Empirical Puzzles or Aggregation Problems

- A View of Agent-based Model

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Traditionally, most literatures supposed that the interactions between heterogeneous individuals had relatively limited influence on explaining macroeconomic phenomena, hence they simplified the whole economy into sole representative agent or even its multiple. For recent decades, notwithstanding the representative agent model has remarkably progressed in its theorem completeness and mathematics algorithm, some empirical puzzles remains unsolved. Taking Hall(1978) ,the random walk of consumption model, as an example, there still are some debates in excess sensitivity. Therefore, in this paper, we desire to figure out two principal potential drawbacks of Hall's model as following: (1) the official consumption is often calculated according to the expenditure amounts, instead of total consumption, (2)If agents are heterogeneous and interactive, we can't use central limit theorem(CLT) rashly. In other words, the standard econometric procedures (e.g. cointegration, Granger-causality, impulse-response functions of structural VARs) may generate spurious evidence in aggregate equations. Nevertheless, agent-based model simulation could be a data-generation mechanism (DGM). Not only can it help us avoid using imperfect data but also help us examine the behavior of various econometric methods to see whether they actually well behave when the data is indeed the aggregation over interacting heterogeneous bounded rational individuals.

Keywords: permanent income hypothesis, excess sensitivity, aggregation problem

1 Introduction

For most economists, the most important purpose of constructing the representative agent macroeconomic model is providing a reasonable microfoundation for macroeconomic so that we can link the micro behavior and macro behavior in this way. However, the attempt of theoretical economists has been challenged by the empirical economists. The reason is that the empirical results of representative agent macroeconomics models are producing a series of empirical puzzles. In other words, the prediction of representative macroeconomic theory and empirical results are inconsistent. If we consider further questions, such as where empirical puzzles come from? We can get two possible speculations. First, the data itself is not perfect. In the real world, we are unable to investigate the behavior of every individual. Therefore, we cannot get the aggregate data of total individual behavior. In the last resort, the empirical economists were forced to use the estimated result as macroeconomic variables for their empirical works. Data errors may cause the inconsistencies between theory and empirical result. The second one is aggregation problem. What is aggregation problem? Suppose the economic system exist two people, say, A and B. The consumption function of A is $C_A = 0.8Y_A$ and the consumption function of B is $C_B = 0.4Y_B$. In general, we set $C = mY(m = \frac{0.8+0.4}{2})$ as the consumption function of the representative agent in the economic system. At the same time, it also said that the overall average consumption behavior in the system. Initially, Both A and B have \$100, meaning that aggregate income is \$200 and aggregate consumption is \$120(=\$80+\$40). At this time, the representative agent gets income \$100(=\$200/2) and consumes \$60(=\$120/2), so that m equals to 0.6. If we expand twice the representative agent, we can predict the aggregate income is \$200 and aggregate consumption is \$120(=0.6*200). Fortunately, the prediction of representative agent model is indifferent from the heterogeneous agent model. So far, so good- It is impossible that every day is a sunny day. For example, if the income of A is \$50 and the income of B is \$ 150 then we can get the consumption of A is \$40 and the consumption of B is \$60. Since aggregate income is unchanged(=\$200), the representative agent model predicts aggregate consumption will still be \$120=(\$0.6*200) but the correct answer of real aggregate consumption is \$100(=\$40+\$60). Clearly, the prediction of theoretical model is over-estimated. That said the representation model is not stable.

