_2 concentration by approximately 0.05-0.12%. In addition, a 1% increase in information results in approximately 0.001 to 0.05% decreases in SO_2 ambient.

Table 2.8: Freedom and Information Elasticities in Full Models

	Freedom	Information
Telephone (Model 1)	-0.115	-0.00565*
Schooling (Model 2)	-0.068	-0.005
Education yrs (Model 3)	-0.113	-0.045
TV (Model 4)	-0.067	-0.0487
Telecom (Model 5)	-0.048	-0.001
Newspapers (Model 6)	-0.091	-0.0011*

1. Telephone (Model1) and newspapers (Model 6) are evaluated at sample means.

4.3 The EKC: Concavity, ITP, and maximum pollution level

Our estimation results confirm the existence of the EKC not only in the basic replicated models, but also in the full models with the freedom and information variables. Moreover, the EKC of our full models are flatter than those in the basic replicated models. Flatter EKC curves, accordingly, result in changes in ITPs between the basic and the full models. We examine concavity of the EKC, ITP, and then estimated the pollution level.

Panayotou (1997) points out that when there are policy distortions (for instance, distortions of energy subsidies), "the deterioration of the environment (at low income levels) per unit of per capita GDP increase is higher than it would be otherwise" (Panayotou, 1997: 468), which may result in a steeper environmental Kuznets curve. He argues that removing such distortions can flatten out the EKC.

We find similar tendencies in our full models. When we include the freedom and information variables, the EKC in the full models tend to be flatter than that in the basic models. In a basic quadratic functional form, $SO_2 = aY^2 + bY + c$, the coefficient of the squared term, a, determines the concavity (or convexity) of the quadratic function. If the absolute value of a is increasing, the curve (whether it is inverted U, or simply U shaped) will be steeper, and vice versa.

In our model, the coefficients of the income squared terms are,

$$a_1 \times I^2 + a_2 \times CC \times I^2 + a_3 \times T \times (I/WI)^2 = (a_1 + a_2 \times CC + a_3 \times T \times (1/WI)^2) I^2$$

Where a's denote coefficients, I^2 is per capital income squared, CC is communist country dummy, T is trade intensity, WI is world income average. If the absolute value of $(a_1 + a_2 \times CC + a_3 \times T \times (1/WI)^2)$ is smaller in the full models than in the basic models, the EKCs of the full models are flatter. Table 2.9 shows the results. Except for the model with the telecom variable, all the EKC slopes flattened soon after the freedom and information variables were added.

Table 2.9: Adding Freedom and Information and Concavity of the EKC

Model	Estimated coefficient of income squared term		Change of Concavity in full model
	Basic model	Full Model	
Model 1 (Telephone lines)	-0.0101	-0.007704	Flatter
Model 2 (School enrollment)	-0.02663	-0.02593	Flatter
Model 3 (Education years)	-0.02537	-0.02261	Flatter
Model 4 (TV)	-0.027433	-0.02736626	Flatter
Model 5 (Telecom)	-0.01929	-0.02127	Steeper
Model 6 (Newspapers)	-0.01635	-0.00517	Flatter

The income turning points (ITP) are shown in Table 2.10. They range from US$3,240 to US$4,300 in the basic models, and from US$2,800 to US$4,950 (1985 dollar rate) in the full models, which are close to the previous findings (Grossman and Krueger, 1995; Torras and Boyce, 1998; Panayotou, 1997; and Barrett and Graddy, 2000).

Table 2.10: Income Turning Points

Added variable	Income Turning Points		Change of ITP in full model
	Basic model	Full Model	
Model 1 (Telephone lines)	$4,325	$4,950	+$625
Model 2 (School enrollment)	$3,745	$4,427	+$682
Model 3 (Education years)	$4,311	$4,773	+$461
Model 4 (TV sets)	$4,268	$4,379	+$111
Model 5 (Telecom)	$3.294	$4,582	+$1,288
Model 6 (Newspapers)	$3,940	$2,818	-$1,122

Table 2.11 presents estimated pollution levels at income turning points. In most cases, the inclusion of freedom and information variables results in higher pollution level. However, freedom and information shift down the EKC curve below the maximum pollution level of the EKC in the basic models. In case of Model 6 which includes newspapers, the EKC results show flatter curve in the lower maximum SO_2 even when the freedom and newspaper variables are zero.

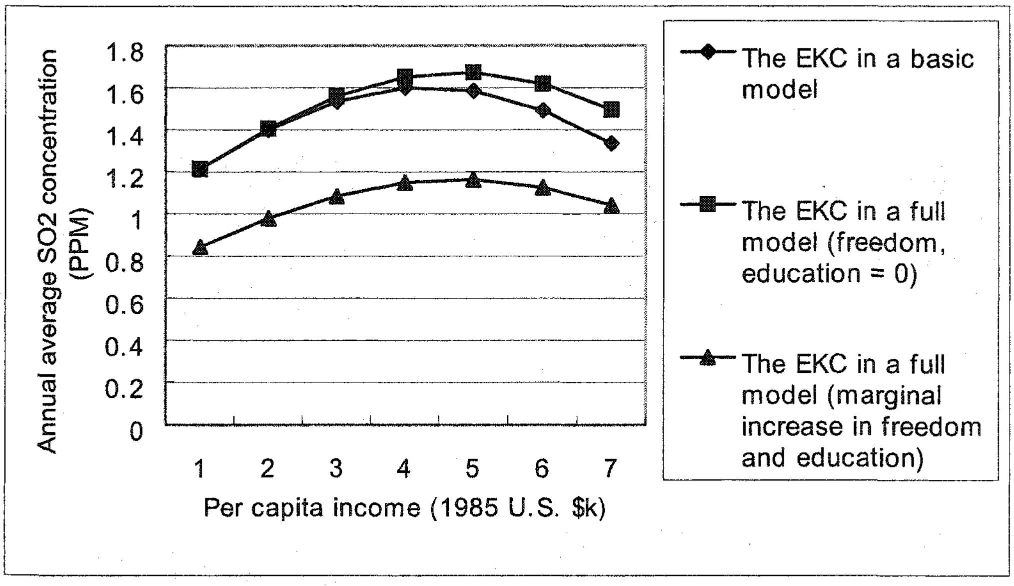
Figure 2.1 displays the EKC in different models with and without the freedom and information variables. As already described, the EKC of the basic model is steeper than that of the full model. Although the maximum pollution level of the full model is higher than that of the basic model, freedom and information (years of education in this graph) shift down the EKC, which results in a lower pollution level than that of the basic model.

