The Bad Government: A Source of Uncertainty and Business Fluctuations

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July 2004

Abstract

Uncertainty represented by volatilities in equity markets has been observed to be time-variable and lead output fluctuations. In the rational expectation framework, uncertainty with this nature needs exogenous variables with time-varying volatilities, but technology, tastes and fiscal and monetary policies do not seem suitable for such variables. The paper contends that supervisions and law enforcement that reduce cheatings in contracts is one of the ultimate sources of uncertainty. The cheating plays an important role for uncertainty since it is the origin of noisy price observations that makes an economy uncertain in the framework of rational expectation approximate equilibria.

JEL Classification code: D50, D80, E32

Keywords: Uncertainty; Rational expectation approximate equilibria; Imperfect commitment; Supervision; Business fluctuations

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*The views expressed herein are those of the author and not necessarily those of the Cabinet Office of the Japanese Government.

I. INTRODUCTION

Volatility in equity markets is regarded as the best indicator for uncertainty, and the nature of uncertainty is considered to be well reflected in the nature of volatility in equity markets.[1] In many empirical researches, volatility in equity markets has been observed to be time-varying and counter-cyclical, and also to be a leading indicator. Campbell and Lettau (1999) examine comprehensively the relation between volatility in stock returns and economic fluctuations and conclude that volatility in stock returns increases substantially in economic downturns and tends to lead recessions. Hamilton and Lin (1996) conclude that stock market volatility and the level of economic activity are typically driven by the same unobserved state variable, and stock volatility may be useful for forecasting the direction of aggregate economic activity, particularly since stocks have been found to be a leading indicator of the state of the business cycle. Schwert (1989a, 1989b) performs regressions of measures of stock volatility on a dummy that takes the value of unity when the economy is in a recession and zero otherwise, and shows that stock volatility is explained by economic recessions that accounts for over 60% of the variance of stock returns. Schwert's (1989a, 1989b) analyses bases on the implicit assumption that recessions cause stock volatility, but the causality is another matter and it can be also asserted that in reverse the variance of stock returns accounts for much of economic recessions from the results in Schwert (1989a, 1989b). Important implication of this stylized fact is that uncertainty is as time-variable as output and leads output.

The nature of time-variability and a leading indicator is very important because it implies that uncertainty causes output fluctuations.[2] Intuitively, this causality may be quite natural, and the

[1] It is naturally assumed that volatilities in stock markets reflects people's expectation of future economic situations. See e.g. Romer (1990).

[2] Romer (1990), e.g. contended that uncertainty aggravated the Great Depression—that is, the collapse of stock prices in October 1929 generated temporary uncertainty about future income, which led consumers to forgo purchases of durable goods.

conjecture that uncertainty has influence on output may be widely believed among people as many newspaper articles suggest its influence. However, theoretically this causality appears to be problematic and the certainty equivalence is accepted by many economists. Many attempts to solve this problem has been done, and among them e.g. Harashima (2004a, b) presents a new model that can explain the observed correlation between uncertainty and output by extending the endogenous time preference model of Uzawa (1968) to a more realistic one and shows a mechanism of time preference shifts due to changes of uncertainty.[3] From the point of view of uncertainty driven time preference shifts, the certainty equivalence does not hold.

However, even if the problem of correlation between uncertainty and output is solved, the time-variable nature of uncertainty is still problematic. The second problem is that it is hard to find an exogenous variable that generates uncertainty with time-variable nature under the rational expectation. Uncertainty can be defined as the expected variance of future output. In the framework of rational expectation equilibria, the stochastic feature is only generated by exogenous variables. Exogenous variables that are economically important and presumed to be closely related to output fluctuations are limited, i.e. the deep parameters such as technology, tastes and fiscal and monetary policies. To be the source of uncertainty, they must satisfy the following conditions: firstly they should be exogenous variables, secondly they should have time-variable variances, and thirdly they should have a feature of leading indicators. However, technologies, tastes, and fiscal and monetary policies do not seem to satisfy one of the above criteria.

A problem for technologies and tastes is that their variances do not seem to be time-variable. Aggregated technology and tastes are averaged variables, and if a firm's technology or a consumer's taste is independent from other firms or consumers and has almost same distribution

[3] Harashima (2004a) showed that the rate of time preference is determined endogenously by the "size" of future utility stream. As a result of endogeneity of time preference, higher uncertainty makes the rate of time preference higher, and vice versa.

with other firms or consumers, the expected variance of aggregated technology and tastes may be almost constant by the central limit theorem. If there are much deeper independent variables that control the expected variance of aggregated technology and tastes, the expected variance of them can be time-variable. Without these deeper exogenous variables, they will not be time-variable, and therefore technologies and tastes do not appear to be the ultimate origin of uncertainty.

Fiscal and monetary policies are not aggregated variables and taken solely by a government, thus they do not have the problem technology and tastes face, and in reality their variances will be time-variable according to changes of policy stance of the government. However, fiscal and monetary policies have another kind of problem. The problem of fiscal and monetary policies is exogeneity of them. Fiscal and monetary policies are often taken in the countercyclical and discretionary manner. This means that fiscal and monetary policies will not be purely exogenous variables.

As a result, technologies, tastes and fiscal and monetary policies do not seem to be sufficient for the ultimate origin of the time-variable uncertainty, and other possibilities may have to be explored. The main objective of the paper is to solve this second problem arisen from the time-variable nature of uncertainty. One strategy to solve the second problem is to still stick to search an unknown variable that satisfies the conditions under the framework of rational expectation, e.g. to search a deeper exogenous variable that controls variances of technology or tastes. Another strategy is to relax the concept of strict rational expectation equilibria and widen the scope for search. Green (1977) showed that in an economy with private information, if additional noises exist, rational expectation equilibria can not exist anymore, and to solve this problem, Allen (1985) relax the concept of strict rational expectation equilibria and proposed the concept of rational expectation approximate equilibria. In the framework of rational expectation approximate equilibria, noises that can not be presumed to exist in the framework of rational expectation equilibria can be candidates of sources of uncertainty, and allow us to explore much wider possibilities. The paper adopts the strategy to relax the framework of strict rational expectation equilibria and explores a new possibility by extending the model of rational expectation approximate equilibria in Allen (1985).

The paper shows that noises on price observations, which Green (1977) showed does not make rational expectation equilibria exist, satisfy the condition for the source of time-variable uncertainty we are looking for. In addition, extending the model of revelation principle under imperfect commitment in Bester and Strausz (1998), the paper shows that supervisions and law enforcement to cheatings in contracts is a source of noises. Cheatings in contracts can not coexist with rational equilibrium equilibra, and thereby can not be a candidate of the source of uncertainty, however, in the framework of rational expectation approximate equilibria, cheatings in contracts can exist and play an important role for uncertainty that is time-varying and has the nature of a leading indicator. The paper shows that a change of people's perception of prudentiality of supervisions and effectiveness of law enforcement leads to a change of noises and as a result a change of uncertainty.

The importance of prudential supervisions and strict law enforcement directly means that a bad government that can not provide high quality services of supervisions and law enforcement is an important source of higher uncertainty. A similar conclusion in the sense that cheatings are important factors for economic fluctuations is reached by Akerlof and Romer (1993) from a different approach, although their approach is not comprehensive and mostly descriptive. They conclude that lootings by financial intermediaries were the main causes of S & L crisis in the US and of the Chilean banking crisis.

The paper is organized as follows. In section II, conditions for the time-variable uncertainty are explored and noises on price observations in the framework of rational expectation approximate equilibria is shown to be an important source of the time-variable uncertainty. In section III, as a noise on price observations, supervisions and law enforcement are shown to play an important role. In section IV, the results in the paper are compared with results in other related researches, and plausibility of the hypothesis in the paper is discussed. Finally some concluding remarks are offered.

II. A SOURCE OF UNCERTAINTY

1. Rational expectation approximate equilibra

Rational expectation equilibria in an economy with private information was studied by e.g. Green (1977), Grossman (1981), Allen (1982, 1985).[4] Grossman (1981) showed that even though there is private information, rational expectation equilibria exist since market prices fully reveal the state probabilities to the uninformed traders. On the other hand, Green (1977) showed that if there is additional noises on prices, rational expectation equilibria do not exist any more. As a solution to the problem presented by Green (1977), Allen (1985) tried to relax the concept of strict rational expectation equilibria and proposed the concept of rational expectation approximate equilibria.

In the model of Allen (1985), agents are of two basic information types. A typical uninformed agent will be donated by α. Let $A = \{\alpha_1, \ldots, \alpha_{\#A}\}$ be the set of uninformed agents. The symbol β will indicate a typical informed agent. The set of informed agents will be the set of $B = \{\beta_1, \ldots, \beta_{\#B}\}$. Let $C = A \cup B$ be the set of all agents, where $\#C = \#A + \#B$. Informed agents know the precise parameter value $\omega \in \Omega$ (or "state of the world") prior to trading, while the uninformed agents can be learn about parameters only through market information. Prices will transmit some of the knowledge of each informed, who will attempt to infer something about the correct state of the world from the prices that they observe on the market and their hypotheses about the relationship between (equilibrium) prices and states of the world. In the absence of information, uninformed agents would maximize their unconditional expected utilities subject to the

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[4] See Allen (1998).

appropriate budget constraints, where expected utilities are calculated by integrating state-dependent utilities over the set of Ω of states of the world using probability measure. The letter q with superscripts or other symbols added will refer to a price vector. Let $\Delta = \{q \mid \sum_{j=1}^{l} q_j = 1\}$ be the (l -1)-dimension open unit price simplex, and $\Delta(\gamma^*) = \{q \in \Omega \mid q_j \geqq \gamma^* \text{ for all } j = 1, \ldots, l\}$ is the trimmed price simplex and $\Delta(\gamma^{**}) = \{q \in \Omega \mid q_j \geqq \gamma^{**} \text{ for all } j = 1, \ldots, l\}$ is a larger trimmed simplex in Δ which contains $\Delta(\gamma^*)$ in its interior with $\gamma^{**} < \gamma^*$.