Under what circumstances will we be able to get a consistent representative agent model? According to Gorman(1953), if the heterogeneous agents in the economic system have the same marginal propensity to consume, the prediction of the representative agent model will be equivalent to the macro model. In such situation, aggregation problem does not exist. However, the strong condition is difficult to make all economists nod; see, for example, Friedman(1957), Branson(1972). They observed that the fraction of income saved increases with income. Hence, the marginal propensity to consume is decreasing with income. On the other hand, if we focus on the consumer behavior, the representative agent model is illusory. In Deaton's(1992) word, the representative agent knows too much and lives too long relative to reality. Therefore, once we recognize the economic system is composed of a group of heterogeneous agents, then the aggregation problem also have to be recognized when we use the representative agent model to predict macro behavior. If the series of empirical puzzles is caused by aggregation problem, it is clear that economists have to more seriously look at the existence of heterogeneity and the interactive behavior in the economic system. Fortunately, there are some economists noted that aggregation may produce dramatic differences between micro and macro behavior. For instance, Granger(1980), Trivedi(1985), Lippi(1988) and Lewbel(1994). However, the scope of those paper, as sated above, which are limited to the heterogeneous agents in the economic system act similar. This is a strange setting. For example, Keynesian believes that current consumption depends on current income but PIH(permanent income hypothesis) supporters believe that current consumption depends on permanent income. Obviously, their decision rules are quite different. We are not sure whether econometrics can help us deal with the aggregation problem for totally different behaviors. Another problem is that in complex economic systems, can econometrics help estimate the correct model of the specific agent? In addition to the above articles, Stocker(1982) and Hildenbrand and Kneip(2004) offered the other way to think about aggregation problem. They are not directly summing up the individual behavior but applying the characteristics of income distribution to macro level. However, we can argue what the rule to form the characteristics of income distribution is. Nevertheless, agent-based model simulation could be a data-generation mechanism (DGM). Not only can it help us avoid using imperfect data but also help us examine the performance of various econometric methods for aggregation problems to see whether they actually well behave when the data is indeed the aggregation over interacting heterogeneous bounded rational individuals.

As aggregation problem is a big-big question. Therefore, we start from a simplest case. We choose excess sensitivity as our first topic of study. Through the merger of Hall's life-cycle model and agent-based model to study that excess sensitivity is really an empirical puzzle or an aggregation problem. The paper is organized as follows. In section 2, we describe the empirical puzzle, excess sensitivity, and how economist deal with aggregation problem. Next, we present a version of standard Hall's model and the simulation model. In section 4, we simulate the simplest situation and present the result. Section 5 concludes.

2 Excess sensitivity and econometric approach

The background of excess sensitivity

In general, the highest proportion of national income is consumption. Therefore, the aggregate consumption has also become an important research for economists. Keynes(1936) proposed the general equilibrium theory had referred to the psychological Law. When people increase their income, the psychological mechanism will induce them to increase consumption but the increase of consumption will less the increase of income. Thus, the consumption function can be expressed as $C_t = \alpha + \beta Y_t$. However, Friedman(1957) created a macroeconomic model with microfundation. Economists call the theory as permanent income hypothesis. Permanent income hypothesis predicts that people will consume their permanent income(The expected income) rather than consume their current income. Base on permanent income hypothesis, the consumption function can be written as $C_t = y_t^p + u_t$. People will compute their average wealth (or permanent income) through their lifetime and consume their permanent income. Therefore, the period of consumption can be maintained at a stable level and produce Consumption Smoothing phenomenon. However, Lucas(1976) pulled the attention of the economists to the expectation of consumption levels. He pointed out that the relationship of past income and future expected income will be changed when policy changes or other the expectations of consumer changes. Lucas' critique inspired Hall(1978) to adapt the life-cycle permanent income framework under uncertainty by assuming that in forming expectations about future variables consumers use all information available in period t. In Hall's model, if assume that the utility function is quadratic form, the consumption will follow a random walk. In other words, besides current consumption, the other all information cannot help to predict the change in consumption. This result implies that Hall's model supports the permanent income hypothesis. Excess sensitivity is a puzzle which challenges the empirical validity of rational expectations permanent income hypothesis if aggregate consumption is to be treated as that of the representative agent. Flavin(1981) thought that current consumption cannot represent all current information. So he considered with changes in the past period as the information of current period, and the result showed that changes of income has a significant influence on consumption. The conclusion of the paper rejects the permanent income hypothesis and this phenomenon is known as excess sensitivity.

Is excess sensitivity a puzzle?