Table 2.11: Estimated SO_2 Pollution Level at Income Turning Points

	Basic Model	Full Model (freedom, info =0)	Full Model (Marginal increase in freedom and info)
Model 1 (Telephone)	1.545 ($4,325)	1.545 ($4,950)	1.171 ($4,950)
Model 2 (School enrollment)	1.453 ($3,745)	1.663 ($4,427)	1.141 ($4,427)
Model 3 (Education years)	1.603 ($4,311)	1.674 ($4,773)	1.164 ($4,773)
Model 4 (TV sets)	1.648 ($4,268)	1.690 ($4,379)	1.295 ($4,379)
Model 5 (Telecom)	1.233 ($3.294)	1.563 ($4,582)	1.395 ($4,582)
Model 6 (Newspapers)	1.289 ($3,940)	1.042 ($2,818)	0.844 ($2,818)

1. Unit of SO2 is PPM.
2. ITPs are in parenthesis.
3. Telephone and Newspapers are calculated at sample mean.

Figure 2.1: The EKC in Different Models and Maximum Pollution Levels



5. CONCLUSIONS

This paper investigated the empirical relationship between information, freedom and the environment. Our estimates indicate that a 1% increase in freedom reduces the annual SO2 concentration by approximately 0.05-0.12%, and a 1% increase in information results in approximately 0.001 to 0.05% decreases in SO2 ambient. Although the elasticity is different from the information indicators we selected, all information and freedom variables are significantly negative at 1% level and other main variables such as scale, composition, technique, and trade are still significant and carry the right signs. Moreover, the EKC of the full models is flatter and ITPs are higher than those in the basic replicated models. Higher ITP doesn't necessarily mean that higher maximum pollution levels (more freedom and information) shift the EKC down, which brings lower maximum pollution levels than those of the basic models.

In addition, we find that there is a U-shaped relationship in some information devices and SO_2 ambient. Telephone and newspapers are negatively related to SO_2 concentration in the earlier stage of development. However, the effect marginally decreases with respect to the income growth, and in highly developed economy, positive relations appear. In contrast, years of education, school enrollment, and other information devices are consistently and negatively related to the pollution level. These findings imply that the software side of information sharing is more important in environmental protection in the later stage of development. Software side means human capital and institutions that encourage sharing environmental information. In a less developed society, the hardware side of information sharing along with the software side is also important; development of information related infrastructure might be as important as education.

Limitations of this paper should not be ignored. First, we employed limited proxies for information sharing and information gap realizing that more direct indicators of information and the environment are essential for further empirical studies. Second, because we used only SO_2 data as a dependent variable, we are not able to generalize our findings to other pollution problem in general. Third, some causal pathways are still unclear in income-environment relations. We implicitly assumed that political climate determines the quantity and quality of information, but freedom and information may be interacting with each other, which shapes the socio-economic conditions for the environmental recovery or damage.

These limitations guide a direction for the future studies. More appropriate information data should be created and employed to shed light on the information-environment relations. In addition, we need more empirical tests using various pollutant data to verify our hypothesis on the environment and information.

CHAPTER 3: A POLITICAL ECONOMIC MODEL OF TAXATION IN NATIONAL DEFENSE: REPRESENTATIVENESS, ASYMMETRIC INFORMATION, AND PROVISION OF DEFENSE GOODS

ABSTRACT

This paper develops a political economic model of taxation in national defense under the assumptions of asymmetric information and representativeness, and draws its implications in the studies on the provision of defense goods. Our findings suggest that : 1) the optimal supply of defense goods is not likely to be achieved even under the perfect information setting due to the regulator's rent-seeking and group interests, 2) the asymmetric information between the consumers and politician causes the problem of oversupply of defense goods, 3) but democracy alleviates the oversupply problem in defense by narrowing the information gap. These findings are consistent with Lake's (1992) argument that the state's rent-seeking behavior under the asymmetric information will cause the oversupply of defense goods. With these findings, we reject Downs' (1960) arguments that the "correct" budget would emerge when the citizens have perfect information and that the incomplete information problem causes the undersupply of defense goods. In addition, we conclude that Wittman's (1989) claim that democracies bring efficient results is exaggerated.

1. INTRODUCTION

It has been widely argued that the government's performance of defense goods provision will be inefficient; some predict that defense goods are likely to be over supplied by government, while others predict the opposite direction. While the idea of over supply of defense goods is based on such concepts as state monopoly over the supply of protection and asymmetric information (Ames and Rapp 1977; Lake 1992), that of under supply of defense goods is rooted on the assumptions of voters' ignorance and inefficiency that results from democracy (Downs 1960; Tullock 1959, Hewitt 1986). Jones (1997) summarizes the situation as follows. "Public choice analysis often indicates that public expenditure in western democracies is 'excessive'. However, the same analysis suggests that the more 'public' the good supplied within the public sector the more likely it is to be 'under supplied'" (Jones, 1997: 173).

It is puzzling whether and why the arguments–over supply and under supply–are different, or whether they can be special cases of a bigger picture that previous works are missing. Moreover, Wittman (1989) contends that democratic political markets tend to produce efficient results, which implies that the notions of 'inefficient' provision of defense goods (regardless of oversupply or undersupply) are inaccurate. Now the debates on government's provision of defense goods cover not only 'over' or 'under' supply, but also 'efficiency' of democracies.

The problem of current studies on these issues is that there is no consensus on the relations among asymmetric information, democracy, and provision defense goods; while Lake (1992) predicts that the asymmetric information results in over supply of defense goods, Downs (1960) and Hewitt (1986) argue that it leads to under supply of defense goods. Similarly, the effect of democracy to the provision of defense goods is also different from one study to another; Lake (1992) asserts that political participation will reduce state rent-seeking, which will decrease the extent of over provision of defense goods, while Tullock (1959), Downs (1960), and Hewitt (1986) point out that inefficiency of democracy will contribute to under supply of defense goods.

To understand the relationship between asymmetric information, democracy, and defense good provision, we may need a more unified theory that specifies the conditions of under supply or over supply of defense goods. The purpose of this paper is to develop a political economic model of taxation in national defense under the assumptions of asymmetric information and representativeness, and to draw its implications in the studies on the provision of defense goods.

Our findings suggest that : 1) the optimal supply of defense goods is not likely to be achieved even under the perfect information setting due to the regulator's rent-seeking behavior and group interests, 2) the asymmetric information between the consumers and politician causes the problem of oversupply of defense goods, 3) but democracy alleviates the oversupply problem in defense by narrowing the information gap. These findings are consistent with Lake's (1992) argument that the state's rent-seeking behavior under asymmetric information will cause the oversupply of defense goods. With these findings, we reject Downs' (1960) arguments that the "correct" budget would emerge when the citizens have perfect information and that the incomplete information problem causes the undersupply of defense goods. In addition, we conclude that Wittman's (1989) claim that democracies bring efficient results is exaggerated.

The paper is organized as follows: section 2 reviews the related literature, section 3 introduces a model of taxation in national defense, and section 4 presents conclusions.

