Would and Should Government Lie about Economic Statistics: Understanding Opinion Formation Processes through Evolutionary Cellular Automata

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Abstract. Are there any possible situations in which the state of the economy tomorrow depends on that of the economy today revealed by the government? If so, does the government have any "incentives" to manipulate statistics? Using a simulation approach based on a model of *evolutionary cellular automata*, this paper tackles the issue by taking explicitly into account *self-fulfilling expectations* and the existence of *multiple equilibria*. We find that the government will not always lie, especially when agents use the Bayesian learning algorithm to adjust their reliance on government statistics. Nevertheless, there is an incentive for the government to lie under certain circumstances, that is, when the economy, in terms of our model, is in a cloudy zone or the scale of the pessimistic shock is moderate.

1 Introduction

> There is nothing exceptional about the result that changes in expectations affect the equilibrium of the economy; the interesting feature is that those changed expectations (animal spirits) may be correct and thus self-justifying. This is a rigorous justification of the notion that *optimism itself may be sufficient to create a boom, or that all we have to fear is fear itself.* (Fischer, 1991: p.32. Italics added)

In modern society, when a government announces some official economic statistics or news, and if the news is beyond the expectations of the public, then, usually, the public will react in two ways: (1) The public will admit that they have either overestimated or underestimated the statistics (2) The public will assume that the economic statistics might be incorrect. For the latter, the public will usually attribute the incorrect statistics to two kinds of reasons: (i) technical reasons, such as the disagreement on the definitions of some economic indices or statistics, or (ii) *deliberate* manipulation of data on the part of the government. If it is only technical reasons, the situation would be

much easier because the government can simply release economic statistics by different definitions, but if it is caused by intentional manipulation, then the situation becomes complicated and merely solving the problem of definitions is not enough. *The purpose of this paper is to inquire the nature and possibility of the intentional manipulation of economic statistics.*[1]

From the perspective of economics, the fundamental issue is: "Is there any *incentive* for the government to manipulate economic statistics ?" If the answer is *no*, then all the problems left will be definitions only. In this situation, the public can only disagree with the official definitions used by the government but should not be skeptical about the credibility of the government. But, if the answer is *yes*, then it is necessary for us to further understand the *temptation* for the government to lie.

A question concerning the *temptation* is whether the statistics of the recent economic situation announced by the government will affect future economic situations? By economic theory, a positive answer to this question is inspired by the the study of *self-fulfilling expectations* and *the existence of multiple equilibria*. As Woodford (1988) said:

> People's adherence to a particular theory about the significance of that realization leads them to act in a way that *makes that theory true*,... [Woodford (1988), p.5].

Leeper (1991) also cited Roger Brinner, the supervisor of the research department of the DRI/McGraw-Hill Co., as follows:

> If consumers hadn't panicked [in August 1990], there wouldn't have been a recession. (p.3)

Therefore, there will be no bad news so long as the government does not announce any. From this viewpoint, the government not only *can* lies about economic statistics but *should* do so as well. While this argument sounds appealing, what we need is a rigorous analysis to justify it, or to challenge it for that matter. In this paper, we shall apply the model of *evolutionary cellular automata* to analyzing whether self-fulfilling expectations can entice the government to lie. More precisely, within an *evolutionary* framework, we are studying whether the government has any incentives to lie, given that the agents (businessmen) are smart (adaptive). To the best of our knowledge, such an application in economics is unprecedented. The choice of this methodological technology seems to be natural because traditional economic approaches are not capable of simulating the processes of *dissemination*, *infection* and *reinforcement* of news, which are the essence of self-

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[1] In the real world, what we frequently observe is that businessmen show their distrust in government statistics, and the government always defends their statistics by arguing that it is a problem of defintion. For an extensive survey of the distrust of businessmen in government statistics, see Appendix.

fulfilling expectations.[2] We shall use Wolfram's cellular automata to simulate a *co-evolutionary (learning) process*, by which we can capture the processes of *dissemination, infection* and *reinforcemet* of news. Agents in this model are modelled as *Bayesian learning agents* who try to judge the reliability of economic statistics by using the *Kalman Filter*.

The rest of this paper is organized as follows. Section 2 presents the basic cellular automata (CA) model with monopolistic media (government). In Section 4, each individual is modelled as a *Bayesian learning agent* and the basic CA model is extended into an *evolutionary CA model*. Section 5 presents the simulation results based on the evolutionary CA model. Two cases are compared. In the first case, the government will lie about economic statistics; in the second, the government will not. We will study the temptation to lie by comparing the difference between these two cases in terms of *economic performance* and *the credibility of the government*. Concluding remarks are given in Section 6.

2   The Model of Cellular Automata with Monopolistic Media

In this paper, we would like to use the following simple flow chart, Figure 1, to analyze our problem. In a society, at any given point of time t, each agent has his/her expectations with respect to the general prospect of the economic state, such as GDP growth rates, or the future prices of the stock market. Let us use the symbol $X(t)$ to represent the collection of all agents' expectations. Thus, $X(t)$ includes Mary's optimistic expectations for the economic prospect as well as John's pessimistic expectations for the economy. In addition to their own expectations, each agent is supposed to know the expectations of his or her neighbors. We shall use $X_L(t)$ to represent the collection of the neighbors' expectations. The "L" above refers to "local", whose meaning will be clear later in this text. Apart from the local information, there are some institutions, for example, the government, who hold a larger information set $X_G(t)$ by making an extensive survey periodically.[3] The "G" above refers to "global".

There is an aggregate variable $p(t)$ in the information set $X(t)$, such as the percentage of the agents who entertain optimistic expectations for the economic prospect. $p(t)$ is the key variable based on which agents' expectations

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[2] For a comprehensive criticism on the failure of the mainstream economics to deal with the complex adaptive systems, readers are referred to Chen (1996).