If the discovery of Flavin(1981) is caused the incomplete explanatory variable in Hall(1978),then excess sensitive is only an omitted variable problem rather than a puzzle. However, the economists found that the empirical results are quite different between household data and aggregate data. For example, Xu(1991) provides some evidence that the types of aggregation problem we are discussing here could have significant implications in empirical work. The economy in Xu's paper is an overlapping generation model in which 200 generations. Simulation results show that if consumers are not liquidity constrained, the consumption of individual level will follow a random walk process but the consumption of aggregation level will depend on lagged income. Goodfriend(1992) gives a striking example of the effect of aggregating information. He finds that individual consumption is a random walk, exactly as predicted by the Hall model. However, consumption is not a random walk but rather an AR(1) in the aggregation level. Attanasio and Weber(1995) get a similar result. In their simulations of overlapping generation models, the Euler equation does not necessarily hold at the aggregate level. They argue that this result is due to aggregation bias arising from the existence of finite lives and the lack of complete markets. Ostergaard, Sorensen and Yosha (2002) shows that state-level consumption exhibits excess sensitivity to lagged income to the same extent as U.S. aggregate data, but state-specific consumption exhibits substantially less sensitivity to lagged stated-specific income. At this point, excess sensitivity is not only an omitted variable problem but an empirical puzzle.

Aggregate or disaggregate?

Whether it is Friedman's permanent income hypothesis or the Hall's random walk model are starting from individual decision-makers and there is no reason to replace aggregate data on individual data. Aggregate the individual data directly may produce some challenges. For instance, even if every consumer has a strong computing power, but the rule of maximization may be different. Another example is the response of shocks on individual level may be different from aggregate level. Some economists think that aggregation is permitted and contribute efforts on the legality of aggregate. Gorman(1953) is the most important paper on consistent aggregation. The Gorman condition for consistent aggregation is that marginal change must be the same for all agents at all level of income. However, the Gorman condition is very stringent and incredibly implausible. Since Gorman(1953), there have been several papers providing additional conditions which will yield consistent aggregation. For example, Grossman and Shiller(1982) is the first paper to give the legality of the aggregate consumption which could be replaced by individual consumption. Stocker(1986) believes that when consumers do not have the same marginal propensity to consume will produce distributional bias when we use the aggregate data replace the individual data. He suggests that we should consider the distributional effect when we try to estimate the dynamic of macro behavior.

3 The model

3.1 Hall's model and permanent income hypothesis

Hall(1978) considered a representative consumer who maximizes the expected present value of his time separable utility function. The notation E_t denotes the expectation that is conditional on overall information during period t. T means that the representative agent can live T periods. The symbol δ refers to the time preference of the representative agent. Utility of the economic life is defined over consumption C_t and the utility is assumed to be strictly concave. Maximization of expected utility given by (1) is subject to the standard restriction (2). In equation (2), A_t is the financial wealth of the representative agent at the beginning of period t and r is the real interest rate. Hall(1978) assumed that the real interest rate is constant over time and it satisfy the condition $r \geq \delta$. Y_t refers to the labor income of the representative at time t. According to Hall's assumption, income is stochastic and the only source of uncertainty. Although income is random, the representative agent knows the value current income,y_t, when he decides how much to consume in current period.

$$(1)\ \ \mathrm{Max}\, E_t \sum_{i=0}^{T-t} (1+\delta)^{-i}\, u(C_{t+i})$$

$$(2)\ A_{t+1} = (1 + r)(A_t + Y_t - C_t)$$

The first order condition for maximizing (1) and subjecting to (2) implies the euler equation (3). This equation that implies only current consumption could help to predict future consumption. In a special case, the utility function is quadratic function, say, equation (4). Therefore, equation (3) becomes equation (5). At this time, consumption follows a random walk.

$$(3)\ \ E_t u'(C_{t+1}) = \left[\frac{1+\delta}{1+r}\right] u'(C_t)$$

$$(4)\ u(C_t) = -\frac{1}{2}(b - C_t)^2$$

$$(5)\ E_t C_{t+1} = C_t \ \text{ or }\ C_{t+1} = C_t + \epsilon_{t+1}$$

How does Hall perform a test of the permanent income hypothesis? He regresses C_{t+1} against $C_t, C_{t-1}, C_{t-2}, \ldots,$ equation (5) says that the coefficients of $C_{t-1}, C_{t-2}, \ldots,$ should be zero. The empirical result of Hall(1978) cannot reject the permanent income hypothesis.