2. REVIEW OF LITERATURE

2.1 Taxation in National Defense

It has been asserted that there is a public good called protection, and the foremost service provided by the government is protection (Lake 1992). A government has a monopoly over the supply of protection to its subjects, and taxes are the price paid to the monopolist (Ames and Rapp, 1977: 166).

Ames and Rapp (1977) provide a simple model of defense and taxation. In the model, there are two individuals *X* and *Y*, and *Y* has a utility function $U(a_i, b_j)$, with i, j=1, 2 so that *Y*'s welfare depends upon his own actions (a_1 or a_2) and also on the actions of X(b_1 or b_2). *X*'s choice of action b_1 is assumed to be harmful to *Y*, and *X* threatens *Y* by saying "If you choose a_1, I will choose b_1." Then, *Y* faces with an uncertain situation; *X*'s threat may or may not be a bluff, and he may choose b_1 even if Y chooses a_2. In this situation, Y must assign probabilities to each of the possible outcomes, (a_1, b_1), (a_2, b_1), (a_1, b_2), (a_2, b_2), and the expected utility for Y of action a_1, say $U_E(a_i)$, $i = 1, 2$, is given by

$$U_E(a_i) = p(a_i b_1)\ U(a_i, b_1) + p(a_i b_2)\ U(ai, b_2)$$

If $U_E(a_2) > U_E(a_1)$, then Y will yield to X's threat and choose a_2. If $U(a_1, b_2) > U(a_2, b_2)$, Y prefers a_1 to a_2. Hence, if $U_E(a_2) > U_E(a_1)$ and $U(a_1, b_2) > U(a_2, b_2)$, Y would choose action a_1 if he were not threatened by X. Then, Y would be willing to make a payment to X to induce X to withdraw or reduce the threat. This is "a payment for protection, which involves extortion if X makes a monopoly profit on the transaction." (Ames and Rapp, 1977: 168).

Now, if there is a third individual Z who is willing to protect Y, Y may make a payment to Z in return for a threat by Z against X. Z reduces the threat that X poses to Y by saying "If you choose b_1 (which harms Y), I will harm you." The effect of such protection is to reduce the probability that X will choose b_1, and it will convert the inequality $U_E(a_2)$ into the inequality $U'_E(a_1) > U'_E(a_2)$, because the probability $p(a_1, b_1)$ is reduced. "Such payments as Y would make to Z are for the service of defense or justice depending on the nationality of X" (Ames and Rapp, 1977: 168).

With this basic concept, Ames and Rapp (1977) argue that a one-time threat will cause Y to make perpetual protection payments to Z (government). If a threat will damage Y by some amount D, he assigns a probability p to the execution of the threat, so that his expected loss is pD. All the damage is assumed to occur at time t=0.

Y pays a tax T per unit of time, and in perpetuity the immediate threat is assumed to be removed. Given a discount rate r, then, the maximum value of T is given by

$$pD = \int_0^{\infty} Te^{-rt}dt = T/r$$

$$T = rpD$$

Ames and Rapp (1977) argue that the price of the defense good (tax) can become extortionate if governments earn monopoly profits; such profits are less likely if there are substitutes available for a given government. "Since "extortion" can finance expenses other than protection, governments will collude (if demand is inelastic) with competing suppliers in order to sustain such profits." (Ames and Rapp, 1977: 177).

2.2 Asymmetric Information, Democracy, and the Provision of Defense Goods

The monopolistic conditions of Ames and Rapp's (1977) model indicate that defense goods are likely to be over provided more than needed. Extortion and collusions of governments will increase tax levels more than is efficient when the government is a monopoly.

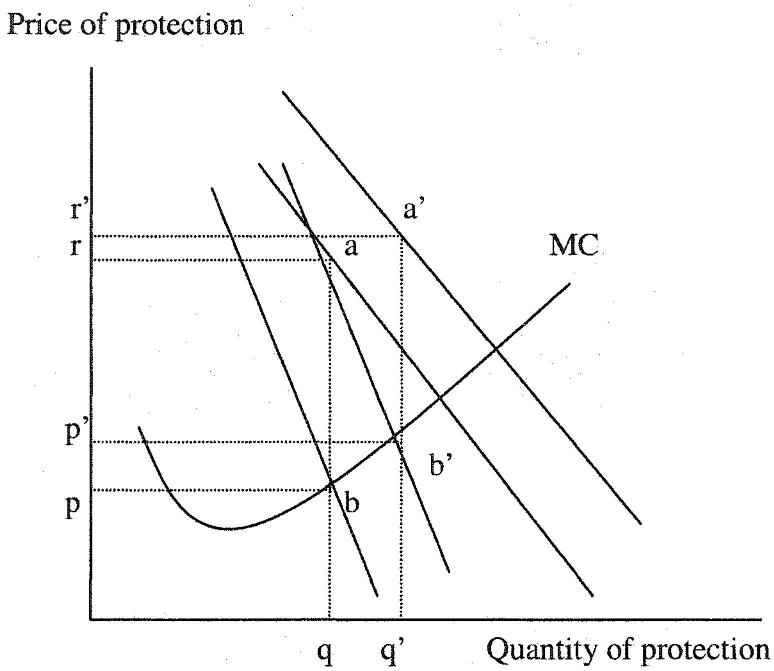
Lake (1992) also predicts that defense goods can be over supplied due to the state's rent-seeking in national defense. The demand curve for protection in a society slopes downward and to the right, as in Figure 3.1. Further, the level of protection demanded by society is a function of external threat. More threat will necessitate a higher demand for protection. In Figure 3.1, the original demand curve shifts outward due to an increase in threat ($D<D'$). On the supply side, the state enjoys

monopoly power and can control the quantity of the protection supplied. In order to maximize profit, the state will set its output at the level where marginal cost and marginal revenue are same. The normal price and quantity level are represented by *p* and *q*, in Figure 3.1, while *r* and *q* show those in monopoly market. The difference between *p* and *r* defines the rent earned by the state (*p-r-a-b* in Figure 3.1).

States can magnify, exaggerate, or oversell foreign threats to society, whether by supplying incomplete information or engaging in outright deception (Ames and Rapp, 1977; Lake, 1992). In this case, a state effectively shifts the demand curve outward (*D'>D*) and thereby earns greater rents (*p'-r'-a'-b'* > *p-r-a-b*). The amount, *q'-q*, is over supplied by the state by exaggerating foreign threat. "The state faces strong incentives to seek rents at the expense of society. In other words, the state can benefit itself by charging consumers the monopoly price for protection (*r* in Figure 3.1) and by artificially inflating demand through extortion or racketeering" (Lake, 1992: 25).

Lake points out that because consumers prefer a lower price of protection, they need to monitor the state's performance and "acquire information on the strategies it is pursuing. ...no single citizen has any incentive to invest in information; and, because of the free-rider problem, collective investment in information occurs only at suboptimal levels. The higher the costs of acquiring information regarding state performance, the greater latitude state officials possess to engage in rent-seeking behavior" (Lake, 1992: 26).