[3] The meaning of the term *"monopolistic media"* in our text can be explained as follows. Monopolistic media do not mean that they are the only media in the society that collect and disseminate information. In fact, all agents in society have the function of media, as far as the collection and dissemination of information are concerned. However, their activities are rather "local", compared with the government's.
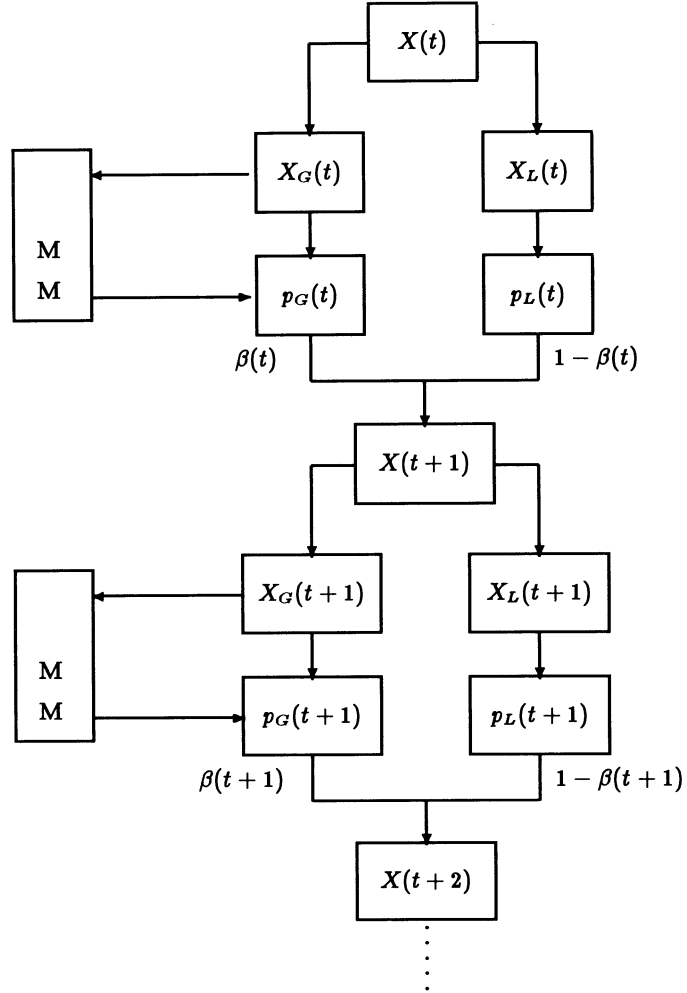
Figure 1: The Flowchart: The Interaction between Monopolistic Media (M.M.) and Agents

will be formed and updated. But since no one knows the whole $X(t)$, agents can only substitute $p(t)$ by their estimates based on their local information $X_L(t)$, i.e., $p_L(t)$. In other words, agents use $p_L(t)$ to shape or form their expectations for the next period $X(t+1)$. Besides $p_L(t)$, the government will also offer their estimate of $p(t)$ based on the global information, i.e., $p_G(t)$. This information $p_G(t)$ will then be given to each agent for free, and, depending on a parameter $\beta(t)$, $p_G(t)$ may, or may not, be used by agents to form their expectations for the next period.

This process goes on and on as a dynamic system. When this dynamic system reaches an equilibrium at t^*, the utility function of the monopolistic
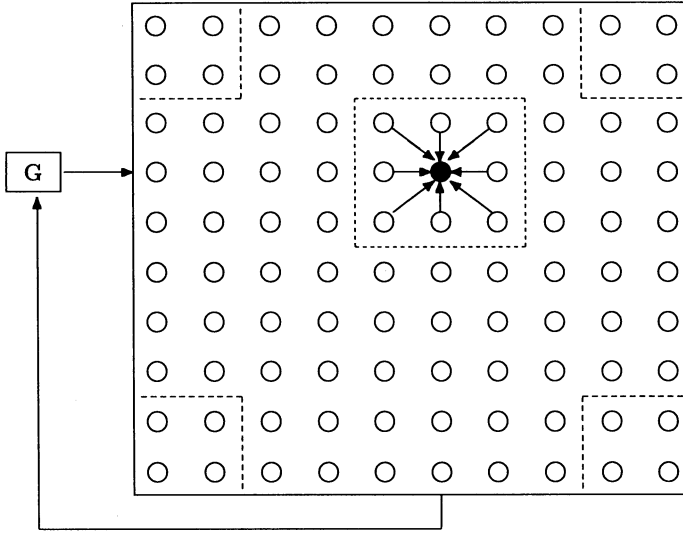
Figure 2: The 10 by 10 Matrix Society

media is determined by two factors: one is the $p(t^*)$ in the equilibrium, which shall be denoted by p^*, the other the general degree of public reliance on the media $\beta(t^*)$, denoted by $\bar{\beta}$. Within this framework, we would like to ask some simple questions: *Do monopolistic media have any incentives to give false reports? If they do, what factors will affect the incentive(s)?*

To answer the questions above, we designed a 10 by 10 two dimensional square matrix X, depicted as figure 2. Each point in the matrix X represents one agent in the society, and the point (i, j) represents the person whose address is at the i-th row and the j-th column. $x_{ij}(t)$ represents the expectations of the agent (i, j) in period t. $X(t) = [x_{ij}(t)]$ represents the matrix consisting of the expectations of all agents. To simplify our analysis, we assume that there are only two types of expectations, one being the positive (or optimistic, expanding) expectations, denoted by "1", the other the negative (or pessimistic, contracting) expectations, denoted by "-1".

We then introduce a *network* or a *communication channel* to the square matrix X. The network consists of two parts. The first part is a local network N_{ij}, and to each agent (i, j), there exists one local network. The network is composed of the first layer of the neighbors surrounding the agent (i, j). For instance, in Figure 2, the neighbors N_{46} of the agent $(4,6)$ include agents $(3,5),(3,6),(3,7),(4,7),$ $(5,5),(5,6),(5,7)$. The second part is a global network which is built up by monopolistic media G, as shown in Figure 2. Based on the information in X, the global network makes an announcement, and then this announcement is disseminated to each agent (i, j) in every period.