3.2 The simulation design

The design of income uncertainty

The simulation model is based on Hall's life-cycle model but the agent living in the economic system could use simple heuristics, says, Keynesian rule and PIH rule, rather solve the underlying intertemporal optimization problem. We use the more general version of the life-cycle model(Carroll(1992)) with implicit borrowing constraints and both income and life-time uncertainty. Equation (6) denotes the income process. S_t is the survival status. If S_t equal to 1, the agent is alive at period t. If S_t equal to 0, the agent is dead at time t. The notation y_t refers to the income for economic life at period t. P_t is a long-term income component. We have to particularly note that the long-term income component is not exactly equal to the permanent income in traditional sense, but the literature usually refers to P_t as permanent income. Finally, we use V_t to express the agent which is employed or unemployed and would be determined by the first order Markov process. Here, for the simplest case, we assume the probability of zero-income is zero and the economic life will live forever. In other words, we let S_t and V_t equal to one. In this case, equation (6) will be reduced to $Y_t = P_t$.

$$(6)\ Y_t = S_t V_t P_t$$

Equation (7) refers to the behavior of permanent income. We follow a standard assumption of literatures and assume that the log-from income component itself is assumed to follow a random walk with drift. The notation G_t refers to rate of wage growth, it is exogenous and fixed. We set the rate of wage growth equals to 0.03. N_t represents a random variable which is from a specific normal distribution. The mean of the distribution is 0 and the standard deviation of N_t is σ. In particular to note that σ captures income uncertainty and we set σ equals to 0.03.

$$(7)\ P_t = G_t P_{t-1} N_t$$

The description of Keynesian rule

As the name implies this rule is based on the Keynesian consumption function. In the simplest case of our simulation, we assume that all Keynesian believers are *moonlite*. In other words, we are ruling out the minimum consumption for living and any saving, equation (8) will be reduced to $C_t = Y_t$.

$$(8)\ C_t = \alpha + \beta Y_t$$

The description of PIH rule

The permanent income rule is proposed by Friedman(1957). Friedman hypothesized that consumption is a function of permanent income which is defined as that constant flow which yields the same present value as an agent's expected present value of actual income. In Friedman's original work, agents use a weighted average of past income to compute permanent income. In the simplest case of this paper, we impose rational expectations about future income so that we can compute permanent income easily. Therefore, equation (9) is the identity where Y_t^p is permanent income of period t, A_t is current asset, and H_t is the present value of income which follows equation (10).

$$(9)\ \sum_{i=t}^{T} Y_t^p\,(1+r)^{t-i} = A_t + H_t$$

$$(10)\ H_t = Y_t + E[\sum_{i=t+1}^{T} Y_i\,(1+r)^{t-i})]$$

Since the consumption of the economic life is as a result of his permanent income, we can rearrange equation (9) and obtain the PIH decision rule. If we set the interest rate equal to zero then equation (10) will be reduce to equation (11).

$$(10)\ C_t = Y_t^p = \frac{r}{1+r}\frac{1}{1-(1+r)^{-(T-t+1)}}(A_t + H_t)$$

$$(11)\ C_t = Y_t^p = \frac{1}{T-t}(A_t + H_t)$$

Budget constraint

To simplify the model, we do not allow borrowing and lending but we allow consumer save for their own. So, if the expected consumption of permanent income consumers is greater than current wealth, the surplus will be saved. When the expected consumption of permanent income believer is less than his current wealth, his maximum consumption is limited to his current wealth and he has no choice to consume the limited level.