Figure 3.1: The Supply and Demand for Protection under Monopoly Provision



There are other studies that suggest the possibility of over supply of public goods, which imply over provision of the defense goods. Niskanen (1968) presents a model of a bureau where bureaucrats tend to maximize the total budget of their bureau. "Among the several variables that may enter the bureaucrat's utility function are the following: salary, perquisites of the office, public reputation, power, patronage, ease of managing the bureau, and ease making changes." (Niskanen, 1968: 293). This implies that the defense goods could be over supplied due to the defense bureau's self interest. Brennan and Buchanan (1980) make similar point by stressing that the state is "Leviathan" that seeks revenue maximization.

While studies above predict over supply of defense goods, others suggest that defense goods are likely to be under supplied by the government. This line of studies tends to emphasize the inefficiency of democracy and asymmetric information problem.

Tullock (1959) argues that the inefficiency of majority voting system results in under supply of public goods. Government policymaking is decided by majority voting where logrolling (vote-trading) is practiced. Political organizations bargain with other parties to achieve their political goal, but the most effective bargainer will have a considerable advantage under majority voting. Then, "if a given sum of money is to be spent on two different types of governmental activity, one of which is of general benefit and one of which benefits a series of special groups, too much will be spent on the latter. Defense, for example, will be slighted in favor of river and harbor" (Tullock, 1959: 578).

Downs (1960) suggests that voters do not fully recognize the benefits from public sector goods and public goods tend to be under provided in a democracy. Each government sets the government budget to maximize its chances of winning the election. Likewise, the voters vote for the party whose policies will benefit them more than those of any other party. However, it is complex and time-consuming for the voters to acquire adequate political information, and this ignorance causes governments to enact budgets smaller than what they would enact if the electorate possessed complete information. In other words, the government is primarily interested in people's votes, not their welfare, and will not increase their welfare if doing so by taxation would decrease votes.

Downs contends that information plays a critical role in determining the budget size, because citizens' rational political ignorance produces an "incorrect" government budget. The "correct" budget is "the one which would emerge from the democratic process if both citizens and parties had perfect information about both actual and potential government policies. Insofar as an actual budget deviates from the 'correct' budget, it is 'incorrect'"(Downs, 1960: 545). Then the incomplete information will result in the sub optimal level of budget as follows:

> As long as citizens know what benefit them, there should be no difference between the actual budget and the 'correct' budget. But if there are benefits which government spending would produce that people are not aware of, the government will not spend money to produce them unless it believes it can make them well-known before the next election. … Thus if voters are unaware of the potential benefits of certain types of government spending, party competition may force the actual budget to become smaller than the 'correct' budget" (Downs, 1960: 546).

Downs provides us a rationale for the under provision of defense goods which is based on the concept of 'incomplete information' in democracies.

Hewitt (1986) stresses that federal and state level public goods tend to be less provided for than local public goods. Consumers and voters are largely unaware of intergovernmental transfers from federal and state government to local government, and then they think the federal and state governments are inefficient, which decreases demand for federal and state public goods. His survey result indicates "residents of states that gave a high proportion of their state revenues to localities in the form of grants tended to have lower demand for state government expenditures, holding other variables constant. In contrast, residents of states that received a high proportion of federal grants relative to their state expenditures tended to have a higher demand for state government expenditures (however, this coefficient was only marginally significant)" (Hewitt, 1986: 479). Again, under provision of defense goods is predicted.

2.3 Democracy, Efficiency, and Provision of Defense Goods

While the idea of over supply of defense goods is based on such concepts as state's monopoly over the supply of protection and asymmetric information (Ames and Rapp 1977; Lake 1992), that of under supply of defense goods is rooted on the assumptions of voters' ignorance and inefficiency that results from democracy (Downs 1960; Tullock 1959, Hewitt 1986). Both views show that government's performance on defense goods provision will be 'inefficient' due to the reasons listed above.

However, Wittman (1989) contends that democratic political markets tend to produce efficient results, which implies that the notions of 'inefficient' provision of defense goods (regardless of oversupply or undersupply) are inaccurate. To him, reputation, political competition, etc. in democracy will reduce opportunist behavior of government. Moreover, voters are not that stupid, and the amount of information held by voters has been underestimated by previous work (for instance, Downs 1960). "A voter needs to know little about the actions of his congressman in order to make intelligent choices in the election. It is sufficient for the voter to find a person or organization(s) with similar preferences and then ask advice on how to vote" (Wittman, 1989: 1400). In addition, the deleterious effect of biased information has been overstated in previous work (for instance, Lake, 1992). "I have never met anyone who believes that the Defense Department does not exaggerate the need for defense procurement. But if everyone knows that the Defense Department will exaggerate the importance of its contribution to human welfare, then, on average, voters will sufficiently discount Defense Department claims. Hence, biased sources of information need not lead to biases in belief." (Wittman, 1989: 1401). Further, due to competition among the rivalry defense contractors, the total amount of defense expenditures will not reach the excessive level. In sum, downplaying the possibility of government failure, Wittman (1989) presents the prediction that the provision of defense goods will be efficient in democracies.

2.4 Evaluation

Table 3.1 summarizes previous studies on asymmetric information, democracy, and the provision of defense goods. The problem of previous studies on these issues is that there is no consensus on the relations between asymmetric information, democracy, and provision defense goods; while one side predicts that the asymmetric information results in over supply of defense goods (Lake 1992), the other argues that it leads to under supply of defense goods (Downs 1960, Hewitt 1986). Likewise, the effect of democracy to the provision of defense goods is also different from one study to another; Lake (1992) asserts that political participation will reduce the state's rent-seeking, which will decrease the extent of over provision of defense goods, while Tullock (1959), Downs (1960), and Hewitt (1986) point out that inefficiency of democracy will contribute to under supply of defense goods.

Table 3.1: Asymmetric Information, Democracy, and Provision of Defense Goods: Previous Works

Authors	Causes of Over/Under Supply of Defense Goods	Consequences	Rationale
Lake (1992)	Monopoly power, Asymmetric information	Over supply	Asymmetric information problem enables the regulator rent-seeking.
Tullock (1959)	Problem of majority voting	Under supply	Majority voting system doesn't represent demand for defense goods.
Downs (1960)	Asymmetric information, Democracy	Under supply	Demand for defense goods are under revealed in democracy due to asymmetric information problem
Wittman (1989)	NA	Optimum supply	Democracy produces efficient results.

To understand the relationship between asymmetric information, democracy, and defense good provision, we may need a more unified theory that specifies the conditions of under supply or over supply of defense goods. The next section presents a political economic model of taxation in national defense for this purpose.

3. MODEL

In this section we present a simple model of the interaction among three interest groups, consumers, a defense good provider and a politician, within a rent-seeking context. This enables us to consider the effects of changes in the exogenous parameters of the model on the control variables.