According to these two networks, we can then discuss the information flow in X and the formation of $x_{ij}(t + 1)$. First, let us consider the system of

behavior Equations (1)-(3):

$$x_{ij}(t+1) = \begin{cases} 1, & \text{if } f_{ij}(X(t)) > 0, \\ x_{ij}(t), & \text{if } f_{ij}(X(t)) = 0, \\ -1, & \text{if } f_{ij}(X(t)) < 0. \end{cases} \qquad (1)$$

$$f_{ij}(X(t),t) = (1-\beta_{ij}(t))\frac{\sum_{N_{ij}} x_{ij}(t)}{\#(N_{ij})} + \beta_{ij}(t)G(t)$$
$$= (1-\beta_{ij}(t))(2p_{ij}(t)-1) + \beta_{ij}(t)G(t) \qquad (2)$$

where

$$0 \le \beta_{ij}(t) \le 1$$

$$p_{ij}(t) = \frac{\#\{x_{ij}(t)=1 \mid x_{ij} \in N_{ij}\}}{\#(N_{ij})}$$

$$G(t) = \begin{cases} 1, & \text{if } g(X(t)) > 0, \\ 0, & \text{if } g(X(t)) = 0, \\ -1, & \text{if } g(X(t)) < 0 \end{cases} \qquad (3)$$

$$g(X(t)) = \frac{\sum_{x_{ij}(t)\in S_t} x_{ij}(t)}{n}$$

Basically, Equations (1) to (3) indicate the information flow of the matrix $X(t)$, the use of $X(t)$, and the formation of $x_{ij}(t+1)$. Equation (1) indicates that the agent (i,j) forms his/her expectations $x_{ij}(t+1)$ according to the *statistic* $f_{ij}(X(t),t)$. There are three kinds of possibilities: first, when the *statistic* is larger than 0, then the agent will have "positive" or "optimistic" expectations; second, when it is equal to 0, then his/her expectations in the previous period will remain unchanged; third, when it is smaller than 0, then the person will have "negative" or "pessimistic" expectations.

By Equation (2), the *statistic* $f_{ij}(X(t))$ is composed of two types of information, namely, the local information N_{ij}, and the global information $G(t)$ which, according to Equation (3), is determined by g$(X(t))$. g$(X(t))$ is the sampling survey, which is made by the government in period t. This survey first draws a random sample S_t with a fixed sample size n. It then asks about the expectations of every agent in S_t, i.e., $x_{ij}(t)$ $(x_{ij}(t) \in S_t)$, and processes the data by computing the sample average. Finally, the government will make an announcement of the current economic situation based on g$(X(t))$. According to Equation 3, when the sample average is larger than 0, indicating that the number of the agents who have positive expectations is larger than that of those who entertain negative expectations in the sample S_t, the government (monopolistic media) will make a "positive" announcement, coded as "1". When $g(X(t))$ equals to 0, indicating the number of agents who have

positive expectations is the same as that of those who have negative expectations, the government will give *no comment*, coded as "0". Otherwise, it will make a negative announcement, coded as "-1".

Therefore, $f_{ij}(X(t), t)$ for (i, j) synthesizes two kinds of estimates. On the one hand, it is the average of the agent (i, j)'s expectations for the economy based on (i, j)'s personal feelings. On the other hand, it is the "general" feelings revealed by the government. The first kind of information is reliable but too local. The second kind is global but may not be reliable. Under the circumstances, we assume that each agent assigns weights, i.e., $\beta_{ij}(t)$ and $(1 - \beta_{ij}(t))$, to each of these two types of information. Given $\beta_{ij}(t)$, each agent (i, j) can form his/her expectations by integrating the local information with the global information.

Equations (1) to (3) constitute a dynamic system. According to Wolfram's (1984) research, there are four kinds of equilibria for this dynamic system: the fixed point, the periodic cycle, the chaotic structure, and the highly complex irregular structure. For the convenience of our analysis, let's make a few definitions.

Definition 1: **Consensus**

We would say that the (i, j)s in the matrix X have reached a *consensus*, if

$$x_{ij}(t^*) = 1 \quad \forall i, j$$

$$\text{or } x_{ij}(t^*) = -1 \quad \forall i, j$$

Obviously, the *consensus* is a fix-point equilibrium, but it is not the only fix-point equilibrium. In fact, we shall define the *non-consensus* fix-point equilibrium as follows.

Definition 2: **Non-consensus equilibrium**

We would say that the (i, j)s in the matrix X have reached a non-consensus equilibrium, if there exists a t^* such that, for all (i, j)s, one of the following two conditions holds.

$$x_{ij}(t) = 1 \quad \forall t \geq t^*$$

$$\text{or } x_{ij}(t) = -1 \quad \forall t \geq t^*$$

Since there are many non-consensus equilibria, for the convenience of analysis, the following definition, which also gives us a measure of *the diversity of agents' beliefs*, is useful.

Definition 3: p^*-equilibrium

We call a non-consensus equilibrium the p^*-equilibrium, if

$$\frac{\#\{(i, j) : x_{ij}(t^*) = 1\}}{100} = p^*$$

and the p^* is called the "equilibrium degree of diversity" of the associated equilibrium.

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3 Simulation 1: The Role of the Monopolistic Media

The purpose of this section is to understand the role of the monopolistic media (simply *media*, hereafter) in a network model. Without loss of generality, we shall simplify Equaition (2) by assuming that all agents (i,j) behave identically, i.e.,

$$f_{ij}(X(t), t) = f(X(t), t) = (1 - \beta)\frac{\sum_{N_{ij}} x_{ij}(t)}{\#(N_{ij})} + \beta G(t) \qquad (2')$$

where $0 \leq \beta \leq 1$.

According to equation $(2')$, when $\beta=0$, the media is *essentially non-existent* because agents do not care about what it says. Therefore, simulating the model of cellular automata, i.e., Equations (1) $(2')$ and (3), with different βs enables us to understand *how the dissemination of information and the formation of expectations can be affected by people's different degrees of reliance on the media*. For this purpose, Simulation 1 is designed with Gauss 2.2.

Since the dynamics of the cellular automata can crucially depend on the *"initial configuration"* of the cellular automata, for each β and each p(0), we implemented 1000 runs of simulation[4]. In each run, when the equilibrium was achieved, we computed the p^* defined in Definition 3. Tables 1.a to 1.d present the frequency distribution of p^* over the respective 1000 runs. In these tables, we divide the interval $[0,1]$ into two two endpoints, $\{0\}$ and $\{1\}$, and nine subintervals $(0, 0.1], (0.1, 0.2], ..., (0.9, 1)$. The number of p^* appearing in each of these subintervals is counted from the leftmost interval $\{0\}$ to the rightmost one $\{1\}$ and is denoted by $q_0, ..., q_{11}$. Notice that q_0 and q_1 are also the numbers of consensus equilibrium (Definition 1).

The main results on the formation of expectations can be briefly summarized as follows. *The emergence of the consensus and and the speed of this coordination is affected by two factors, namely, agents' "degree of reliance" on the media (β) and the diversity of agents' initial expectations (p(0)).* The lower the degree of reliance on the media and the more diverse the initial expectations[5], the more difficult for the media to coordinate agents' expectations to the consensus. Even it could, it takes a long time to do so. On the other hand, when the public reliance on media is high, and the diversity of initial expectations is low[6], then the media not only can coordinate agents' expectations to the consensus equilibrium but can do it very fast.