Consider a specific uninformed agent α who believes that the true (equilibrium) price function is p_α sees the price vector q_α on the market. If she believes that both p_α and q_α represent equilibria, then she knows that the true state of the world lies in the subset $\{\omega \in \Omega \mid p_\alpha(\omega) = q_\alpha\} \subset \Omega$. In Allen (1985), noisy price observations are defined as tightly concentrated as follows;

Definition (3.6): The distribution $\psi(\ ,\ )$ of noisy price observations are said to be (δ, ε)-*tightly concentrated* if for every $\omega \in \Omega$ and every $q \in \Delta(\gamma^*)$, $\psi(\omega, q)(\{\tilde{q}_C \in \Delta^{\#C} \mid$ for every $\alpha \in A$, $\tilde{q}_\alpha \in \Delta(\gamma^{**})$ and $\| \tilde{q}_\alpha - q \| < \delta$, and for every $\beta \in B$, $\tilde{q}_\beta \in \Delta(\gamma^{**})$, and $\| \tilde{q}_\beta - q \| < \delta\}) \geqq 1 - \varepsilon$.

Allen (1985) proved the following theorem;

Theorem (8.4): For any economy satisfying the assumptions of my model and any $\varepsilon > 0$ and $\varepsilon' > 0$ (the magnitude of total excess demand does not exceed ε'), there exists $\delta > 0$ such that whenever the distributions of noisy price observations are (δ, ε)-tightly concentrated, then the economy with such noisy price observations has a fully rational expectations $(\varepsilon, \varepsilon')$ –equilibrium.

Allen proved the existence of rational expectation approximate equilibria but does not show the detailed relation between noisy price observations and output or consumption. The paper extends Allen's model to investigate the relation between them closely.

2. The extended model

Firstly the relationship between δ and ε is examined. The (δ, ε)-*tightly concentrated* distribution of a noisy price observation can be expressed by using many combinations of δ and ε. Intuitively, it is likely that, to express the ($\delta^{\#}$, $\varepsilon^{\#}$)-*tightly concentrated* distribution of a noisy price observation, if $\delta^{\#\#}$ that is smaller than $\delta^{\#}$ is used instead of $\delta^{\#}$, then 1 - $\varepsilon^{\#}$ need to be replaced by 1 - $\varepsilon^{\#\#}$ that is smaller than 1 - $\varepsilon^{\#}$. Thereby δ and ε will be in inverse proportion to each other as shown in Figure 1 that illustrates lines of two distributions. If they can be expressed by a continuous function, then 1 - ε can be seen as the cumulative distribution function of noisy price observations.

The second but more important relation that should be probed is the relation between noisy price observations and consumption. It seems intuitively likely that an approximate equilibrium generated by noisy price observations has a stochastic steady state consumption. Since prices are noisy, the expected steady state consumption will not be deterministic but be stochastic. In addition, it appears likely that, if an observed price is situated in a largely deviated point, the price will make the distribution of expected steady state consumption more disperse compared with the case of the price that is situated in a less largely deviated point. High level of noises will lead to the more diverse distribution of expected steady state consumption. Figure 2 illustrates an image of the relation where π indicates density of the expected steady state consumption c.

Taking the abovementioned arguments into consideration, the following assumptions are added into the model of Allen's (1985) to explore the relation between noisy price observations and consumptions in detail.

Assumptions:

(A1) The probability 1- ε is a continuous and differentiable function of δ and $\frac{d\varepsilon(\delta)}{d\delta} < 0$.

(A2) Each rational expectation approximate equilibrium has a corresponding cumulative distribution function $\pi(c)$ of the expected steady state consumption c. A noisy price observed in a small interval $d\delta$ between δ and $\delta + d\delta$ makes the expected steady state consumption c stochastic, the cumulative distribution function of which is $\pi(c|\delta)$.

The assumption (A2) is one of the key assumptions of the paper, which links noisy price observations and consumptions. By the assumptions (A1) and (A2), the cumulative distribution function of an expected steady state consumption can be expressed by the parameters δ and ε of noisy price observations:

$$\pi(c) = -\int_0^\infty \pi(c \mid \delta) \frac{d\varepsilon(\delta)}{d\delta} d\delta . \tag{1}$$

The assumptions (A1) and (A2) and the equation (1) postulate the characteristics of a distribution of noisy price observations.

The characteristics of $\pi(c)$ depends on the natures of $\varepsilon(\delta)$ and $\pi(c|\delta)$. It seems natural to assume that densities smoothly diminish as δ increases for every distribution, and thus, for any two distributions, if the slope $\varepsilon(\delta)$ of a distribution for a certain value of δ is smaller than that of the other distribution, the slope $\varepsilon(\delta)$ of the former distribution is smaller than the latter for any δ. The example of two distributions is illustrated in Figure 1. The distribution indicated by the solid line shows relatively sharply diminishing density and the distribution indicated by the dotted line shows relatively gradually diminishing density.

Taking the above arguments into consideration, the following additional assumptions about different distributions of $\varepsilon(\delta)$ are introduced.

Assumptions: Let $\bar{\delta} = -\delta$. For any set of two noisy price observations; one is (δ_1, ε)-*tightly concentrated* and the other is (δ_2, ε)-*tightly concentrated* for a common ε,

(A3) if $\delta_1 < \delta_2$ then $\varepsilon_2(\bar{\delta})$ second-order stochastically dominates $\varepsilon_1(\bar{\delta})$ such as $\int_{-\infty}^{D} \varepsilon_1(\bar{\delta})\, d\bar{\delta} \le \int_{-\infty}^{D} \varepsilon_2(\bar{\delta})\, d\bar{\delta}\ \forall D$, and if $\delta_1 = \delta_2$ then $\int_{-\infty}^{D} \varepsilon_1(\bar{\delta})\, d\bar{\delta} = \int_{-\infty}^{D} \varepsilon_2(\bar{\delta})\, d\bar{\delta}\ \forall D$, where $\varepsilon_i(\delta)$ is $\varepsilon(\delta)$ in case of δ_i. $\varepsilon_i(0) = 1$ for any *i*.

(A4) $\varepsilon(\delta)$ smoothly decreases as δ increases such that, if $\delta_1 < \delta_2$, then for a certain $\delta^*(> 0)$, $-\frac{d\varepsilon_1(\delta)}{d\delta} > -\frac{d\varepsilon_2(\delta)}{d\delta}$ in case of $\delta^* > \delta \ge 0$, $-\frac{d\varepsilon_1(\delta)}{d\delta} = -\frac{d\varepsilon_2(\delta)}{d\delta}$ in case of $\delta = \delta^*$ and $-\frac{d\varepsilon_1(\delta)}{d\delta} < -\frac{d\varepsilon_2(\delta)}{d\delta}$ in case of $\delta^* < \delta$, where $\varepsilon_i(\delta)$ is $\varepsilon(\delta)$ in case of δ_i,

Next, the nature of $\pi(c|\delta)$ is examined. A distribution of noisy price observations with δ that is more disperse has more dense density of $\pi(c|\delta)$ at any δ compared with a less disperse distribution of noisy price observations by the assumption (A1). It seems likely that the denser the density of noisy price observation is the smaller the effect on consumption by a noisy price is. For example, imagine a situation that only one noisy price in an interval between δ and $\delta + d\delta$ and another situation that two noisy prices in the interval. Because, in the latter situation, a part of the effect of each of two noisy prices on consumption will be canceled out each other, the effect on consumption per a noisy price in the latter situation will be smaller than that in the former situation. This means that the cumulative distribution function $\pi(c|\delta)$ for a distribution will be more disperse than that with smaller δ for the same ε since $\pi(c|\delta)$ indicate cumulative distributions per one noisy price by the assumption (A2). Hence it appears natural that, for the same ε, $\pi(c|\delta)$ of a distribution second-order stochastically dominates $\pi(c|\delta)$ of distributions with smaller δ for any b. Hence, the following additional assumption is introduced.

Assumption: For any set of two noisy price observations; one is (δ_1, ε)-*tightly concentrated* and the other is (δ_2, ε)-*tightly concentrated* for a common ε,

(A5) if $\delta_1 < \delta_2$ then $\pi_2(c \mid \delta)$ second-order stochastically dominates $\pi_1(c \mid \delta)$ such as $\int_{-\infty}^{\Phi} \pi_1(c \mid \delta)\, dc \leq \int_{-\infty}^{\Phi} \pi_2(c \mid \delta)\, dc \;\; \forall \Phi \forall \delta$ where $\pi_i(c \mid \delta)$ is $\pi(c \mid \delta)$ in case of δ_i,

Finally, it is likely that prices deviated farther will make consumption more disperse. Taking this conjecture into account, the following assumption is added.

Assumption:

(A6) for any $\delta' > 0$, $\pi(c \mid \delta + \delta')$ second-order stochastically dominates $\pi(c \mid \delta)$ such as $\int_{-\infty}^{\Phi} \pi(c \mid \delta)\, dc \leq \int_{-\infty}^{\Phi} \pi(c \mid \delta + \delta')\, dc \;\; \forall \Phi \forall \delta$ for any $\delta' > 0$.

3. The noise on price observations as a source of uncertainty

Based on the assumption (A3) – (A6), the following important result can be drawn.

Proposition 1: Assume that there are two approximate rational expectation equilibria such that δ are δ_1 and δ_2 while ε is identical in both cases. If $\delta_1 < \delta_2$, then $\pi_1(c)$ second-order stochastically dominates $\pi_2(c)$.