3.1 Firms

Firms maximize profit by producing goods. In particular, some subsets of firms maximize profit by producing defense goods in our model. Assume that there is a defense good q, and a typical defense goods supplier (a firm in defense industry) makes profit π by producing q. The price of defense good q is defined as D that is assumed to be a normal markup. For simplicity, we assume that D is given. Then, the firm's profit function is $\pi = Dq$, where $D>0$. If q^* is the minimum amount of defense goods under a certain threat, the firm can make super normal profits by increasing the amount of defense goods. In other words, if q is greater than q^*, the firm earns more profits, $(q\text{-}q^*)D$, than necessary.

3.2 Consumers

Assume that consumers constitute the largest group in an economy, and each consumer maximizes utility. Every consumer has well-behaved preferences and maximizes their utility. The consumers' utility is a function of consumption.

$U = u(c)$, subject to $I=pc$,

where c is consumption levels of goods and services, I is income, p is a price of consumption good, and all income is spent on consumption, c. The utility function u is assumed to be concave in consumption $u_c>0$, $u_{cc}<0$.

Consumers face an external threat that foreign countries pose and we denote threat as θ. The threat increases the possibility of war, W, that decreases consumer's utility. To alleviate the possibility of war, the government collects tax and provides the public good, q, that is known as 'protection'. Then, war is an increasing function of θ, and decreasing function of q, $W=W(\theta, q)$, where $W_\theta>0$, $W_q<0$. Now, the consumers' utility is denoted as follows.

$U = u(c, W)$, subject to $I-tI=pc$

Where W is war, $W(\theta, q)$, θ is an external threat ($W_\theta>0$), q is defense goods ($W_q<0$), and t is the income tax. All tax is spent on the defense good.

We also assume that an average consumer is a stockholder of the defense firm. Let g be the dividend of profit from the defense firm, then $(g/n)\pi$ is an average consumer's stake in defense industry, where g is $0\leq g\leq 1$, and n is the number of shareholders (consumers). The other source of consumer's income is denoted as w, and then, consumer's total income I is $I = (g/n)\pi + w$. The parameter g indicates how much consumers are financially dependent on defense sector. If g is 0, an average consumer has no stake in defense sector, while if it gets larger, an average consumer is more financially dependent upon the defense sector.

3.3 Regulator

3.3.1 The regulator's objective function under complete information

The regulator's role in our model is to detect an external threat, to impose tax to the voters, especially for the consumers, and to provide protection to society. The regulator is assumed to be an incumbent who maximizes his welfare by setting optimal tax rate in this economy (Besley and Case, 1995). If a certain threat θ is posed by a foreign country, this will necessitate the government to purchase q and provide protection. The quantity of a defense good q^* is the minimum amount of defense to alleviate the threat. Then, q^* is a function of θ, $q^*=q(\theta)$, where $q_\theta > 0$.

The price of the defense good q is D, and Dq^* is the total amount of money that this society should spend for protection. The government needs to finance Dq^* by imposing tax on the consumers. For simplicity, we assume that the income tax is used only for national defense, in that the tax is the payment for protection. The total tax revenue is ntI, where I is the consumer's income, t is income tax, n is the number of taxpayers. If the government maintains a balanced budget, the defense spending should be equal to the tax revenue, $Dq^* = ntI$.

Then, $q^*(\theta)$ is ntI/D, and the consumer's utility and firm's profit function should be redefined in the regulator's perspective as follows.

$$\pi = Dq^*(\theta) = ntI \qquad (1)$$

$$u = u(c, W(\theta, q(\theta))) = u(c, W(\theta, \mathrm{ntI/D})) \qquad (2)$$

Where $c=c((1-t)I, p)$, $I = (g/n)\pi + w$.

We assume consumers' political support for the incumbent depends on changes in utility; an increase in utility leads to greater political support, while a decrease in utility causes opposition to the politician. Similarly, firm's political support for incumbent is based on a change in profit; an increase (decrease) in profit leads to political support (opposition) for the politician.

Denote political support as μ that is an index between 0 and 1. While 0 means no votes, 1 means that incumbent earns 100% support from the voters where voters include consumers and firms. We assume that μ is a function of political support from consumers L and that from producer F, meaning that incumbent seeks votes from two interest groups, as explained above. In turn, L and F are assumed to be functions of consumers' utility and firms' profit respectively, where $\mu=\mu(L(u), F(\pi))$, $\partial L/\partial u>0$, and $\partial F/\partial \pi>0$.

The regulator's welfare depends on wealth in the current period (before the election) and future expected wealth in the next period (after the election). We define the politician's wealth by salary and a certain share of defense firm's profit. Denote current salary as y, and the incumbent's stake in defense industry as G. The incumbent's stake G includes any form of financial giving such as contributions, dividend of profits, and bribes. As the result of reelection is uncertain in period 0, we introduce expectation $E[.]$, and the politician's expected salary after election is $E[y_1]$. Politician's total welfare from the office is $y + G\pi + E[y_1+G_1\pi_1]$.

We assume that $E[y_1+G_1\pi_1]$ depends on political support from consumers and firms (Appelbaum and Katz, 1987), and the incumbent maximizes net votes (votes from one interest group minus opposition from the other group, see Peltzman) by imposing income tax on consumers. More votes increase the probability of reelection.

The politician's optimization problem is to maximize the his welfare (V) by choosing t: $\underset{t}{Max}\, V = y + G\pi + \beta\mu(t)[y_1 + G_1\pi_1]$

Where y and y_1 are the politician's salary before and after the election; 1 denotes the term after the election.

β is a discount factor,

$\mu = \mu(nL(u(c, W(\theta, q^*)), (N\text{-}n)F(\pi)),$

$c = c(p, (1\text{-}t)I),$

$I = (g/n)\pi + w,$

$q^*(\theta) = ntI/D,$

$\pi = Dq^*(\theta) = ntI,$

N is the number of votes in the society,

n is the number of votes (taxpayers) in consumer group.

The first order condition is,

$V_t = G\pi_t + \beta\mu_t[y_1 + G_1\pi_1] = 0$

Where $\pi_t = \mathrm{D}q_t$,

$\mu_t = n(\mu_L L_u u_c c_t) + n(\mu_L L_u u_W W_t) + (N\text{-}n)\mu_F F_\pi \pi_t,$

$c_t = \text{-}I + (1\text{-}t)I_t,$

$I_t = (g/n)\pi_t,$

$q_t = nI/D,$

$I=(g/n)\pi+w,$

$W_t = W_q q_t.$

$G\pi_t$ is the marginal increase in wealth that comes from the defense industry, while μ_t is the net change in political support from consumers and defense firms. The first term of μ_t, $n(\mu_I L_u u_c c_t)$, is the marginal net loss in political support from consumer group due to the increased tax burden, while the second term, $n(\mu_I L_u u_W W_t)$, is the marginal increase in political support from consumer group which comes from the enhanced protection, and the third term, $(N\text{-}n)\mu_F F_\pi \pi_t$, is a marginal increase in political support from the defense industry. Overall, V_t shows the marginal benefit and cost of taxation that captures a change in the regulator's expected wealth due to the a change in net public support. The regulator's optimal policy balances the effects above.