To elaborate on this result, let us take some numerical examples from Table 1. In Table 1.a ($\beta = 0$), when $p(0)$ is between 0.4 and 0.6, the probability of

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[4] In this paper, the "initial configuratin" is simply the (1,-1) binary square matrix. In the model of cellular automata, even that the p(0) is the same, i.e., the ratio of 1 and -1 in the 0-th period is the same, the dynamics and hence the equilibrium can still be different.

[5] I.e., $p(0)$ gets closer to 0.5.

[6] I.e., p(0) either approaches 0 or 1.

the emergence of the consensus is less than a half[7]; moreover, when $p(0) = 0.5$, the probability of the emergence of the consensus comes dome to nil. However, as the initial expectations of agents is less diverse, such as $p(0) \leq 0.3$ or $p(0) \geq 0.7$, it is easier to reach a consensus. Furthermore, as β increases up to 0.2, no matter whether $p(0)$ is close to 0.5 or not, the chance of reaching a concensus can be high up to 1 (see Tables 1.b-1.d).

Table 1.a : Equilibrium distribution of p^* ($\beta=0$)

p(0)	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}	q_{11}	n^*
0.10	1000	0	0	0	0	0	0	0	0	0	0	0	1.24
0.20	998	2	0	0	0	0	0	0	0	0	0	0	2.17
0.30	928	30	40	2	0	0	0	0	0	0	0	0	4.22
0.40	378	100	309	144	57	11	1	0	0	0	0	0	6.75
0.50	4	4	20	75	177	263	267	127	50	11	1	1	6.71
0.60	0	0	0	0	0	5	17	47	168	311	43	409	6.88
0.70	0	0	0	0	0	0	0	0	3	46	23	928	4.31
0.80	0	0	0	0	0	0	0	0	0	0	0	1000	2.26
0.90	0	0	0	0	0	0	0	0	0	0	0	1000	1.26

q_j: the times of the p^* equilibrium which falls into the interval of $(\frac{i-1}{10}, \frac{i}{10}$ ($j = 1, ...9$)
q_0: the times of the p^* equilibrium which falls into $\{ 0 \}$
q_{10}: the times of the p^* equilibrium which falls into the interval of $(0.9,1)$
q_{11}: the times of the p^* equilibrium which falls into $\{ 1 \}$ n^*: the average time needed for reaching the equilibrium in 1000 runs of simulation

Table 1.b : Equilibrium distribution of p^*; ($\beta=0.2$)

p(0)	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}	q_{11}	n^*
0.10	1000	0	0	0	0	0	0	0	0	0	0	0	1.11
0.20	1000	0	0	0	0	0	0	0	0	0	0	0	1.63
0.30	1000	0	0	0	0	0	0	0	0	0	0	0	2.24
0.40	958	0	0	0	0	0	0	0	0	0	0	42	4.07
0.50	500	0	0	0	0	0	0	0	1	0	0	499	6.33
0.60	40	0	0	0	0	0	0	0	0	0	0	960	4.04
0.70	0	0	0	0	0	0	0	0	0	0	0	1000	2.24
0.80	0	0	0	0	0	0	0	0	0	0	0	1000	1.63
0.90	0	0	0	0	0	0	0	0	0	0	0	1000	1.13

For the meaning of notations, see Table 1.a.

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[7] Taking $p(0) = 0.4$ as an example, out of 1000 runs, there are only 378 runs which have reached the consensus equilibrium; when $p(0) = 0.6$, there are only 409 times which have reached the consensus equilibrium.

Table 1.c : Equilibrium distribution of p^*; (β=0.4)

p(0)	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}	q_{11}	n^*
0.10	1000	0	0	0	0	0	0	0	0	0	0	0	1.00
0.20	1000	0	0	0	0	0	0	0	0	0	0	0	1.05
0.30	991	0	0	0	0	0	0	0	0	0	0	9	1.19
0.40	910	0	0	0	0	0	0	0	0	0	0	90	1.84
0.50	496	0	0	0	0	0	0	0	0	0	0	504	2.44
0.60	109	0	0	0	0	0	0	0	0	0	0	891	1.80
0.70	13	0	0	0	0	0	0	0	0	0	0	987	1.25
0.80	0	0	0	0	0	0	0	0	0	0	0	1000	1.03
0.90	0	0	0	0	0	0	0	0	0	0	0	1000	1.00

For the meaning of notations, see Table 1.a.

Table 1.d : Equilibrium distribution of p^*; (β=0.6)

p(0)	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}	q_{11}	n^*
0.10	1000	0	0	0	0	0	0	0	0	0	0	0	1.00
0.20	1000	0	0	0	0	0	0	0	0	0	0	0	1.00
0.30	992	0	0	0	0	0	0	0	0	0	0	8	1.02
0.40	894	0	0	0	0	0	0	0	0	0	0	106	1.13
0.50	511	0	0	0	0	0	0	0	0	0	0	489	1.25
0.60	93	0	0	0	0	0	0	0	0	0	0	907	1.12
0.70	9	0	0	0	0	0	0	0	0	0	0	991	1.02
0.80	0	0	0	0	0	0	0	0	0	0	0	1000	1.00
0.90	0	0	0	0	0	0	0	0	0	0	0	1000	1.00

For the meaning of notations, see Table 1.a.

So Simulation 1 shows us that, *when the public reliance on the media increases to a certain degree, then the role of the media is not merely to report what agentspeople think, but can also shape and coordinate what people think.*

Although reaching a consensus is always possible when the public reliance on the media is high up to a certain degree, the speed of consensus formation can be slow if the initial diversity of agents' expectations is high. Take Table 1.b ($\beta = 0.2$) as an example, when p(0)=0.5, on the average, it takes 6.33 periods to reach a consensus (the last column of Table 1.b); but when p(0)=0.1, it takes only 1.11 periods to reach a consensus. However, this difference in the speed of reaching a consensus is reduced as β increases. For example, in Table 1.c ($\beta = 0.4$), it is reduced to 1.4 periods, and in Table 1.d ($\beta = 0.6$), it is further reduced to less than 0.25 period. Therefore, the media not only can homogenize agents' expectations but can also speed up this process.