Proof: See Appendix.

For a given ε, the larger δ is, the higher the uncertainty about c is. Hence under the rational expectation approximate equilibrium, determinants of δ are crucial for the uncertainty. δ can be interpreted as the degree of unobserved noises that prevent from transmitting private information to prices.

Remark 1: Assume that a set of exogenous variables that are both stochastic and make a certain endogenous variable stochastic, and assume that there is a noise that is independent of the state of the world but there is a rational expectation approximate equilibrium. If δ changes, the expected distribution of the endogenous variable at the steady state changes, even though the distribution of any variable that is included in the set of the exogenous variables does not change.

The remark 1 contends that even though variances of technologies, tastes and fiscal and monetary policies do not change, uncertainty can change over time due to changes of noises on price observations in the framework of rational expectation approximate equilibria, and the noise on price observations can be the source of time-variable uncertainty. Thereby, in the framework of rational rational expectation approximate equilibria, if a variable satisfies the following conditions: firstly it is an exogenous variable, secondly it is a source of noises, and thirdly it has a feature of leading indicators, it will be a source of time-variable and leading uncertainty. The next step for exploring this possibility is to specify the noises.

III. A SOURCE OF NOISES

1. Noises in circumstances under limited commitment

What are the state independent noises on price observations? According to Allen (1985), prices may contain noises because of some additional random disturbances which are independent of the state of the world that enters into agents' utility functions, or prices may be transmitted to agents along a noisy channel.[5] Hence, prices do not transmit all the information on the state of the world, which the informed agents know precisely, to the uninformed agents who attempt to infer the correct state of the world from the prices that they observe in the market. What can be such state independent noises which agents ignore when they form prices but have influence on prices?

For a rational expectation approximate equilibrium to exist, the uninformed agents should know the information about noises, i.e. the distribution $\psi(\, , \,)$ of noisy price observations, and their choices of actions depend on the information about noises by the theorem (8.4) of Allen's. However, if the informed agents realize that the noises affect actions of the uninformed, the informed will try to exploit their advantage of having the precise information of the state of the world, and thereby eventually noises will enter the utility functions of the informed and will be transmitted to prices. Hence, the informed must be unaware of the information about noises that are independent of the state of the world, or they must generate the noises intentionally pretending not knowing the information. It is hard to imagine a situation that the informed do not know the information about noises which nevertheless the uninformed know. As a result, the only remaining possibility will be that the informed intentionally generate noises.[6] However, such intentionally generated noises are not so easily imagined. They may be possible to exist if you assume that the informed intentionally do not maximize their utilities using the advantageous information. This is the very point that the opponents to the concept of the rational expectation approximate equilibrium criticize. They assert that the rational expectation

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[5] Since the additional disturbance is independent of the state of the world that enters into agents' utility functions, the informed agents do not consider this disturbance when they offer prices.

[6] If there is a noise on prices which is independent of the state of the world and both informed and uninformed agents do not know, then there is neither rational expectation equilibrium nor rational expectation approximate equilibrium. By Green (1977), if there is a noise on prices which is independent of the state of the world, there is no rational expectation equilibrium. If both informed and uninformed agents do not know the noise, they also do not know the distribution ψ. Hence, in this case any rational expectation approximate equilibrium can not exist.

approximate equilibrium contains implicitly some kinds of irrationality.[7]

Hence again it needs to relax some assumptions for noises to exist. It has been implicitly assumed that all the contracts that agents make for their maximizations are made under the condition of full commitment. The full commitment guarantees the revelation principle, however, if the assumption of the full commitment is removed, there will be a possibility that noises are intentionally generated by the informed who behaves fully rationally. The key for this possibility is cheatings by the informed. A cheating is defined as an agent's action of reporting untruth information deliberately to a principal in a contract between them. Cheatings are rationally made under limited commitment. If the commitment by a principal is imperfect, the revelation principle does not hold and the possibility of cheatings comes out. It will be the natural instinct of human beings to be tempted to cheat other agents if it is foreseen that penalties are not likely as it will be also the natural instinct for human being to act rationally.

Bester and Strausz (2001) provided a generalized concept of the revelation principle under imperfect commitment. They found that essential features of the revelation principle extend to situations with imperfect commitment, but also showed that it can not be guaranteed that agents report their private information truthfully with probability one and that instead they may have to cheat with positive probability. Under imperfect commitment, the agent may think that truthfully reporting to the principal is disadvantageous to her, since revealing the result truthfully may induce the principal to exploit this new information and renegotiate the contract. Hence the agent may cheat the principal and report untruthfully. Positive possibility of cheatings by agents has significant meaning since it allows existence of noises on prices.

To sum up, cheating can coexist with rationality assumption under imperfect commitment. If cheatings exist, prices that principals form are contaminated by noises generated by cheatings of some agents.

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[7] See e.g. Kurz and Motolese (2000).

2. A source of noises: bad government

(1) Cheatings and governments

A possibility of cheatings automatically necessitates monitoring, which has been studied in the costly state verification literature. One way of monitoring cheatings of agents is the monitoring by principals and the other way is supervisions and law enforcement by governments.

If it is assumed that there are three types of agents such as firms, consumers and a government, there will be two types of contracts: one is contracts in which an agent is the government and the other is contracts in which an agent is a firm or a consumer. The former type of contracts, i.e. contracts in which an agent is the government, are the services that the government provides to the citizen such as general administrative services, education, health care, law enforcement, supervisions on financial intermediaries or so on. In those contracts, principals are firms and consumers who pay taxes in return for government services. These kinds of administrative activities are every day businesses conducted by government officials and are not provided for the purpose of macro economic stability. They are different activities from fiscal and monetary policies that are taken to manipulate output for economic stability and decided by politicians under political consideration.

The latter type of contracts, i.e. contracts in which an agent is a firm or a consumer, disperse over the economy. However, cheatings in these contracts are controlled by some of the former type of contracts, i.e. supervisions and law enforcement of the government, for example, the supervision to financial intermediaries or security firms by government's supervisory agencies or law enforcement to firms' window dressing settlements. Without supervisions or law enforcement, cheatings would be rampant if monitoring by principals is too costly, and in the end many of the economic activities would be distorted significantly.[8]

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[8] See e.g. Mishkin (2000).

(2) The model

To examine cheatings in detail, the model considered in Bester and Strausz (1998) is modified in the paper.[9] To their original model, supervisions and law enforcement are added. The new elements in the model are as follows;

(E1) Supervisions and law enforcement detect a cheating with probability $g(e)$ ($0 \leqq g(e) \leqq 1$ and $0 < e$) and impose a penalty π to the agent for each cheating. $g(e)$ is a continuous differentiable function of technology (or prudentiality and effectiveness) e of government officials in charge of supervisions.

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[9] Their model of a contract between a principal and an agent starts with the following revelation game between them. The equilibrium of the game determines an allocation $z = (x, y) \in Z = X + Y$ where X is the set of all those decisions to which the principal can contractually commit herself and the set Y consists of all those decisions that are not contractible and are chosen at the principal's discretion. The decision x restricts the principal's feasible choices in Y described by the correspondence F: $X \Rightarrow Y$. The principal has to select $y \in F(x) \subseteq Y$ when she is committed to the decision $x \in X$. The principal has no private information, but the agent is privately informed about her type (or technology) $t \in T = \{t_1, \ldots, t_i, \ldots, t_m\}$. The principal only knows the probability distribution $\theta = (\theta_1, \ldots, \theta_i, \ldots, \theta_m)$ of the agent's type, with $\theta_i > 0$, $i = 1, \ldots, m$, and $\sum_I \theta_i = 1$. The payoffs of both players depend on the allocation (x, y) and the agent's type: When the agent is of type t_i, the principal's payoff from (x, y) is $V_i(x, y)$. The agent's payoff in this situation is $U_i(x, y)$. As part of game, the agent can send some message $m \in M = \{m_1, \ldots, m_h, \ldots, m_n\}$ to the principal. The principal can commit herself to a decision function x^*: $M \rightarrow X$, and once the principal has committed herself to the decision function $x^*(.)$, the agent can enforce the decision $x^*(m)$ by sending the message m. A contract $\Gamma = (M, x^*)$ specifies a message space M in combination with a decision function $x^*(.)$. The agent's strategy is a mapping q: $T \rightarrow Q$ where $Q = \{q \in R_+^n \mid \sum_h q_h = 1\}$ is the set of probability distribusions over M. If the agent of type t_i adopts the strategy $q(t_i)$, the message m_h is selected with probability $q_h(t_i)$. The principal's strategy y: $M \rightarrow F(x^*(m))$ describes her choice $y(m)$ as a function of the observed message m. The principals posterior belief by the mapping p: $M \rightarrow P$ where $P = \{p \in R_+^n \mid \sum_i p_i = 1\}$ is the set of probability distributions over T. After receiving some message m, the principal believes that the agent is of type t_i with probability $p_i(m)$.

(E2) The technology e has l types; e_i ($i = 1,\ldots,l$) and $e_i > e_j$ if $i > j$.

(E3) Information about e is common knowledge to all the agents and principals. Hence, $g(e)$ and π are given constants for each agent and principal in each contract.

It is assumed that there are a large number of almost identical agents and principals in the private sector and there are also a special agent and a special principal: a government as the special agent and citizens as the special principal. Agents and principals in the private sector make contracts each other, and the special agent and the special principal make a contract about supervisions and law enforcement.