Three simulation examples

In this paper, we have done three simulation cases. The first one is all agents are the economic system and using PIH rule, and they have perfect information of their permanent income. The second example is 90 agents adopt PIH rule and 10 agents adopt Keynesian rule. Example three is the half agents use the PIH rule, the other half to use the Keynesian rule. We run the simulation system 20 times for each example. Each simulation evolves 100 periods and each period contains 100 agents.

4 The simulation results

Inconsistencies in individual and aggregate behavior

In our 60 simulation experiments, the consumption movements between agents are quite different. As shown in Figure 1, some consumers increase their consumption and some consumers decrease their consumption over time. We can see that consumption paths of consumers are different. However, the macro behaviors of 60 simulation results are quite consistent. Through the 60 simulation experiments, we can find that both aggregate consumption and aggregate income are increasing over time. In Figure 2, the dotted line refers to aggregate consumption and the solid line represents the aggregate income.

Figure 1 : Individual consumption behavior

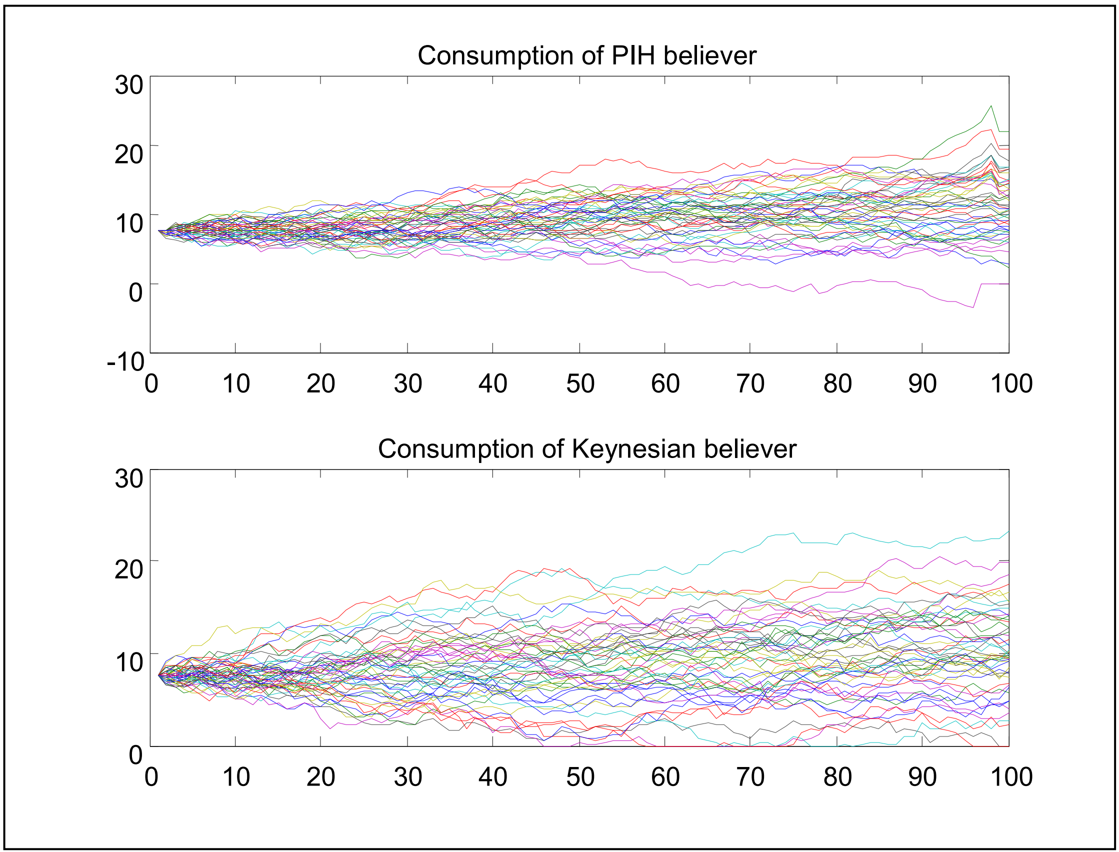
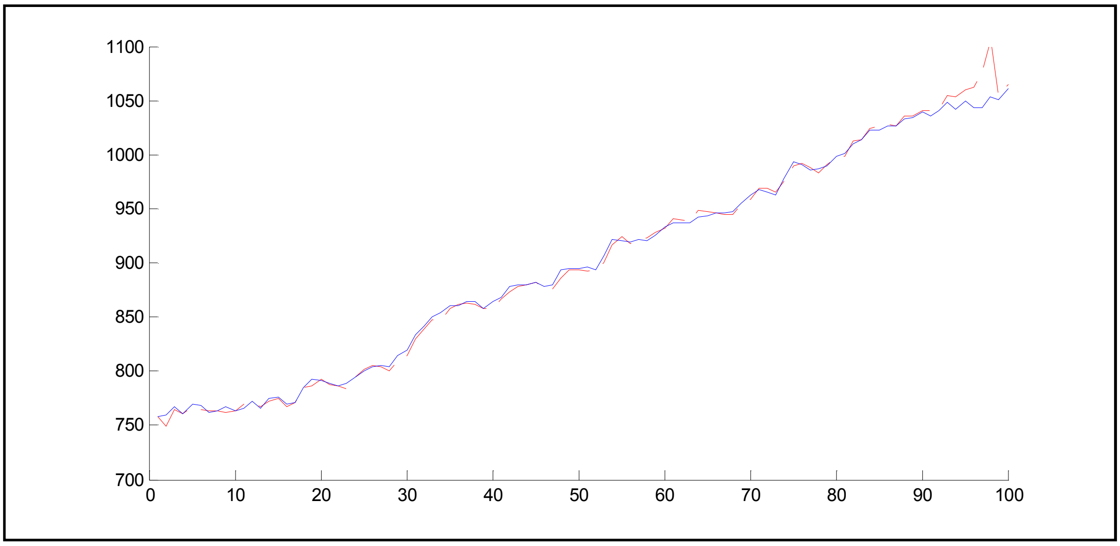