4   Simulation 2: Would the Government Lie?

Given the potential impact of the media on shaping agents' expectations, in this section we will further inquire: *when the media is completely controlled by the government, does the government has any incentive to use the media to make false report?* In order to analyze this question, we modify Equation (3) as follows.

$$G^1(t) = 1, \forall t. \tag{4}$$

The difference between $G^1(t)$ (Equation 4) and $G(t)$ (Equation 3) is that $G(t)$ can be considered as a honest report, while $G^1(t)$ is not. When the media $G(t)$ reports that the economic prospect looks promising $(G(t) = 1)$, it is based on an unbiased statistics (sample average) of her survey S_t. In other words, $G(t) = 1$ only when the *majority* of people in the survey are quite optimistic about the economic prospect, and $G(t) = -1$ only when the opposite holds. However, for the media $G^1(t)$, the announcement is entirely independent of the sample average of the survey, and no matter what the majority of people really think, $G^1(t)$ always says that the economy prospect is in a good shape. Clearly, in some cases, $G^1(t)$ is not telling the truth.

Thouogh the report based on $G^1(t)$ is feasible for a monopoloistic media, the essential question is *whether or not the government has any incentive to do so?* In other words, is there any potential gains which can entice the government to do so. In order to gauge the potential gains earned by the media $G^1(t)$, we simulate the model of Equations $(1)(2')$ and (4) in the same manner as Simulation 1. The result of this simulation, called Simulation 2, is in Table 2.a to 2.c. This simulation is driven by the desire to understand: *if the majority of agents' initial expectations are pessimistic, then what kind of change will the distorted report $G^1(t)$ bring forth?*

Table 2.a : Equilibrium distribution of p^*; $(\beta=0.2;\ G^1)$

p(0)	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}	q_{11}	n^*	$\bar{n}$
0.10	932	64	4	0	0	0	0	0	0	0	0	0	2.57	39
0.20	337	368	199	59	24	3	0	0	0	0	0	10	5.42	287
0.30	1	23	83	143	151	84	31	10	0	0	0	474	14.03	271
0.40	0	0	0	0	0	1	1	11	3	0	0	984	10.26	6
0.50	0	0	0	0	0	0	0	0	0	0	0	1000	5.20	0
0.60	0	0	0	0	0	0	0	0	0	0	0	1000	3.21	0
0.70	0	0	0	0	0	0	0	0	0	0	0	1000	2.22	0
0.80	0	0	0	0	0	0	0	0	0	0	0	1000	1.59	0
0.90	0	0	0	0	0	0	0	0	0	0	0	1000	1.10	0

$\bar{n}$: the number of limit-cycle equilibrium whose period is 2. Other notations are the same as those of Table 1.a.

Table 2.b : Equilibrium distribution of p^*; $(\beta=0.4;\ G^1)$

p(0)	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}	q_{11}	n^*
0.10	0	0	0	0	0	0	0	0	0	0	0	1000	5.53
0.20	0	0	0	0	0	0	0	0	0	0	0	1000	3.56
0.30	0	0	0	0	0	0	0	0	0	0	0	1000	2.67
0.40	0	0	0	0	0	0	0	0	0	0	0	1000	2.11
0.50	0	0	0	0	0	0	0	0	0	0	0	1000	1.97
0.60	0	0	0	0	0	0	0	0	0	0	0	1000	1.58
0.70	0	0	0	0	0	0	0	0	0	0	0	1000	1.18
0.80	0	0	0	0	0	0	0	0	0	0	0	1000	1.04
0.90	0	0	0	0	0	0	0	0	0	0	0	1000	1.00

Notations are the same as those of Table 2.a.

Table 2.c : Equilibrium distribution of p^*; (β=0.6; G^1)

p(0)	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}	q_{11}	n^*
0.10	0	0	0	0	0	0	0	0	0	0	0	1000	1
0.20	0	0	0	0	0	0	0	0	0	0	0	1000	1
0.30	0	0	0	0	0	0	0	0	0	0	0	1000	1
0.40	0	0	0	0	0	0	0	0	0	0	0	1000	1
0.50	0	0	0	0	0	0	0	0	0	0	0	1000	1
0.60	0	0	0	0	0	0	0	0	0	0	0	1000	1
0.70	0	0	0	0	0	0	0	0	0	0	0	1000	1
0.80	0	0	0	0	0	0	0	0	0	0	0	1000	1
0.90	0	0	0	0	0	0	0	0	0	0	0	1000	1

Notations are the same as those of Table 2.a.

The result of Simulation 2 is as follows. The incentive for the government to lie about her statistics is determined by the following two factors, first, the degree of public reliance on the government report (β), and second, the diversity of agents' initial expectations for the economic prospect $p(0)$. Generally speaking, the higher the β and the lower the absolute value of $(p(0) - 0.5)$ is, the stronger the incentive for the government to manipulate her statistics.

Before we explicate this result, let's be precise about what we mean by *incentive*, i.e., the *"gains"* for the government to lie. To do so, we assume that the goal of the government is to have an equilibrium where most people holds optimistic expectations for the economic prospect so that the popularity of the incumbent government can be secured. Without loss of generality, the target is set to be "more than 70% of the public having opitimistic expectations for the economic prospect", i.e., $p^* \geq 0.7$. We then compare the difference in the probability of achieving this target between $G^1(t)$ (false reports, Equation 4) and $G(t)$ (honest reports, Equation 3) given the coefficient β and p(0), and Table 3 shows all these differences under different values of p(0) and β.

In Table 3, those values outside the parentheses are the probabilities of reaching the target $(p^* > 0.7)$ when using G^1 report and those inside the parentheses are the probabilities when using G report. The difference between the value outside the parenthesis and the value inside the respective parenthesis can then serve as an indicator for the *"gains"* of using G^1 report. The larger the difference, the higher the gains. For example, consider the case when $p(0) = 0.1$ and $\beta = 0.4$, if $G(t)$ is used, then according to the second row of Table 1.c, the probability of reaching the target $p^* > 0.7$ is 0. But, if $G^1(t)$ is used, then from the second row of the Table 2.b, the probability of reaching the same target is increasing significantly to 100%. Hence, the probability for $G^1(t)$ to reach the target (p^*) is 100% more than that for $G(t)$. In this case, the gains of using $G^1(t)$ report is 100%; hence, the incentive to lie is extremely strong.