Each principal's strategy has to be optimal given her beliefs about the type of the agent in the private sector with whom the principal made a contract. Hence, for all $m \in M$,

$$y^*(m) \in \text{argmax}_{\, y \in F(x^*(m))} \textstyle\sum_i p_i^*(m) V_i(x^*(m), y). \tag{2}$$

The agent anticipates the principal's behavior y^* and chooses q to maximize her payoff. Thus, for each $t_i \in T$, q^* has to satisfy

$$q^*(t_i) \in \text{argmax}_{\, q \in Q} \textstyle\sum_h q_h U_i(x^*(m_h), y^*(m_h), \pi g(e)). \tag{3}$$

The principal's posterior beliefs are consistent with Bayes' rule, and thus for all $m_h \in M$ and all $t_i \in T$,

$$p_i(m_h) = \frac{\gamma_i q_h^*(t_i)}{\sum_j \gamma_j q_h^*(t_j)} \qquad \text{whenever } \sum_j q_h^*(t_j) > 0 \cdot \tag{4}$$

In the equilibrium the principal receives the expected payoff $V^*(q^*, y^*, p^* \mid \Gamma)$ and the t_i-type agent's expected payoff is $U^*_i(q^*, y^*, p^* \mid \Gamma)$. By the theorem in Bester and Strausz (1998), there is positive possibility of cheating in each contract.

This model is extended to a sufficiently large number of contracts. It is assumed that there are sufficiently large number of V principals, agents and contracts in the private sector. A principal and an agent make one contract in each period. Each principal's amount of investment is identical. A special agent, that is, the government, and a special principal, that is, the citizens, make a contract on supervisions and law enforcement in each period with the same manner as the equations (2) – (4). With a possible cheating, private information of an agent concerning her type can not be transmitted fully to the other agents outside the contract through prices. Hence, cheatings as noises contaminate prices.

The environment of the model is as follows;

(E4) The type or technology $t^v \in \boldsymbol{T} = \{t_1, \ldots, t_m\}$ $(v \in \{= 1, \ldots, V\})$ of an agent v in the private sector and the prior probability distribution $\boldsymbol{\theta}_w = (\theta_{w1}, \ldots, \theta_{wi}, \ldots, \theta_{wm})$ $(w = 1, \ldots, V)$ of a principal w in the private sector are governed by stationary processes.

(E5) Stationary processes of all the agents' types or technologies are uncorrelated each other and have the same stationary probability distribution. Stationary processes of all the principals' probability distributions are uncorrelated each other and have the same stationary probability distribution.

(E6) The special agent(government)'s type or technology on supervisions and law enforcement $e_i \in \{e_1, \ldots, e_l\}$ and the special principal(citizens)'s prior probability distribution are governed by the stationary process.

(E7) There are χ $(> V)$ prices.

(E8) A value added is realized through a contract and is reflected in a price.

(3) Price contamination

The analysis of price formation in the paper is approached from cost side and prices are viewed as a sum of costs and values added. Thus, for comparison of static states, the price model based on Leontief's input-output analysis can be applied. It is considered to be an effective tool to extract impacts on prices when a factor that has influence on prices changes.

Assumption:

(A7) In approximate equilibria, prices follow Leontief's input-output model such that $\boldsymbol{\Lambda} = \boldsymbol{\Phi}' \boldsymbol{\Lambda} + \boldsymbol{\Xi}$, where $\boldsymbol{\Lambda}$ is a vector of distribution of all the prices, $\boldsymbol{\Phi} = \{\varphi_{ij}\}$ (>0) is the matrix coefficients from a goods of price i to a goods of price j with $0 < \varphi_{jj} < 1$ and $\sum_i \varphi_{ij} \leqq 1$ (i = 1,2,.., χ and j = 1,2,…, χ), and $\boldsymbol{\Xi} = \{\varphi_{a1}, \varphi_{a2}, \ldots, \varphi_{aV}, 0, \ldots, 0\}$ ($\varphi_{ai} > 0$) is a vector of value added in price j (j = 1,2,…, χ).

(A8) The matrix coefficients $\boldsymbol{\Phi} = \{\varphi_{ij}\}$ are constant. $(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}$ is not singular.

By the assumption (A7), $\boldsymbol{\Lambda} = (\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}\boldsymbol{\Xi}$ where $\boldsymbol{E}$ is the identity matrix.

Cheatings affects values added that are realized as a result of contracts. If there is positive probability of cheating, values added are contaminated by noises. Thus, with positive probability of cheatings, values added are stochastic, and if a contract is cheated, the value added in the contract will be smaller than that in case of no cheating.

Assumption:

(A9) Since each contract has a positive probability of cheating, each value added has noise such that $\varphi_{av} = V_v \Sigma(h_v)$ ($v \leqq \chi$), where V_v is the value added in case that there is no cheating, $\Sigma(h_v)$ ($0 \leqq \Sigma(h_v) \leqq 1$) is a stochastic variable, and h_v is probability of cheating in the contract for a value added for a price v in case of no supervision nor law enforcement, that is, probability that an agent in the private sector reports untruthfully her type to the principal in the private sector with whom the agent made a contract in case of no supervision nor law enforcement.

(A10) The cumulative density function of $\Sigma(h_v)$ is $\sigma(\Sigma,\ h_v)$, that is continuous and differentiable, and has the following features;

$$\frac{\partial\sigma(\Sigma,\ h_v)}{\partial\Sigma} > 0 \text{ and } \frac{\partial\sigma(\Sigma,\ h_v)}{\partial h_v} > 0.$$ [10]

Since each price is formed by prices of inputs and added values by the assumption (A7), contamination of a price by a cheating in a contract is transmitted to other prices through the mechanism described in the assumption (A7). Total contamination of a price is a sum of its own noises and noises transmitted from prices of other inputs and added values. By the assumption (A9), the variance of a price represents the degree of total contamination of the price.

(4) Cheatings and rational expectation approximate equilibria

Through contamination of prices, cheatings in contracts and rational expectation approximate equilibria are linked.

Proposition 2: δ is an increasing function of h_v ($v \leqq \chi$): $\frac{\partial\delta(h_v)}{\partial h_v} > 0$.

Proof: See Appendix.

The proposition 2 describes the link between the model of rational expectation approximate equilibria used in the proposition 1 and the modified Bester and Strausz's model. Both models are linked by prices contaminated by cheatings. Contracts that satisfy the above optimization

[10] The cumulative density function $\sigma(\Sigma,\ h_v)$ is shown in Figure 3.

conditions, i.e. equations (2) – (4), are a part of firms' or consumers' maximization processes in the model of rational expectation approximate equilibria, and prices formed by some contracts are contaminated by cheatings.

The key ingredient in the link is the probability of cheatings h_v. If h_v changes, rational expectation approximate equilibria change. Hence if the exogenous variable h_v is stochastic, it is possible to be a source of time-variable uncertainty. However, there a question about exogeneity of the variable h_v, such that there may be a deeper exogenous variable that controls the variable h_v, e.g. the government's supervisions and law enforcement $g(e)$ that determines the probability of cheatings will make h_v change.[11] The strong influence of $g(e)$ is not deniable. Hence, the model should include the link between h_v and $g(e)$ as a deeper relation.

(5) Governments and rational expectation approximate equilibria

The relation between the probability of cheatings h_v and the government's supervisions and law enforcement $g(e)$ is assumed as follows;

Assumptions:

(A11) With detection by supervisions and law enforcement, the probability of cheating in each contract v is reduced by - $h_v g(e)$.

(A12) $\frac{dg(e)}{de} > 0$.

The assumption $\frac{dg(e)}{de} > 0$ do not be seen as unnatural and seem acceptable, i.e. the more

[11] There is another question such that output fluctuations may affect the variable h_v and thus h_v may be an endogenous variable. For example, when the economy is in a downturn, every h_v may become higher vice versa. However, if output is a factor that makes h_v changes, output will lead uncertainty, which contradicts many observations shown in the introduction. Hence, output may not be relevant with h_v or h_v may not be relevant with uncertainty.

prudential and effective the supervisions and law enforcement are, the more the cheatings are detected and punished.

Let $\tilde{h}_v$ be the probability of cheatings in case that there are supervisions and law enforcement.

Remark 2: $\tilde{h}_v = h_v[1 - g(e)]$ by the assumption (A11), and the cumulative density function $\sigma(\Sigma, h_v)$ in case that there are supervisions and law enforcement is $\sigma(\Sigma, \tilde{h}_v)$.

The relation between the government's supervisions and law enforcement $g(e)$ and rational expectation approximate equilibria $\pi(c)$ are examined firstly in the special case and afterward in a more general case. The special case assumes that the true value of e is known to people and thus e is not private information. In this case, the special principal(citizens)'s prior belief about θ is not stochastic but the special principal knows the true value of e, and thus h reflects the true e.

Proposition 3: Given that e is known to people, for any set of two states of prudentiality and effectiveness e_1 and e_2 ($e_1, e_2 \in e$) and $e_1 > e_2$, $\pi_2(c)$ second-order stochastically dominates $\pi_1(c)$ where $\pi_i(c)$ is $\pi(c)$ in case of e_i.

Proof: See Appendix.

The proposition 3 contends that there is a one to one map from the degree of prudentialty and effectiveness of supervisions and law enforcement e to the scale of noises, and the scale of noises is a monotonically decreasing function of the degree of prudentiality of supervisions and effectiveness of law enforcement. Hence, supervisions and law enforcement that determine the scale of noises can be an important source of time-variable uncertainty.

Next, a more general case where e is not known to people and thus e is private information of the special agent(government) is examined. In this case the special principal(citizens)'s prior cumulative density function $\xi(e)$ is stochastic thus the expected $g(e)$ of each agent in the private sector and thus h depends not on e but on the special principal(citizens)'s prior distribution $\xi(e)$.