Figure 2 : Aggregate consumption behavior



Excess sensitivity testing

We use the simulation results to run the excess sensitivity test. The concept of excess sensitivity testing is from Flavin(1981). We regress ΔC_t on ΔY_t and test whether the coefficient of ΔY_t is zero. In example 1, the 100 agents are all PIH believers, the coefficients of ΔY_t are not significant. This means that when all agents are using PIH rule, the phenomenon, excess sensitivity, is not exist. However, when we add the Keynesian believers in the economy such as example 2 and example 3, we could get the excess sensitivity phenomenon. Table 1 shows that excess sensitivity estimation of our regressions. The symbol * indicates the change of income has a significant impact on the change of consumption. We can find that when ninety percent agents who use PIH rule in the economic system, some empirical results show that the excess sensitivity is significant but some are not. Nevertheless, when the proportion of Keynesian believer increases, say, example 3, we can see the excess sensitivity is significant in all simulation experiments. In addition to table 1, we also draw histograms of the estimated coefficients of excess sensitivity such as figure 3. In figure 3, we can see that excess sensitivity effect in example 3 is bigger than example 2. Therefore, we can get a summary from the above analysis. Absolutely, there is no excess sensitivity in example 1. However, if there are not only PIH believers in the economic system, we may get the excess sensitivity result. In Example 3, the power of Keynesian rule dominates the PIH rule, so their degrees of excess sensitivity are bigger than example 2.