Table 3 : Intensity of Motivation to Use the G^1 rule; $\check{p}$

	$\beta=0.2$	$\beta=0.4$	$\beta=0.6$	average
p(0)=0.1	0.00 (0.00)	1.00(0.00)*	1.00(0.00)*	0.66
p(0)=0.2	0.01(0.00)*	1.00(0.00)*	1.00(0.00)*	0.67
p(0)=0.3	0.47(0.00)*	1.00(0.01)*	1.00(0.01)*	0.82
p(0)=0.4	0.98(0.00)*	1.00(0.10)*	1.00(0.11)*	0.92
p(0)=0.5	1.00(0.45)*	1.00(0.50)*	1.00(0.49)*	0.50
average	0.392	0.878	0.878	

Those values outside the parentheses are the probabilities of reaching the target ($p^* > 0.7$) when the the government use the G^1 report. Those values inside the parentheses are the probabilities of reaching the target ($p^* > 0.7$) when the the government use the G report. The "*" indicates that, at the statistical significance level 0.01, the difference between the outside and the inside values is significantly not equal to zero. [8].

The numbers appearing in the last row and the last column are the averages of these gains over different βs and different $p(0)$s. From the last row of Table 3, we can see that the incentive for the government to use $G^1(t)$ report will tend to increase when the degree of public reliance on the media increases. For instance, when $\beta=0.2$, the average gains is only 0.392; but when $\beta=0.4$, this indicator rises highly to 0.878. From the last column of Table 3, we can also see that the incentive for the government to use $G^1(t)$ will tend to increaes when the initial diversity of agents' expectations increases. For example, when p(0)=0.1, the average gains is only 0.66; but when p(0)=0.4, the indicator rises to 0.92. In conclusion, the government tends to lie when β is high and $p(0)$ is very close to 0.5.

5 Bayesian Learning Agents

In previous sections, we treat β as a constant. However, treating β as a constant means that, no matter how distorted the government report is, i.e., no matter what inconsistency there is between the statistics agents get by themselves and the statistics they receive from the government, agents' confidence in government statistics will remain the same. This essentially assumes that agents are not *adaptive* at all. Perhaps the more convincing way is to treat β as an endogenous variable which is affected by the trustworthiness of the government. If agents feel that the quality of government statistics is good, then they will raise their β, and vice versa.

Thus, in this section, we will introduce a learning model which can manifest such behaviour. It is called the *Bayesian Learning Algorithm*. Using this learning algorithm, we can represent the agent (i,j)'s reliance on government statistics by Equations (5)-(8).

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[8] The statistical test conducted in this Table 3, as well as those in Table 5,7,9, is based the asymptotic distribution implied by the Lindeberg-Levy Central Limit Theorem.

$$\beta_{ij}(t) = \omega_{ij}(t)\beta_{ij}(t-1) + k_{ij}(t)\Delta\beta_{ij}(t) \tag{5}$$

where $\omega_{ij}(t) + k_{ij}(t) = 1$.

$$\delta_{ij}(t) = \mid p_{ij}(t) - \frac{1 + G(t)}{2} \mid \tag{6}$$

$$\Delta\beta_{ij}(t) = \begin{cases} 0.4, & \text{if } 0 \le \delta_{ij}(t-1) \le 0.2, \\ 0.2, & \text{if } 0.2 \le \delta_{ij}(t-1) \le 0.4, \\ 0.0, & \text{if } 0.4 < \delta_{ij}(t-1) \le 0.6, \\ -0.2, & \text{if } 0.6 < \delta_{ij}(t-1) \le 0.8, \\ -0.4, & \text{if } 0.8 < \delta_{ij}(t-1), \end{cases} \tag{7}$$

$$\omega_{ij}(t) = \begin{cases} 0.9, & \text{if } 0.48 \le \beta_{ij}(t-1) \le 0.6, \\ 0.7, & \text{if } 0.36 \le \beta_{ij}(t-1) < 0.48, \\ 0.5, & \text{if } 0.24 \le \beta_{ij}(t-1) < 0.36, \\ 0.7, & \text{if } 0.12 \le \beta_{ij}(t-1) < 0.24, \\ 0.9, & \text{if } 0 \le \beta_{ij}(t-1) < 0.12, \end{cases} \tag{8}$$

Equation (5) is a typical representation of Bayesian learning. $k_{ij}(t)$ can be regarded as the *Kalman gain*. Equations (6) and (7) state that the credibility assigned to the government from sample observations is based on the discrepancy between what the government said and what agents saw. The greater the distance, the lower the credibility; the relation between distance and credibility is symmetric. Equation (8) is the algorithm to update the Kalman gain. Starting with a very low prior such as $\beta_{ij}(0) = 0$ or a very high prior such as $\beta_{ij}(0) = 0.6$, this learning algorithm acts as if the quality of the information is relatively poor (the noise in the information is relatively high); therefore, the weight assigned to any learning from that information is also very low.[9]

6   Simulation 3

After incorporating into our cellular automata the learning algorithm, represented by Equations (5) to (8), we continue to ask: *would the government have any incentives to manipulate official economic statistics?* If the answer is *yes*, then how strong is the motivation? To answer these questions, the system composed of Equations (1),(2),(4), (5) to (8) plus the following initial condition (9) was simulated.

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[9] This assumption is based on the intuition that to learn that someone you trust is actually lying to you is a very slow process in the beginning.

$$\beta_{ij}(0) = 0 \sim uniform[0, 0.5] \quad \forall i, j \tag{9}$$

Initial condition (9) says that while some people may start with strong confidence in the government, others may not, and these different degrees of initial confidence are uniformly distributed within [0,0.5]. Since the *initial configuration* of the cellular automata will affect the emerging equilibrium, we implemented 1000 simulations for each $p(0)$ $(p(0) = 0.1, 0.2,... 0.5.)$[10], and the results are listed in Table 4. For the purpose of making a comparison, we also simulated the *benchmark system* composed of Equations (1),(2),(3), and (5) to (8) and the results are given in Table 5.

When the p^*-equilibrium is achieved, we will have a $\beta_{ij}(t^*)$ for each (i,j), and the *general credibility* $\tilde{\beta}$ can be defined as:

$$\tilde{\beta}(t^*) = \frac{\sum_{i,j} \beta_{ij}(t^*)}{100} \tag{10}$$

We can estimate the expected value of $\tilde{\beta}(t^*)$, i.e., $E(\tilde{\beta}(t^*))$, by the sample mean,

$$\bar{\beta} = \frac{\sum_{k=1}^{1000} \tilde{\beta}_k(t^*)}{1000}, \tag{11}$$

where $\tilde{\beta}_k(t^*)$ is the value of k-th simulation of $\tilde{\beta}(t^*)$. The result is listed in the column of $\bar{\beta}$ in Tables 4 and 5. In addition, we also list the sample standard deviation in the column of σ_β.