The second order condition is,

$V_{tt} = G\pi_{tt} + \beta\mu_{tt}[y_1 + G_1\pi_1] < 0$

Where $\pi_{tt} = Dq_{tt}$,

$\mu_{tt} = n(\mu_I L_u u_c c_{tt}) + n(\mu_I L_u u_W W_{tt}) + (N\text{-}n)\mu_F F_\pi \pi_{tt}$,

$c_{tt} = -I_t - I_t + (1-t)I_{tt}$,

$c_t = -I + (1-t)I_t$,

$I_t = (g/n)\pi_t$,

$I_{tt} = (g/n)\pi_{tt}$,

$q_t = nI/D$,

$I = (g/n)\pi + w$,

$W_{tt} = W_q q_{tt}$.

3.3.2. Comparative statics: Full information case

3.3.2. A. The external threat

The sign of $dt/d\theta$ will show whether the threat positively or negatively affect the tax level. The external threat is expected to be positively related to the tax level, because the state will need to provide more defense goods with respect to an increase in the threat. The following result is obtained.

$$dt/d\theta = \{G\pi_{t\theta} + \beta\mu_{t\theta}[y_1 + G_1\pi_1]\}\lambda >=< 0$$

Where $\pi_{t\theta} = (1/t)Dq_\theta \geq 0$,

$\mu_{t\theta} = n(\mu_L L_u u_c c_{t\theta} + \mu_L L_u u_W W_{t\theta}) + (N-n)\mu_F F_\pi \pi_{t\theta} >=< 0$,

$c_{t\theta} = -I_\theta + (1-t)I_{t\theta} >=< 0$,

$I_\theta = (g/n)\pi_\theta \geq 0$,

$I_{t\theta} = (g/n)\pi_{t\theta} \geq 0$,

$\pi_\theta = Dq_\theta \geq 0$,

$\pi_t = Dq_t \geq 0$,

$c_t = -I + (1-t)I_t$,

$W_{t\theta} = W_q q_{t\theta} \leq 0$,

$I_t = (g/n)\pi_t \geq 0$,

$I = (g/n)\pi + w$,

$W_t = W_q q_t$,

$\lambda = [-1/V_{tt}] > 0$.

The sign of $dt/d\theta$ is ambiguous, because the voters' support for the government's tax policy $\mu_{t\theta}$ is ambiguous. In $\mu_{t\theta}$, there are two terms, $n(\mu_L L_u u_c c_{t\theta} + \mu_L L_u u_W W_{t\theta}) + (N\text{-}n)\mu_F F_\pi \pi_{t\theta}$, and the ambiguity of $\mu_{t\theta}$ originates from the first term $n(\mu_L L_u u_c c_{t\theta} + \mu_L L_u u_W W_{t\theta})$. The term, $n(\mu_L L_u u_c c_{t\theta} + \mu_L L_u u_W W_{t\theta})$, represents the support of consumer group for the government's tax policy with respect to a change in threat, while $(N\text{-}n)\mu_F F_\pi \pi_{t\theta}$ shows the producer's support for tax policy. The sign of $\mu_L L_u u_c c_{t\theta}$ is negative, while that of $\mu_L L_u u_W W_{t\theta}$ is positive[22], which makes $\mu_{t\theta}$ ambiguous. While the negative $\mu_L L_u u_c c_{t\theta}$ means a decreased support from the consumers due to their income loss that results from more tax, the positive $\mu_L L_u u_W W_{t\theta}$ means an increase in support from the consumer group due to the enhanced security provided by paying more tax. We assume that the former ($\mu_L L_u u_c c_{t\theta}$) is smaller than the latter ($\mu_L L_u u_W W_{t\theta}$), $\mu_L L_u u_c c_{t\theta} \leq \mu_L L_u u_W W_{t\theta}$, and then this makes $\mu_{t\theta}$ and the whole sign of $dt/d\theta$ positive. The rationale behind this assumption is that in a full information case, consumers have perfect information concerning the external threat, and they will prefer security to income when foreign countries pose more threat to the host country.

This comparative static result is realistic in that political leaders would increase taxes or expand military budget when they face an increase in the external

[22] In $c_{t\theta}$, there are two income effects regarding a change in the threat; one is $-I_\theta$ and the other is $(1\text{-}t)I_{t\theta}$. While the former represents the consumers' income loss due to an increase in the threat, the latter shows an increase in consumers' income that comes from more profits due to more threats (note that consumers in this model are stakeholders of a defense firm). We assume that $-I_\theta + (1\text{-}t)I_{t\theta}$ is negative, and accordingly, $c_{t\theta}$ is negative as well, because the direct effect of threat $-I_\theta$ will be larger than the

threats. For instance, in the cold war era, the communist countries and the West had actual arms races responding to each other's military threats; the USA and the Soviet Union, the NATO and the Warsaw Pact, and South Korea and North Korea. By contrast, in the post-cold war era, most countries have decreased their military spending, which reflects the disappearance of the Soviet Union and its satellite nations that once posed as a considerable threat to the rest of the world.

3.3.2.B. The regulator's rent from the defense industry

The regulator's rent from the defense industry is also expected to affect the tax level, because he/she may set the tax level for his/her own benefit. The sign of dt/dG will show whether the regulator's rent positively or negatively affect the tax level.

$$dt/dG = \pi_t \lambda > 0$$

Where $\pi_t = nI > 0$,

$\lambda = [-1/V_{tt}] > 0$.

The comparative static result above shows that dt/dG is clearly positive, which means that more rents (or stakes) from the defense industry will motivate the regulator to set a higher tax rate. If the regulator earns profit, rent, or contribution from the defense industry by taxation, he/she will raise the tax level higher than it is necessary.

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indirect effect of threat on income $(1\text{-}t)I_{t\theta}$. In the real world, the negative impact of threat on consumer's income will be larger than the consumer's gain from more threats.

3.3.2.C. Votes in the defense industry

The sign of $dt/d(N\text{-}n)$ will show how votes in the defense industry affect the regulator's tax setting.

$$dt/d(N\text{-}n) = \{(N\text{-}n)\mu_F F_\pi \pi_t\}\lambda > 0$$

Where $\lambda=[-1/V_{tt}] > 0$.

The whole sign of $dt/d(N\text{-}n)$ is positive, which indicates that more votes in the defense industry will induce the regulator to set a higher tax rate. This means that the size of defense industry is another factor that determines the tax level (or the provision of defense goods). If the base of defense industry is large, and it creates a lot of employments, the voters (especially in the defense sector) will allow the regulator to increase the tax rate, and accordingly, the government will provide more defense goods than needed.