Proposition 4: Given that e is not known to people, for any set of two states of prudentiality and effectiveness e_1 and e_2 (e_1, $e_2 \in e$) whose prior cumulative density functions of technology on supervisions and law enforcement are $\xi(e_1)$ and $\xi(e_2)$ respectively, if $\xi(e_2)$ second-order stochastically dominates $\xi(e_1)$ with strict inequality such as $\int_{-\infty}^{F} \xi(e_1)\, de < \int_{-\infty}^{F} \xi(e_2)\, de \ \forall F$, then $\pi_2(c)$ second-order stochastically dominates π_1 (c), where $\pi_i(c)$ is $\pi(c)$ in case of θ_{gi}.

Proof: See Appendix.

The proposition 4 shows that uncertainty is determined by the prior distribution $\xi(e)$. It contends that an ultimate origin of uncertainty that has the time-varying and leading nature is people's perception of government's prudentiality of supervisions and effectiveness of law enforcement. Because uncertainty leads output, and because technologies, tastes, and fiscal and monetary policies all do not appear suitable for a source of uncertainty, the result that prudentiality and effectiveness of governments is a fundamental source of uncertainty has a significant meaning, i.e. it implies that prudentiality and effectiveness of governments is a fundamental source of business fluctuations.

(6) The prior distribution

A question the proposition 4 raises is how the prior distribution is determined in each period. One possible mechanism of forming the prior distribution $\xi(e)$ is that $\xi(e)$ in a period is formed by directly applying the posterior distribution $p_g(m_g)$ in the previous period. This case assumes that private information of the special agent(government) in the past period is not revealed forever and thus the special principal(citizens) can use only the past government's messages to form prior distributions. Another possibility is that part of information about the past realized e will be revealed in future. It may be likely that part of the past true e is periodically revealed by investigations of the press or the Diet, or the special agent(government) may reveal the past true e voluntarily because the special agent(government) thinks revelation of the past true e is harmless no more. Hence although the current e is private information of the special agent(government), part of information about the past e may not be private information.

Expectation of the exogenous variable $\xi(e)$ may be formed by combining the above two possibilities. For $\xi_t(e)$ and $p_{g,\,t\text{-}1}(m_g)$ that are the special principal(citizens)'s prior distribution $\xi(e)$ and the special principal(citizens)'s posterior distribution $p_g(m_g)$ in the period t respectively,

$$\frac{d\xi_t(e)}{de} = \lambda \; p_{g,t-1}(m_g) + (1 - \lambda)\sum_{i=I}^{t-1} \tau_{t-i}(e)\,\varphi_{t-i}\;\eta_{t-i}\,, \tag{5}$$

where λ is a constant ($0 \leqq \lambda \leqq 1$), $\tau_t(e)$ ($\geqq 0$) is a random variable over e in the period t with $\int_{-\infty}^{\infty} \tau_t(e)\,de = 1$, φ_t is the probability distribution in the period t where the probability of the true e in the period is 1 and the other probabilities in the period are all 0, η_t is non-negative constants, at least one of which is non-zero, and $I < t - 1$. Information about both the previous period's posterior distribution and the periodically and partially revealed past realized e are combined to form the expectation of the exogenous variable $\xi(e)$. The belief $p_g(m_g)$, the past technology of supervisions and law enforcement e_t and the shocks τ_t determine the prior probability, i.e. the general mood on order $\xi(e)$ determines the prior probability. In addition to e, τ that indicates periodical revelation of the past realized e plays a very important role. For example, if τ usually takes values around zero but occasionally takes a large value, there is a possibility of sudden large changes of uncertainty even though e changes gradually. This possibility allows observed sudden changes of uncertainty. Furthermore, because $\xi(e)$ is formed independently from output, uncertainty generated by $\xi(e)$ leads output, which is consistent with the observed leading nature of uncertainty.

It was shown in the section II that in the framework of rational rational expectation approximate equilibria, if a variable satisfies the following conditions: firstly it is an exogenous variable, secondly it is a source of noises, and thirdly it has a feature of leading indicators, it will be a source of time-variable and leading uncertainty. The technology of supervisions and law enforcement by government well satisfy these conditions. Firstly e_t is an exogenous stochastic variable, secondly it determines the scale of noises, and thirdly it is determined independently from output and thus can leads output. Furthermore, if $\xi(e)$ is formed by the equation (5), sudden significant changes of uncertainty, that have been often observed, will easily happen.

IV. Discussion

How significant is prudentiality and effectiveness of government services to time-variable uncertainty and economic fluctuations is an empirical question and remains for future works. However, there are several indirect evidences about importance of prudentiality and effectiveness of government services. Firstly, Akerlof and Romer (1993) claim that looting behavior was at the core of the saving and loan crisis in the United States and of the Chilean banking crisis of the late 1970s. They present a simple model that with limited liability of thrifts and government's deposit insurance, there is a possibility of looting by thrifts such that thrifts go bankrupt intentionally, and emphasizes that initial disturbances caused by looting in one market are likely metastasize with serious multiplier effects into other markets. In their model, multiplier effects are generated by broken up of rational expectation equilibrium when thrifts' intention of lootings is revealed. The model of Akerlof and Romer (1993) seems similar to the paper's model in spirit in the sense that a kind of cheating is an origin of disturbances and it destroys a pure rational expectation equilibrium, although their model is too simplified and the mechanism of the linkage between lootings and economic impacts is merely descriptively explained. Demirgüç-Kunt and Detragiache (1997) show that "law and order" index, which should proxy more opportunities to loot and/or a lower ability to carry out effective prudential supervision, are associated with a higher likelihood of a crisis.[12] They show that if bank supervision is weak and legal remedies against fraud are easy to circumvent, banking crises may be caused by widespread "looting": bank managers not only may invest in projects that are too risky, but they may invest in projects that are sure failure but from which they can divert money for personal use. Their work indicates that weakness of supervisions is associated with higher volatility of economic activities.

Hall and Jones (1999) contend that social infrastructure is the key of income divergence among countries, and the differences in capital accumulation, productivity, and thereby output per worker are driven by differences in institutions and government policies, which they call social infrastructure. Their finding is another indirect evidence of significant influence of supervisions and law enforcement to economic fluctuations. The bad social infrastructure is, according to Hall and Jones (1999), almost same as the gad government described in this paper. Although they assume implicitly that the social infrastructure is indigenous in each country and thus not time-variable maybe for the sake of simplicity of their analyses, it will be likely that a part of the social infrastructure in reality is time-variable, e.g. prudentiality of supervisions or effectiveness of law enforcement. If economic activity levels are truly determined considerably by the level of social infrastructure, fluctuations of the level of social infrastructure will generate business fluctuations which may be viewed as fluctuations between the economic

[12] Francis (2003) also showed that indicators representing law and order have statistically significant effects on financial fragility that is represented by investment volatility and banking crises.

activity levels of the developed and the less developed economies.[13] Some may think that the social infrastructure may change, however, only gradually. It may be true, but, the expectation of it can change drastically if the expectation is formed by the mechanism like the equation (5). Thereby changes of expectation of the social infrastructure will make the volatility of the country's economic activities change significantly because the social infrastructure determines the economic activity level in the country.

The experience of Japan since 1990s may also suggest righteousness of the paper's conclusion. The well known protracted slump of Japan since 1990 is often pointed out to be associated with poor corporate governance of the Japanese banks, many of which took excessive risks in the late 1980s. The non-performing loan problem and inability of supervisory authorities are often condemned as the major obstacle to the revival of the Japanese economy.[14] The experience of Japan suggests that the performance of supervisions to financial intermediaries may be closely related with the whole economic development, and thereby its prudentiality may play an important role for uncertainty and economic fluctuations.[15]

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[13] Hall and Jones (1999) do not explain in detail the mechanism of the link between the social infrastructure and income levels. The hypothesis of the paper, which contends that low technology levels of supervisions and law enforcement make uncertainty and the rate of time preference high and then leads to low economic activity levels, may also be applied to the link between the social infrastructure and income levels in Hall and Jones (1999).

[14] See e.g. Hutchison (1997) or Horiuchi (1998).

[15] The recent experience in the US economy may also be examined in detail from the paper's point of view. The failed corporate governance represented by Enron or WorldCom was uncovered in the midst of economic downturn in 2000. The association with the failed corporate governance and the economic downturn is unclear, but it has been recognized that the big boom in 1990 was exaggerated partly by cheatings of those companies, and the cheatings was revealed at the same time of the economic downturn in 2001. The conclusion of the paper suggests a story that anticipation of high possibility of poor supervisions that allowed window dressing settlements like Enron or WorldCom may have deteriorated significantly people's confidence to markets and increased uncertainty that led to a recession.

V. CONCLUDING REMARKS

In many empirical researches, uncertainty represented by volatilities in equity markets is time-varying and counter-cyclical, and is a leading indicator of output. This stylized fact is very important because it implies that uncertainty causes output fluctuations. However, theoretically, this time-variable and leading nature of uncertainty appears problematic. The first problem is that it contradicts the widely believed concept of certainty equivalence. In addition, even if the first problem is solved e.g. by Harashima (2004), there is the second problem. Uncertainty can be interpreted as the expected variance of stochastic output. If we assume rational expectation equilibria, the stochastic feature of output is only generated by exogenous variables. Hence variables that make uncertainty time-variable and leading variables should be firstly exogenous variables, secondly should have time-variable variances and thirdly should have the feature of leading indicators. However, technologies, tastes, or fiscal and monetary policies can not naturally be assumed to satisfy the above conditions. A problem of technologies and tastes is that they do not seem to have time-variable variances. Fiscal and monetary policies are often aimed to be countercyclical in discretionary manner. This means that fiscal and monetary policies are not purely exogenous variables and thus may be predicted by agents.

The novelty of the paper is that it uncovered a mechanism that makes uncertainty possible to be time-variable with the nature of a leading indicator, which will solve the second problem. The origin of uncertainty in the newly uncovered mechanism is the technology of supervisions and law enforcement. Supervisions and law enforcement regulate cheatings in contracts among firms and consumers, which generate noises on prices under the rational expectation approximate equilibria. Prudentiality and effectiveness of supervisions and law enforcement determines the amount of cheatings in contracts, thus their fluctuations cause uncertainty fluctuations.