Table 4: Equlibrium distribution of p^* and the credibility of monopolistic media $(\beta_{ij}(0) = 0 \sim$ uniform[0,0.5] $\forall$ i,j; G^1)

p(0)	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}	q_{11}	n^*	$\bar{\beta}$	σ_β
0.10	1000	0	0	0	0	0	0	0	0	0	0	0	2.06	0.00	0.00
0.20	965	18	15	2	0	0	0	0	0	0	0	0	4.11	0.00	0.01
0.30	395	64	302	157	59	14	8	1	0	0	0	0	9.60	0.03	0.05
0.40	1	1	8	31	90	162	215	192	161	100	12	27	9.77	0.21	0.11
0.50	0	0	0	0	0	0	1	17	42	189	58	693	7.74	0.36	0.05

q_j: the number of times of the p^* equilibrium which falls into the interval of $(\frac{i-1}{10}, \frac{i}{10})$ $(j = 1, ...9)$.

q_0: the number of times of the p^* equilibrium which falls into 0;

q_{10}: the number of times of the p^* equilibrium which falls into the interval of (0.9,1);

q_{11}: the number of times of the p^* equilibrium which falls into 1;

n^*: the average time needed for reaching the equilibrium in 1000 times of simulation;

the meaning of the p^* equilibrium is given in Definition 3. (See Section 2)

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[10] Recall that

$$p(t) = \frac{\#\{x_{ij}(t) = 1\}}{100}$$

Table 5: Equlibrium distribution of p^* and the credibility of monopolistic media ($\beta_{ij}(0) = 0 \sim$ uniform[0,0.5] $\forall$ i,j; G)

p(0)	q_0	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}	q_{11}	n^*	$\bar{\beta}$	σ_β
0.10	1000	0	0	0	0	0	0	0	0	0	0	0	1.22	0.38	0.00
0.20	1000	0	0	0	0	0	0	0	0	0	0	0	1.93	0.38	0.00
0.30	999	1	0	0	0	0	0	0	0	0	0	0	2.78	0.38	0.01
0.40	863	25	33	22	17	3	4	9	13	10	0	1	5.61	0.37	0.06
0.50	303	37	96	40	19	5	3	18	45	91	27	316	8.57	0.35	0.08

The meaning of all the notations are the same as those of Table 1.

Before we explicate the results above, let's again assume that the goal of the government is to have an equilibrium where most people have optimistic expectations for the economic prospect so that the popularity of the incumbent government can be secured. Without loss of generality, the target is set to be "at least 70% of the public having opitimistic expectations for the economic prospect", i.e., $p^* \geq 0.7$. We then compare the difference in the probability of achieving this target between $G^1(t)$ (false reports, Equation 4) and $G(t)$ (honest reports, Equation 3).

Table 6: Trade-off between performance and credibility (the advantage of G^1 relative to G)

	$\beta_{ij}(0) \sim$ Uniform[0,0.5]
p(0)=0.1	0.00 (−0.38*)
p(0)=0.2	0.00 (−0.38*)
p(0)=0.3	0.00 (−0.35*)
p(0)=0.4	0.28* (−0.16*)
p(0)=0.5	0.50* (0.01*)

Those values outside the parentheses are the differences in the probability of achieving the target between the G^1 and the G report;
Those values inside the parentheses are the differences in credibility $\bar{\beta}$ between the G^1 and the G report;
The "*" indicates that, at the statistical significance level 0.01, the value is significantly different from zero.

Those values outside the parentheses in Table 6 represent the increase in the probability of achieving the target ($p^* > 0.7$) if the government follows the G^1 report rather than the G report. The difference is taken from the comparison of the corresponding row in Tables 4 and 5. For example, when p(0)=0.5, then, according to the last row of Table 5, the probability of using the G function to reach the target ($p^* > 0.7$) is 0.48. Under the same situation, according to the last row of Table 4, the probability of using the G^1 function is 0.98. Thus, the increment is 0.50.

From the right half of Table 6, we can see that, in most of the cases, lying about economic statistics will do no good for the government. It will neither improve the economy by increasing the probability of achieving the prespecified target nor enhance the credibility of the government. Hence, if the public are very pessimistic or if they are not very optimistic ($p(0) = 0.1, 0.2, 0.3$), then there is little incentive for the government to lie. However, if the initial

condition of the economic situation is in the cloudy zone (p(0)=0.4), then there is a trade-off between the credibility $\bar{\beta}$ and the economic performance. In this case, the government can take the risk of sacrificing its credibility in exchange for a better economic performance. Furthermore, when the initial condition of the economic state is in the cloudy zone (p(0)=0.5), the government can not only improve the economic performance but in turn gain its credibility by lying about economic statistics. The economic intuition of these results has already been given at the very beginning of the paper.

7 Concluding Remarks

This paper applied the model of *evolutionary cellular automata* to analyzing the behaviour of the monopolistic media, usually the government, in announcing economic statistics. Based on the results of the simulations, we can see that there is a *tempting space* in which the government tends to manipulate economic statistics. Although this tempting space is constrained by the adaptive behaviour of learning agents, it will not, in general, disappear. Therefore, honesty is not always the best policy. An adaptive government should realize that *conditional honesty*, instead, is a better strategy.[11].

The intuition of this result can be stated as follows. From the viewpoint of agents, when the economy is in a cloudy zone, it is difficult (or more costly) for local Bayesian learning agents to detect simultaneously whether the government is telling the truth, so the optimistic news disseminated by the government has a better chance to reach a larger audience and to predominate over the pessimistic side before it gets stronger. On the other hand, the economy tends to be in a cloudy zone when some unidentified event just emerges and its possible impact on the economy is unclear. Without appropriate coordination, the market might be misled by unwanted speculations and hence might achieve an undesirable equilibrium among multiple equilibria. Therefore, in this situation, the government can coordinate the economy better by casting out those shadows and making sure that the economy is not affected by any psychological nuisances. One of the important results is that government has the tendency to postpone the announcement of bad news such as the economy being in recession. One of the future direction of this research is to test this implication.