3.3.3. Evaluation

Our findings reject Downs' (1960) argument that the "correct" budget would emerge under the perfect information. Because the group interest is engaged in the regulator's determination of tax in national defense, the "correct" budget is hardly achieved even in the full information case. As shown above, the external threat, regulator's rent from the defense industry, and the number of votes in defense industry are positively related to the tax level, which causes deviations from the correct budget.

By contrast, our findings support Lake's (1992) argument that defense goods can be over supplied due to the state's rent-seeking behavior. Even though his argument is based on the asymmetric information between the state and the citizens, the findings of this paper show that defense goods can be oversupplied even in the complete information case due to the regulator's self-interest and the defense industry's influence over the tax-setting process.

In the next section, we explore more this issue by extending the model to an asymmetric information case.

3.3.4 Incomplete information and tax setting

The asymmetric information problem may arise in national defense, because incumbents have more information on external threat than consumers. Having more information enables incumbents to use tax policy to maximize their welfare, and then tax policy is a tool not only for vote seeking but rent seeking.

There are two types of threat; one is the real threat, θ, that is known to the regulator only, and the other is consumers' perceived threat θ^P that is released to the public by the regulator. While the first type is an objective threat that is to be identified by the regulator with intelligence technology, the second type is subject to the value that politicians place upon it depending on their vested interests.

Denote the amount of information that the regulator has as i^R and that of consumers as i^C. Information gap between incumbent and voters is defined as i^R-i^C, and we denote it as i. i is assumed to be positive. We assume that information gap contributes to inaccuracy of the consumers' threat assessment, and that i is related to the deviation between θ and θ^p. Let θ^d be θ^p-θ, and then θ^d that is an increasing function *of i*, $\theta^d = \theta^d(i)$, $\partial\theta^d/\partial i>0$. More information gap results in more deviation between the real threat and the perceived threat, which means the real threat is overestimated.

Information gap may be endogenously determined, and we assume that representativeness is negatively related to the asymmetric information problem, because citizens are free to disseminate information on defense-related issues under representative governments. Representative government is defined as "a system of government in which the people elect agents to represent them in a legislature" (Political Dictionary, http://www.fast-times.com/political/political.html, 1998). Denote d for representativeness, and then i is a decreasing function of d, $i(d)$, where $\partial i/\partial d<0$. Then, θ^d is $\theta^d(\phi i(d))$, where ϕ is a shift parameter of information gap. A certain incidence can change the information gap between the regulator and consumers, and the parameter ϕ captures this shift. For example, a foreign news agency may disclose enemy's military capability that the regulator concealed. This kind of incidence can narrow information gap, which shifts $i(d)$ down. In this sense, ϕ is an unexpected shock that changes the information gap between the regulator and consumers on national defense issue.

We need to replace the real threat θ with perceived threat θ^p in the previous full information model. Consumer's perceived threat contains not only original threat, but also the exaggerated threat; Consumer's perceived threat; $\theta^p = \theta + \theta^d(\phi i(d))$.

Further, the perceived threat should be introduced to the consumer's utility and firm's profit functions. Now, consumer's utility and firm's profit function are described as follows;

Consumer's utility; $u(c, W(\theta^p, q(\theta^p))) = u(c, W(\theta^p, ntI/D))$, where $I = (g/n)\pi + w$,

Firms' profit: $\pi = Dq(\theta^p) = ntI$

Now, the regulator's optimization problem is to maximize his welfare (V) by choosing t;

$$\underset{t}{Max}\, V = [y + G\pi(t)] + \beta\mu(t)[y_1 + G_1\pi_1],$$

where y and y_1 are the politician's salary before and after the election,

G is the regulator's share of the firm's profit,

β is a discount factor,

$\mu = \mu(nL(u(c, W(\theta^p, q)), (N\text{-}n)F(\pi))$,

$c = c(p, (1\text{-}t)I)$,

$I = (g/n)\pi + w$,

$q(\theta^p) = ntI/D$,

$\pi = Dq(\theta^p) = ntI$,

N is the number of votes in the society,

n is the number of votes (taxpayers) in consumer group,

g is consumers' share of firm's stock,

θ^r is the real threat; $\theta^r = \theta + \theta^d(\phi i(d))$,

d is democracy,

π_1 is firm's profit after the election.

The first order condition is,

$V_t = G\pi_t + \beta\mu_t[y_1 + G_1\pi_1] = 0$

Where π_t = Dq_t,

$\mu_t = n(\mu_L L_u u_c c_t) + n(\mu_L L_u u_W W_t) + (N\text{-}n)\mu_F F_\pi \pi_t$,

$\theta^r = \theta + \theta^d(\phi i(d))$,

$c_t = -I + (1\text{-}t)I_t$,

$I_t = (g/n)\pi_t$,

$q_t = nI/D$,

$I = (g/n)\pi + w$,

$W_t = W_q q_t$.

$G\pi_t$ is the marginal increase in wealth that comes from the defense industry, while μ_t is the net change in political support from consumers and defense firms. The first term of μ_t, $n(\mu_L L_u u_c c_t)$, is the marginal loss in political support from consumer group due to the increased tax burden, while the second term, $n(\mu_L L_u u_W W_t)$, is the marginal increase in political support from consumer group which comes from the enhanced protection, and the third term, $(N\text{-}n)\mu_F F_\pi \pi_t$, is a marginal increase in political support from the defense industry. Overall, V_t shows the marginal benefit and cost of taxation that captures a change in the regulator's expected wealth due to a change in net public support. The regulator's optimal policy balances the effects above.

The second order condition is,

$V_{tt} = G\pi_{tt} + \beta\mu_{tt}[y_I + G_I\pi_I] < 0$

Where $\pi_{tt} = Dq_{tt}$,

$\mu_{tt} = n(\mu_L L_u u_c c_{tt}) + n(\mu_L L_u u_W W_{tt}) + (N\text{-}n)\mu_F F_\pi \pi_{tt}$,

$c_{tt} = -I_t - I_t + (1\text{-}t)I_{tt}$,

$c_t = -I + (1\text{-}t)I_t$,

$I_t = (g/n)\pi_t$,

$I_{tt} = (g/n)\pi_{tt}$,

$q_t = nI/D$,

$I = (g/n)\pi + w$,

$W_{tt} = W_q q_{tt}$.

3.3.5 Comparative statics: Incomplete information case

3.3.5. A. Asymmetric information and representativeness

The parameter ϕ captures a shift in information gap, and here we explore $d\phi/dt$. As explained above, ϕ captures an unexpected shock that changes the information gap between the regulator and consumers on national defense issues. While Lake (1992) suggests that the asymmetric information will result in an oversupply of defense goods, Downs (1960) argues that it will lead to an undersupply of them.