Appendix

1. Proof of Proposition 1

(Step 1)

By the assumption (A5),

$$-\int_{-\infty}^{\Phi}\int_{-\infty}^{\bar{\delta}^*}\pi_1\left(c\mid\bar{\delta}\right)\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}\,d\bar{\delta}\;dc\;-\left[-\int_{-\infty}^{\Phi}\int_{-\infty}^{\bar{\delta}^*}\pi_1\left(c\mid\bar{\delta}\right)\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\,d\bar{\delta}\;dc\right]$$

$$=\int_{-\infty}^{\Phi}\int_{-\infty}^{\bar{\delta}^*}\pi_1\left(c\mid\bar{\delta}\right)\left[-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\right]d\bar{\delta}\;dc\;\le\;\int_{-\infty}^{\Phi}\int_{-\infty}^{\bar{\delta}^*}\pi_1\left(c\mid\delta^*\right)\left[-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\right]d\bar{\delta}\;dc$$

$$=\int_{-\infty}^{\Phi}\pi_1\left(c\mid\delta^*\right)\int_{-\infty}^{\bar{\delta}^*}\left[-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\right]d\bar{\delta}\;dc$$ since by the assumption (A4) $-\frac{d\varepsilon_1\left(\delta\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\delta\right)}{d\bar{\delta}}<0$ in case of $\delta^*<\delta\Leftrightarrow\bar{\delta}<\bar{\delta}^*$. On the other hand

$$-\left[-\int_{-\infty}^{\Phi}\int_{\bar{\delta}^*}^{0}\pi_1\left(c\mid\bar{\delta}\right)\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}\,d\bar{\delta}\;dc\right]+\left[-\int_{-\infty}^{\Phi}\int_{\bar{\delta}^*}^{0}\pi_1\left(c\mid\bar{\delta}\right)\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\,d\bar{\delta}\;dc\right]$$

$$=-\int_{-\infty}^{\Phi}\int_{\bar{\delta}^*}^{0}\pi_1\left(c\mid\bar{\delta}\right)\left[-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\right]d\bar{\delta}\;dc\;\ge\;-\int_{-\infty}^{\Phi}\int_{\bar{\delta}^*}^{0}\pi_1\left(c\mid\delta^*\right)\left[-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\right]d\bar{\delta}\;dc$$

$$=-\int_{-\infty}^{\Phi}\pi_1\left(c\mid\delta^*\right)\int_{\bar{\delta}^*}^{0}\left[-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\right]d\bar{\delta}\;dc$$ since by the assumption (A4) $-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}>0$ in case of $\bar{\delta}^*<\bar{\delta}\le 0\Leftrightarrow 0\le\delta<\delta^*$.

Here,

$$\int_{-\infty}^{\Phi}\pi_1\left(c\mid\delta^*\right)\int_{-\infty}^{\bar{\delta}^*}\left[-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\right]d\bar{\delta}\;dc-\left\{-\int_{-\infty}^{\Phi}\pi_1\left(c\mid\delta^*\right)\int_{\bar{\delta}^*}^{0}\left[-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\right]d\bar{\delta}\;dc\right\}$$

$$=\int_{-\infty}^{\Phi}\pi_1\left(c\mid\delta^*\right)\int_{-\infty}^{0}\left[-\frac{d\varepsilon_1\left(\bar{\delta}\right)}{d\bar{\delta}}+\frac{d\varepsilon_2\left(\bar{\delta}\right)}{d\bar{\delta}}\right]d\bar{\delta}\;dc$$. Because $\varepsilon_i\left(0\right)=1$ for any i by the assumption (A3),

$$\int_{-\infty}^{0}\left[-\frac{d\varepsilon_1(\bar{\delta})}{d\bar{\delta}}+\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}\right]d\bar{\delta} = -\varepsilon_1(0)+\varepsilon_2(0) = 0$$, and thus

$$\int_{-\infty}^{\Phi}\pi_1(c\mid\delta^*)\int_{-\infty}^{\bar{\delta}^*}\left[-\frac{d\varepsilon_1(\bar{\delta})}{d\bar{\delta}}+\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}\right]d\bar{\delta}\,dc-\left\{-\int_{-\infty}^{\Phi}\pi_1(c\mid\delta^*)\int_{\bar{\delta}^*}^{0}\left[-\frac{d\varepsilon_1(\bar{\delta})}{d\bar{\delta}}+\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}\right]d\bar{\delta}\,dc\right\} = 0.$$

Hence,

$$\int_{-\infty}^{\Phi}\int_{-\infty}^{\bar{\delta}^*}\pi_1(c\mid\bar{\delta})\left[-\frac{d\varepsilon_1(\bar{\delta})}{d\bar{\delta}}+\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}\right]d\bar{\delta}\,dc \le -\int_{-\infty}^{\Phi}\int_{\bar{\delta}^*}^{0}\pi_1(c\mid\delta^*)\left[-\frac{d\varepsilon_1(\bar{\delta})}{d\bar{\delta}}+\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}\right]d\bar{\delta}\,dc$$, thus

$$-\int_{-\infty}^{\Phi}\int_{-\infty}^{0}\pi_1(c\mid\bar{\delta})\frac{d\varepsilon_1(\bar{\delta})}{d\bar{\delta}}d\bar{\delta}\,dc \le -\int_{-\infty}^{\Phi}\int_{-\infty}^{0}\pi_1(c\mid\delta^*)\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}d\bar{\delta}\,dc.$$

(Step 2)

By the equation (1),

$$\int_{-\infty}^{\Phi}\pi_1(c)\,dc = -\int_{-\infty}^{\Phi}\int_{0}^{\infty}\pi_1(c\mid\delta)\frac{d\varepsilon_1(\delta)}{d\delta}d\delta dc = -\int_{-\infty}^{\Phi}\int_{-\infty}^{0}\pi_1(c\mid\bar{\delta})\frac{d\varepsilon_1(\bar{\delta})}{d\bar{\delta}}d\bar{\delta}\,dc \quad \forall\Phi.$$

By Step 1,

$$-\int_{-\infty}^{\Phi}\int_{-\infty}^{0}\pi_1(c\mid\bar{\delta})\frac{d\varepsilon_1(\bar{\delta})}{d\bar{\delta}}d\bar{\delta}\,dc \le -\int_{-\infty}^{\Phi}\int_{-\infty}^{0}\pi_1(c\mid\delta^*)\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}d\bar{\delta}\,dc$$

$$= -\int_{-\infty}^{0}\int_{-\infty}^{\Phi}\pi_1(c\mid\bar{\delta})\,dc\,\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}d\bar{\delta} \quad \forall\Phi.$$

By the assumption (A6)

$$-\int_{-\infty}^{0}\int_{-\infty}^{\Phi}\pi_1(c\mid\bar{\delta})\,dc\,\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}d\bar{\delta} \le -\int_{-\infty}^{0}\int_{-\infty}^{\Phi}\pi_2(c\mid\bar{\delta})\,dc\,\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}d\bar{\delta}$$

$$= -\int_{-\infty}^{\Phi}\int_{-\infty}^{0}\pi_2(c\mid\bar{\delta})\frac{d\varepsilon_2(\bar{\delta})}{d\bar{\delta}}d\bar{\delta}\,dc = -\int_{-\infty}^{\Phi}\int_{0}^{\infty}\pi_2(c\mid\delta)\frac{d\varepsilon_2(\delta)}{d\delta}d\delta dc = \int_{-\infty}^{\Phi}\pi_2(c)\,dc \quad \forall\Phi.$$

Hence,

$\int_{-\infty}^{\Phi}\pi_1(c)\,dc \le \int_{-\infty}^{\Phi}\pi_2(c)\,dc \ \forall\Phi$, and thus if $\delta_1 < \delta_2$, then $\pi_2(c)$ second-order stochastically dominates $\pi_1(c)$.

Q.E.D.

2. Proof of Proposition 2

The distribution ψ of noisy price observations is a weighted sum of distributions of all prices. Then, for a certain vector $\boldsymbol{W} = \{w_1, w_2, \ldots, w_\chi\}$ ($w_i > 0$), $\psi = \boldsymbol{W}\Lambda = \boldsymbol{W}(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}\boldsymbol{\Xi}$ by the assumption (A7) and (A8).

Given that a certain vector of cheating probability $\overline{\boldsymbol{h}}_v$ where $\boldsymbol{\Xi} = \overline{\boldsymbol{\Xi}}$ and $\psi = \overline{\psi}$. Suppose that nth probability of cheating $\overline{h}_n$ ($\in \overline{h}_v$) ($n \leqq V$) increases to $\hat{h}_n$ $\left(\hat{h}_n > \overline{h}_n\right)$, and $\boldsymbol{\Xi}$ and ψ in that case are $\hat{\boldsymbol{\Xi}}$ and $\hat{\psi}$ respectively.

Here, $\hat{\psi} - \overline{\psi} = \boldsymbol{W}(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}\left(\hat{\boldsymbol{\Xi}} - \overline{\boldsymbol{\Xi}}\right)$ where $\left(\hat{\boldsymbol{\Xi}} - \overline{\boldsymbol{\Xi}}\right) = \left\{0,\ldots,0, V_n\left\lfloor \Sigma\left(\hat{h}_n\right) - \Sigma\left(\overline{h}_n\right)\right\rfloor 0,\ldots,0\right\}$, due to $\varphi_{an} = V_n\Sigma(h_v)$ by the assumption (A9).