Appendix: An Empirical Observation of the Dispute of the "Business Condition Monitoring Indicators" of Taiwan

The first important case of disputes over the Business Condition Monitoring Indicators (BCMI) in Taiwan took place in 1990. Since the beginning of the

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[11] Chen (1996) simulated the adaptive behaviour of governmnent and studied the patterns of "conditional honesty"

year, Taiwan's economic performance had been on the decline. The situation seemed to get even worse in June when the BCMI showed a *blue light*, indicating that the economy is in recession. It was the first blue light since the continuous prosperity that began in 1985.

People were thus extremely concerned and wondered what it would be like in July. Ironically, the Council for Economic Planning and Development (CEPD) published two different reports of the same investigation within one day[12]. The morning report indicated that the BCMI score was 19, but the evening report said that it was 17. The former was apparently more encouraging than the latter. But why was it that there were two different BCMI statistics for the same month issued within a day?

This drastic change of the BCMI report by the official CEPD confused the ordinary people and annoyed those businessmen who suffered from the recession. Some businessmen and the mass media criticized the government for producing a mirage of economic recovery to dodge its responsibility to pull the economy out of the mire. Others argued that the government was trying to encourage those pessimistic entrepreneurs to invest more by using the fake BCMI score. If this was true, then it means that the BCMI has become the instrument for spreading the politically- adjusted figures, rather than the indicators of real economic prospect.

The CEPD denied the accusation of any manipulation of the indicators and said that the key point for this confusion lay in the different indicators used for estimating money supply. Until June 1990, the CEPD had been using M_{1B}[13] as the definition of money supply. In July 1990, M_{1B} was replaced with M_2[14], which was 10% more than M_{1B}. However, on the evening of Aug. 28, the CEPD replaced M_2 back with the smaller M_{1B}. Hence the two different economic reports by the CEPD within one day. Since M_2 is larger than M_{1B} at the time, the morning report of the BCMI by the CEPD showed more encouraging prospects.

The CEPD official claimed that though M_2 is more stable than M_{1B} in business cycles, the M_{1B} is more sensitive to the economy and also consistent with the business cycle curve of the past. They emphasized that the inconsistency between the two BCMI reports was attributed to operational negligence and that no technical manipulation was intended to deceive the public.

On the other hand, the Central Bank of Taiwan, which was in charge of monetary policy, did not see eye to eye with the CEPD in regard to the use of M_{1B}. The Central Bank argued that the M_{1B} does not show the true situation of money supply and that it is an international trend to use a broader definition of money supply.

The scholars expressed different preferences for M_{1B} and M_2, and could

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[12] See *The United Daily*, 1990 August, 28.

[13] $M_{1B}=$ Currency + Demand Deposit

[14] $M_2= M1_B$+Time Deposits

not reach any consensus. As to the ordinary people, they had various opinions too. Some of them concluded that the official BCMI was not reliable because of low administrative efficiency; some people maintained that the CEPD tried to mislead investors on purpose. As a matter of fact, there were a lot of people, businessmen in particular, who only believed what they had experienced such as the company's profit rate, the amount of orders received,...etc.. They did not care much about the argument for a better definition of money supply; nor did they trust official economic reports. Rather, they believed more in their intuition based on personal information.

A year later, disputes over the BCMI caught public attention again . One dispute arose from the contrasting judgements for the economic prospect for September, 1991; another concerned the different ranges and methods of statistical estimation for October.

The CEPD published its September BCMI report of a steady growth for the preceding 3 months. Since continued growth usually reveals recovery from recession, the CEPD felt it justified to declare economic recovery from the recent recession. But, strangely enough, three later surveys contradicted the optimistic report by the CEPD[15].

The first survey which conflicted with the CEPD's BCMI was the *Survey of Firm Operation of Taiwan* by the CEPD itself. Instead of confirming the optimistic prospect of a steady recovery, this *Survey* revealed a deteriorating economy for the previous 4 months[16]. What's more amazing is that, according to a *Gallup poll survey*[17], 44.5% of the people didn't believe the CEPD's optimistic report of recovery.

Table A.1: Gallup Poll of Judgement on the CEPD's Report

	Judgement of CEPD's report	Proportion
1	Disbelieve	44.5%
2	Believe	36.8%
3	Do not know	18.3%

Table A.2: Survey of Judgement, Business Week (Taiwan)

	Judgement of CEPD's report	Proportion
1	Disbelieve	68.0%
2	Believe	10.7%
3	Other	11.3%

Almost half a month later, another survey of businessmen's judgement on the CEPD's report came up with an astonishingly high proportion of

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[15] CEPD ed., BCMI of Taiwan, Taipei:1991, Sep. and Oct..

[16] ibid; the sample of this survey is always 1000 firms.

[17] See the "Economy Daily", 29, October, 1991; the sample was 1074 persons who were older than 20.

disbelievers.[18]. In this survey, 68% of the businessmen did not believe that the economy was already on the way to recovery.

The surveys revealed to various degrees the skeptical attitude of the people towards the CEPD's report of economic recovery.

There are many explanations for the public's divergent opinion from the official CEPD's judgement. Some scholars pointed out that the BCMI's are a macro statistics, therefore it is not surprising that the macro statistics did not coincide with some micro or personal statistics. Other scholars argued that even the survey of a large sample size by the CEPD itself was not consistent with the BCMI report; maybe the problems lay in the CEPD.

One month later, the BCMI reported another steady growth. But another civil economic[19] report revealed continued recession for the previous five months. Although the latter focused its survey on the manufacturing industry, while the CEPD's survey is extended to all industries, their different approaches of survey were still ambiguous.

Reference

Chen, S. (1996), "The Learning and Coordination of Endogenous Beliefs: A Simulation Based on the Model of Evolutionary Cellular Automata," *Working Paper Series 9609*, Department of Economics, National Chengchi University.

Fischer, S. (1991), "Recent Developments in Macroeconomics", in A.J. Oswald (ed.), *Survey in Economics*, Blackwell.

Leeper (1991), "Consumer Attitudes and Business Cycles", *Federal Reserve Bank of Atlanta Working Paper Series*, 91-11.

Wolfram, S. (1984), "Universality and Compleity in Cellular Automata", *Physica D*, 10, January, 1-35.

Woodford (1988), "Self-Fulfilling Expectations and Fluctuations in Aggregate Demand", *UCLA Workshop Paper in Monetary Economics*.

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[18] See Business Week (Taiwan), 10, Nov. 1991; the sample size is smaller, since out of 401 members only 159 participated in this survey. As the survey is limited to the members of a businessmen's association, it only revealed the viewpoint of a small part of the businessmen.

[19] Cited from the *Economy Daily*, 28, Nov, 1991.