$dt/d\phi = \{G\pi_{t\phi} + \beta\mu_{t\phi}[y_I + G_I\pi_I]\}/\lambda >=< 0,$

where $\pi_{t\phi} = Dq_{t\phi} = (D/t)q_{\phi} > 0,$

$q_{\phi} = iq_{\theta}\theta_{\phi} > 0,$

$\mu_{t\phi} = n(\mu_L L_u u_c c_{t\phi}) + n(\mu_L L_u u_W W_{t\phi}) + (N\text{-}n)\mu_F F_{\pi}\pi_{t\phi} >=< 0,$

$c_{t\phi} = -I_{\phi} + (1\text{-}t)I_{t\phi} >=< 0,$

$I_{t\phi} = (g/n)\pi_{t\phi} > 0,$

$I_{\phi} = (g/n)\pi_{\phi} > 0,$

$\pi_{\phi} = Dq_{\phi} > 0,$

$W_{t\phi} = W_q q_{t\phi} < 0,$

$\lambda = [-1/V_{tt}] > 0,$

$I = g\pi + w.$

Because the threat θ under perfect information is replaced with the perceived threat (or exaggerated threat, $\theta^p = \theta + \theta^d(\phi i(d))$ in the asymmetric information case, the comparative static result of $dt/d\phi$ is basically the same with that of $dt/d\theta$ except the subscript ϕ (see pp. 22-26). Hence, as $dt/d\phi$ is positive, $dt/d\phi$ is positive, too, which means that more information gap between the political leaders and the consumers will lead to a higher tax, and accordingly more provision of defense goods.

It is noteworthy that the information gap ϕ is not the real threat itself, but it functions the same way that the real threat motivates the regulator to set a higher tax level. A real world example will be helpful to understand this. In October 1986, an authoritarian ruler Chun Doo Whan of South Korea disclosed the Kumgansan project stating that it might be a new source of threat from North Korea. According to the government officials of South Korea, the North had been building the Kumgangsan hydroelectric dam since mid 1980s in the upstream of the Han River that runs from North to South Korea, and the dam would hold 20 billion metric tons of water. If it were breached after completion, it would release an enormous amount of water into the South that would completely flood the Seoul metropolitan area where a quarter of the total population dwells. The Seoul administration launched a campaign to raise funds to build the "Peace Dam" in the South Korean territory to counteract against a possible threat of a "water bomb" from the North. Although government officials stressed that the threat was real and menacing, the opposing politicians claimed that publicity about the dam helped create a sense of insecurity that generated public support for the Government's stance.[23] U.S. intelligence analysts also perceived no intentional threat to South Korea from the dam.[24] In 1993, after the democratic transition from the authoritarian ruler Chun Doo Whan to President Kim Young Sam, the new democratic Government investigated the Peace Dam project, and concluded

[23] See New York Times, "Dam Worries the South." November 30, 1986.

[24] See Washington Post, "War of Waters: Is North Korea Building a Dam or a Flood Bob?" September 20, 1987.

that the former authoritarian Government in 1986 exaggerated the threat of Kumgangsan Dam.[25]

This incidence shows that if there is a new source of threat, the information gap between the citizens and politicians widens and then the government can take advantage of the situation to earn more public support by exaggerating the potential threat. Arguably in this process, citizens may pay more tax and the defense goods can be over supplied.

3.3.5. B. Representativeness and tax-setting

Note that the representativeness d is negatively related to the information gap i, and the information gap is positively related to the perceived threat ($\theta^p = \theta + \theta^d(\phi i(d))$, where $\partial i/\partial d < 0$) in our model. Then, because $dt/d\theta$ and $dt/d\phi$ are both positive, dt/dd is negative. This means that democracy will lessen the asymmetric information problem, which will also alleviate the oversupply of defense goods, too.

The example of "Peace Dam" project in Korea shows that the asymmetric information problem is more likely to happen under an authoritarian regime than in a democratic one. Chun Doo Whan was able to blame the North for the possibility of water attack from the North because his regime did not disclose full information on the Kumgandsan Dam to the citizens. In democracies, citizens share more information, and hence narrow the information gap and help to downsize the once inflated defense budget under an authoritarian regime.

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[25] See Chosunilbo (a Korean Newspaper), "Exaggerating the Possibility of Water Attack for the Regime Stability." September 1, 1993.

3.3.6. Evaluation

Our comparative static result rejects Downs' (1960) argument that the incomplete information problem causes the undersupply of defense goods. Rather, the asymmetric information problem will result in the oversupply of defense goods. In the section 3.3.3., we discussed that the "correct" budget is hardly achieved even in the full information case, because the group interest is engaged in the regulator's determination of tax in national defense. Our findings under asymmetric information case suggest that the incomplete information hinders the regulator in formulating the "correct" budget, because it contributes to an increase in the defense budget. This is consistent with Lake's (1992) notion that the asymmetric information results in the oversupply of defense goods.

Further, our findings on democracy and tax-setting partly support Wittman's (1989) claim that democracies produce efficient results. Democracy will enhance efficiency by narrowing the information gap between the citizens and the regulator, but it is uncertain whether democracy produces efficient result as Wittman argues.

4. CONCLUSIONS

This paper develops a political economic model of taxation in national defense under the assumptions of the asymmetric information and representativeness, and we draw its implications in the studies on the provision of defense goods. Our findings suggest that : 1) the "correct" defense budget is not likely to be achieved even under the perfect information setting, 2) the asymmetric information between the consumers and politician exacerbates the problem of oversupply of defense goods, 3) but democracy alleviates the oversupply problem in defense by narrowing the information gap. These findings are consistent with Lake's (1992) argument that the state's rent-seeking behavior under asymmetric information will cause the oversupply of defense goods. With these findings, we reject Downs' (1960) arguments that the "correct" budget would emerge when the citizens have perfect information and that the incomplete information problem causes the undersupply of defense goods. The "correct" budget is hardly achieved even in the full information case, because several factors such as votes in the defense industry and regulator's rents motivate the regulator to set a 'biased' tax rate. Furthermore, if the asymmetric information problem arises, the defense goods will be even more oversupplied.

In addition, we conclude that Wittman's (1989) claim that democracies bring efficient results is exaggerated. Although our comparative static result suggests that democracy may reduce oversupply of defense goods, it is not certain whether the 'optimal' defense goods will be supplied under democracy.

The limitation of this study should not be ignored. In order to discuss whether a certain policy produces under or over supply of goods, we need to define the optimum level of defense goods, beforehand. However, our study did not touch on this issue, because it is difficult to stipulate the 'optimum' quantity of defense goods precisely (Jones, 1997). Without the universal benchmark of 'optimum' provision of defense goods, it is difficult to prove 'under' or 'excessive' provision of public goods (Jones, 1997).

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