Since $\dfrac{\partial\sigma(\Sigma, h_v)}{\partial\Sigma} > 0$ and $\dfrac{\partial\sigma(\Sigma, h_v)}{\partial h_v} > 0$ by the assumption (A10), an increase to $\hat{h}_n$ is an upward shift of the graph of $\overline{h}_n$ as is shown in the graph 3. This means that price observations in case of $\hat{h}_n$ have a higher possibility of farther deviation from the prices without cheatings than those in case of $\overline{h}_n$. That is, higher probability ε in case of $\hat{h}_n$ than $\overline{h}_n$ for the same δ, and thus the difference between the cumulative distributions $\Sigma\left(\hat{h}_n\right) - \Sigma\left(\overline{h}_n\right)$ is positive for some δ and zero for other δ. Hence, by $\hat{\psi} - \overline{\psi} = \boldsymbol{W}(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}\left(\hat{\boldsymbol{\Xi}} - \overline{\boldsymbol{\Xi}}\right)$, the graph of the distribution $\hat{\psi}$ is an upward shift of the graph of the distribution $\overline{\psi}$ as shown in the graph 4. Therefore $\int_{-\infty}^{D} \hat{\varepsilon}\left(\overline{\delta}\right) d\overline{\delta} > \int_{-\infty}^{D} \overline{\varepsilon}\left(\overline{\delta}\right) d\overline{\delta}\ \forall D$ where $\hat{\varepsilon}\left(\overline{\delta}\right)$ and $\overline{\varepsilon}\left(\overline{\delta}\right)$ are $\varepsilon\left(\overline{\delta}\right)$ in case of $\hat{\psi}$ and $\overline{\psi}$ respectively. By the assumption (A3), if $\int_{-\infty}^{D} \hat{\varepsilon}\left(\overline{\delta}\right) d\overline{\delta} > \int_{-\infty}^{D} \overline{\varepsilon}\left(\overline{\delta}\right) d\overline{\delta}\ \forall D$, then $\hat{\delta} > \overline{\delta}$ for a certain common ε where $\hat{\delta}$ and $\overline{\delta}$ are δ in case of $\hat{\psi}$ and $\overline{\psi}$ respectively.[16]

Hence, when h_v increases, $\delta(h_v, z_v)$ increases, that is, $\delta(h_v, z_v)$ is an increasing function of h_v ($v \leqq \chi$), and thus $\frac{\partial \delta(h_v)}{\partial h_v} > 0$.

Q.E.D.

3. Proof of Proposition 3

Since $e_1 > e_2$, then $g(e_1) > g(e_2)$ by the assumption (A12). Thereby, if $e_1 > e_2$, then $\widetilde{h}_v(e_1) = h_v[1 - g(e_1)] < h_v[1 - g(e_2)] = \widetilde{h}_v(e_2)$ for any v ($v \leqq \chi$).

Let $\psi(e_i) = \boldsymbol{W}(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}\boldsymbol{\Xi}(e_i)$ where $\boldsymbol{\Xi}(e_i)$ is $\boldsymbol{\Xi}$ in case of $\widetilde{h}_v(e_i)$, and let $\Sigma(e_i)$ be Σ whose cumulative density function is $\sigma\left[\Sigma, \widetilde{h}_v(e_i)\right]$.

Here,

$$\psi(e_1) - \psi(e_2) = \boldsymbol{W}(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}[\boldsymbol{\Xi}(e_1) - \boldsymbol{\Xi}(e_2)] \text{ where } \boldsymbol{\Xi}(e_1) - \boldsymbol{\Xi}(e_2) =$$

$$\left\{V_1\left[\Sigma\left(\widetilde{h}_1(e_1)\right) - \Sigma\left(\widetilde{h}_1(e_2)\right)\right], V_2\left[\Sigma\left(\widetilde{h}_2(e_1)\right) - \Sigma\left(\widetilde{h}_2(e_2)\right)\right], \dots, V_\chi\left[\Sigma\left(\widetilde{h}_\chi(e_1)\right) - \Sigma\left(\widetilde{h}_\chi(e_2)\right)\right], 0, \dots, 0\right\}.$$

Since $\widetilde{h}_v(e_1) < \widetilde{h}_v(e_2)$ for any v ($v \leqq \chi$), then the difference between the cumulative distributions $\Sigma\left[\widetilde{h}_v(e_1) - \widetilde{h}_v(e_2)\right]$ for any v ($v \leqq \chi$) is negative for some δ and zero for other δ. Hence, by $\psi(e_1) - \psi(e_2) = \boldsymbol{W}(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}[\boldsymbol{\Xi}(e_1) - \boldsymbol{\Xi}(e_2)]$, the graph of the distribution $\psi(e_1)$ is a downward shift of the graph of the distribution $\psi(e_2)$ as shown in the graph 5. Therefore $\int_{-\infty}^{D} \varepsilon_1(\overline{\delta})\, d\overline{\delta} < \int_{-\infty}^{D} \varepsilon_2(\overline{\delta})\, d\overline{\delta}\ \forall D$ where $\varepsilon_1(\overline{\delta})$ and $\varepsilon_2(\overline{\delta})$ are $\varepsilon(\overline{\delta})$ in case of

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16 It is because "if $\delta_1 < \delta_2$ then $\int_{-\infty}^{D} \varepsilon_1(\overline{\delta})\, d\overline{\delta} \leq \int_{-\infty}^{D} \varepsilon_2(\overline{\delta})\, d\overline{\delta}\ \forall D$" $\Leftrightarrow$ "if $\int_{-\infty}^{D} \varepsilon_1(\overline{\delta})\, d\overline{\delta} > \int_{-\infty}^{D} \varepsilon_2(\overline{\delta})\, d\overline{\delta}\ \forall D$ then $\delta_1 \geq \delta_2$", and "if $\delta_1 = \delta_2$ then $\int_{-\infty}^{D} \varepsilon_1(\overline{\delta})\, d\overline{\delta} = \int_{-\infty}^{D} \varepsilon_2(\overline{\delta})\, d\overline{\delta}\ \forall D$" $\Leftrightarrow$ "if $\int_{-\infty}^{D} \varepsilon_1(\overline{\delta})\, d\overline{\delta} \neq \int_{-\infty}^{D} \varepsilon_2(\overline{\delta})\, d\overline{\delta}\ \forall D$ then $\delta_1 \neq \delta_2$".

$\psi(e_1)$ and $\psi(e_2)$ respectively. By the assumption (A3), if $\int_{-\infty}^{D} \varepsilon_1(\bar{\delta})\,d\bar{\delta} < \int_{-\infty}^{D} \varepsilon_2(\bar{\delta})\,d\bar{\delta}\ \forall D$, then $\delta_1 < \delta_2$ for a certain common ε where δ_1 and δ_2 are δ in case of $\psi(e_1)$ and $\psi(e_2)$ respectively.

As a result, if $e_1 > e_2$, then $\delta_1 < \delta_2$. Thus, by the proposition 1, if $e_1 > e_2$, then $\pi_2(c)$ second-order stochastically dominates $\pi_1(c)$.

Q.E.D.

4. Proof of Proposition 4

Since $\int_{-\infty}^{F} \xi(e_1)\,de < \int_{-\infty}^{F} \xi(e_2)\,de\ \forall F$, then

$\tilde{h}_v(e_1, F) = \int_{-\infty}^{F} h_v[1 - \xi(e_1)]\,de < \int_{-\infty}^{F} h_v[1 - \xi(e_2)]\,de = \tilde{h}_v(e_2, F)\ \forall F$. Hence,

$\tilde{h}_v(e_1,0) = \int_{-\infty}^{0} h_v[1 - \xi(e_1)]\,de < \int_{-\infty}^{0} h_v[1 - \xi(e_2)]\,de = \tilde{h}_v(e_2,0)$ for any v ($v \leqq \chi$).

Let $\psi(e_i) = \boldsymbol{W}(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}\boldsymbol{\Xi}(e_i)$ where $\boldsymbol{\Xi}(e_i)$ is $\boldsymbol{\Xi}$ in case of $\tilde{h}_v(e_i,0)$, and let $\Sigma(e_i)$ be Σ whose cumulative density function is $\sigma\left[\Sigma, \tilde{h}_v(e_i,0)\right]$.

Here,

$\psi(e_1) - \psi(e_2) = \boldsymbol{W}(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}[\boldsymbol{\Xi}(e_1) - \boldsymbol{\Xi}(e_2)]$ where $\boldsymbol{\Xi}(e_1) - \boldsymbol{\Xi}(e_2) =$

$\left\{V_1\left[\Sigma\left(\tilde{h}_1(e_1,0)\right) - \Sigma\left(\tilde{h}_1(e_2,0)\right)\right], V_2\left[\Sigma\left(\tilde{h}_2(e_1,0)\right) - \Sigma\left(\tilde{h}_2(e_2,0)\right)\right], \ldots, V_\chi\left[\Sigma\left(\tilde{h}_\chi(e_1,0)\right) - \Sigma\left(\tilde{h}_\chi(e_2,0)\right)\right], 0, \ldots, 0\right\}$.

Since $\tilde{h}_v(e_1,0) < \tilde{h}_v(e_2,0)$ for any v ($v \leqq \chi$), then the difference between the cumulative distributions $\Sigma\left[\tilde{h}_v(e_1) - \tilde{h}_v(e_2)\right]$ for any v ($v \leqq \chi$) is negative for some δ and zero for other δ. Hence, by $\psi(e_1) - \psi(e_2) = \boldsymbol{W}(\boldsymbol{E} - \boldsymbol{\Phi}')^{-1}[\boldsymbol{\Xi}(e_1) - \boldsymbol{\Xi}(e_2)]$, the graph of the distribution $\psi(e_1)$ is a downward shift of the graph of the distribution $\psi(e_2)$ as shown in the graph 5. Therefore $\int_{-\infty}^{D} \varepsilon_1(\bar{\delta})\,d\bar{\delta} < \int_{-\infty}^{D} \varepsilon_2(\bar{\delta})\,d\bar{\delta}\ \forall D$ where $\varepsilon_1(\bar{\delta})$ and $\varepsilon_2(\bar{\delta})$ are $\varepsilon(\bar{\delta})$ in case of

$\psi(e_1)$ and $\psi(e_2)$ respectively. By the assumption (A3), if $\int_{-\infty}^{D} \varepsilon_1(\bar{\delta})\, d\bar{\delta} < \int_{-\infty}^{D} \varepsilon_2(\bar{\delta})\, d\bar{\delta} \ \forall D$, then $\delta_1 < \delta_2$ for a certain common ε where δ_1 and δ_2 are δ in case of $\psi(e_1)$ and $\psi(e_2)$ respectively.

As a result, if $\xi(e_2)$ second-order stochastically dominates $\xi(e_1)$ with strict inequality such as $\int_{-\infty}^{F} \xi(e_1)\, de < \int_{-\infty}^{F} \xi(e_2)\, de \ \forall F$, then $\delta_1 < \delta_2$. By the proposition 1, if $\delta_1 < \delta_2$, then $\pi_1(c)$ second-order stochastically dominates π_2 (c). Hence, if $\xi(e_2)$ second-order stochastically dominates $\xi(e_1)$ with strict inequality such as $\int_{-\infty}^{F} \xi(e_1)\, de < \int_{-\infty}^{F} \xi(e_2)\, de \ \forall F$, then $\pi_2(c)$ second-order stochastically dominates π_1 (c).

Q.E.D.

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Figure 1: The Relation between *ε* and *δ*

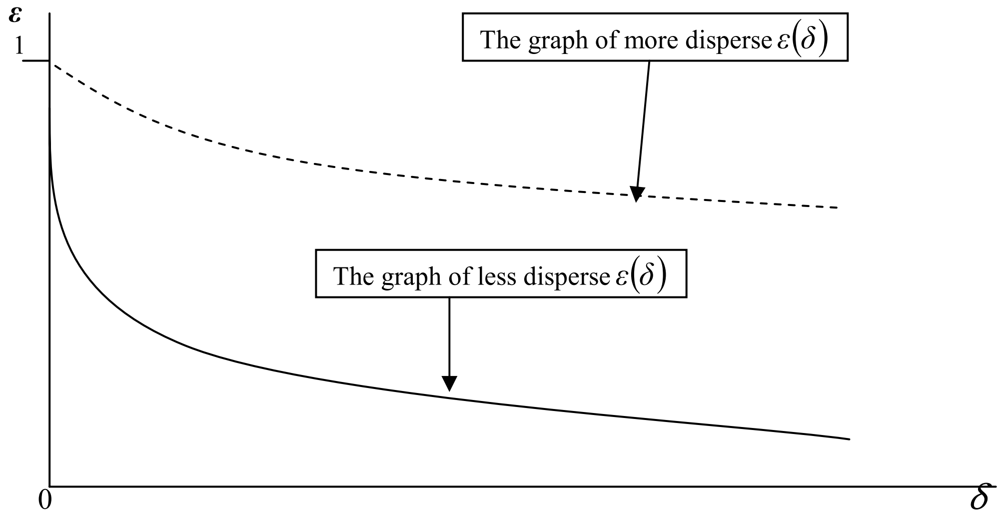

Figure 2: The Distribution of Expected Steady State Consumption

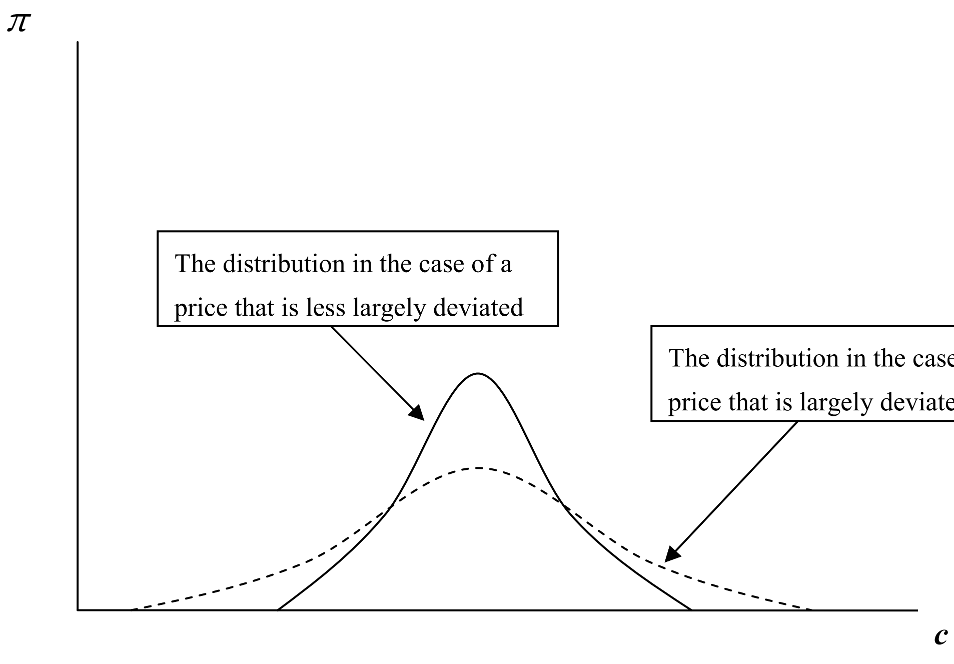

Figure 3: The Graph of $\sigma(Z, h_v)$

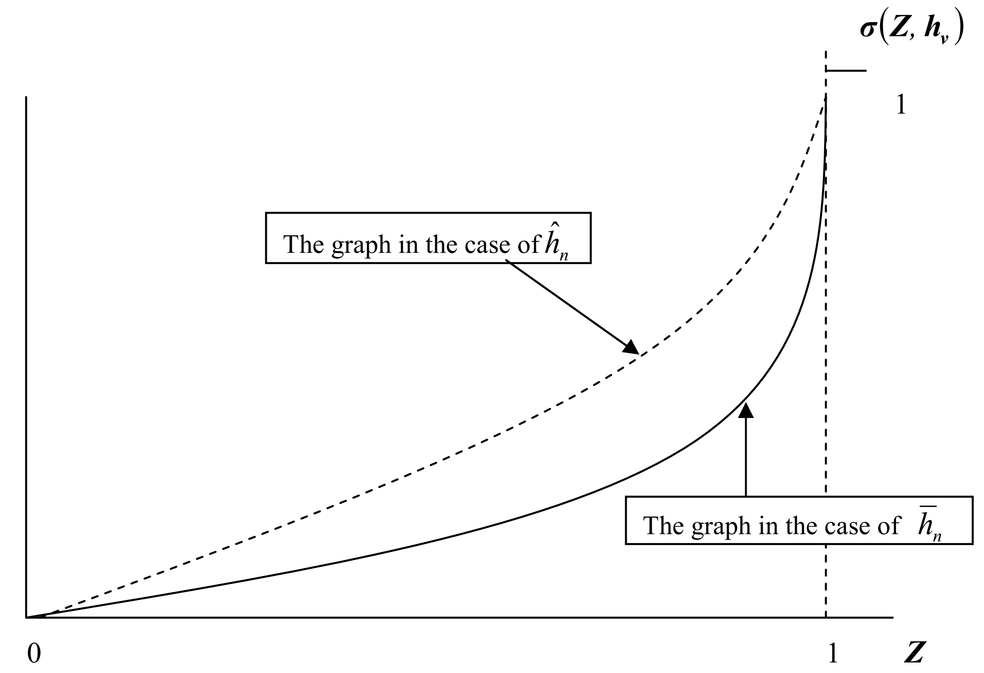

Figure 4: The Graphs of $\bar{\psi}$ and $\hat{\psi}$

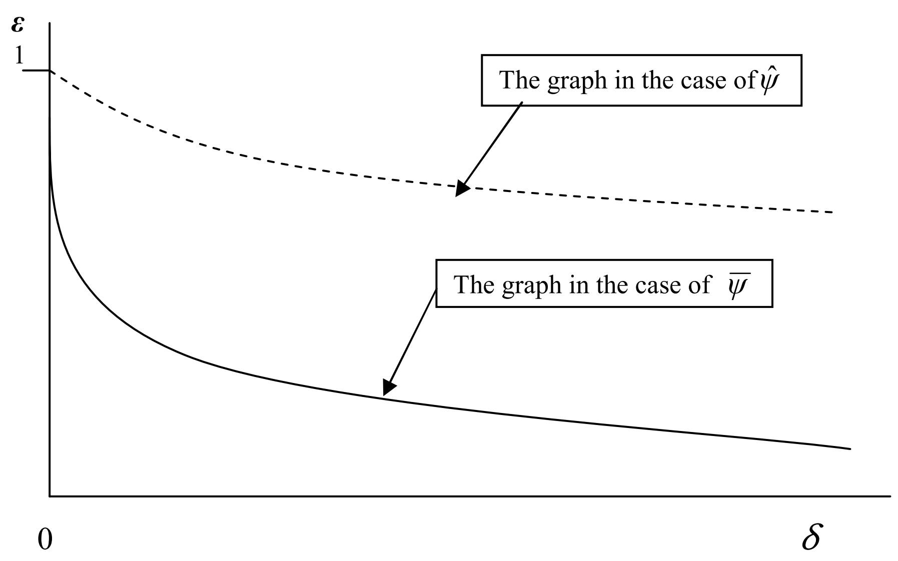

Figure 5: The Graphs of $\psi(e_1)$ and $\psi(e_2)$