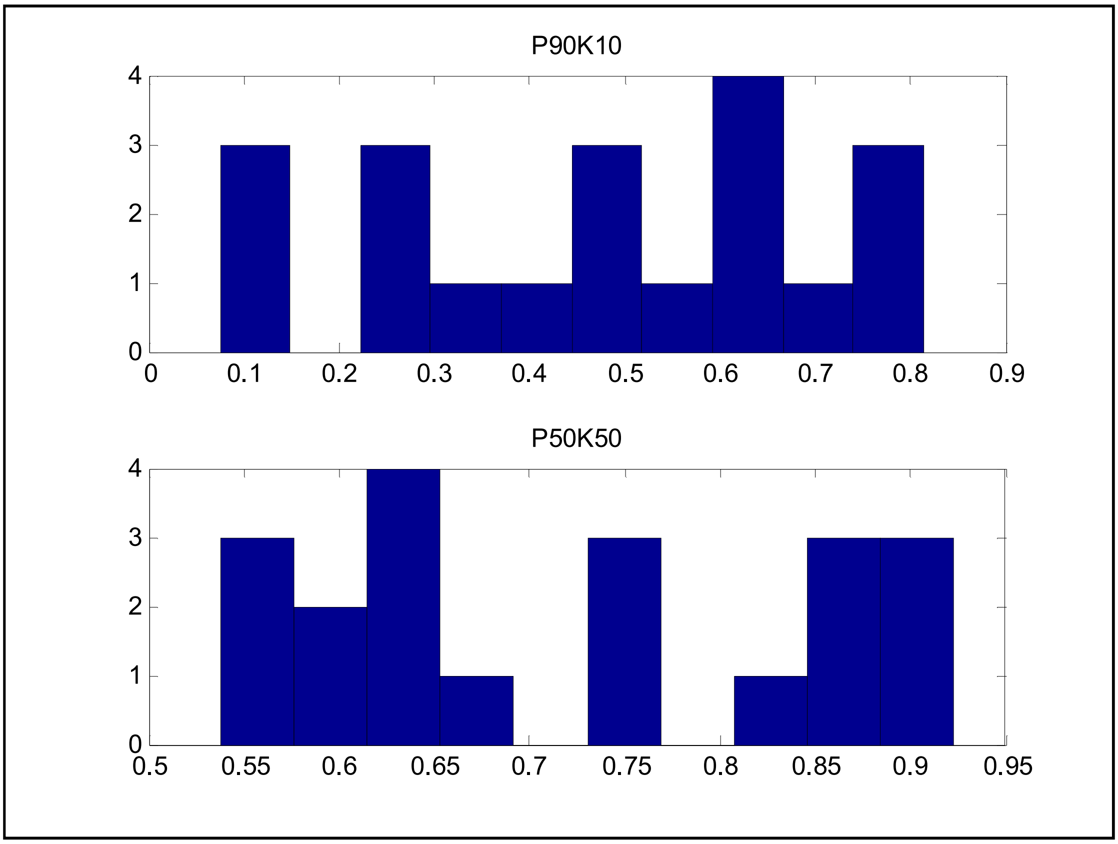
5 Conclusion

To tell the truth, this article has not been completed an agent based model. For example, we have not yet acceded to learning and interaction. However, we can see consumer behavior is key factor in excess sensitivity in this simple simulation. This caused a problem, when different consumers use different rule, can we add their behavior directly? It is still hard to say right now. But at least, we think that if we can have a better understanding of the individual behaviors, we can get a better prediction of macro behavior. For example, maybe excess sensitivity is not a puzzle but a product of the heterogeneity in the economic system.

Table 1: parameters estimation

Dependent variable : ΔC_t		
Independent variable ΔY_t	Example2 PIH:90 & Keynesian:10	Example3 PIH:50 & Keynesian:50
Simulation experiment 1	0.811958587(***)	0.578478867(***)
Simulation experiment 2	0.80240439(***)	0.63168506(***)
Simulation experiment 3	0.279009925	0.684501449(***)
Simulation experiment 4	0.632164358(***)	0.651611375(***)
Simulation experiment 5	0.142465737	0.745209426(***)
Simulation experiment 6	0.669437577(***)	0.594251539(***)
Simulation experiment 7	0.651962046(***)	0.863538302(***)
Simulation experiment 8	0.651962046(***)	0.863538302(***)
Simulation experiment 9	0.48393821(***)	0.808217726(***)
Simulation experiment 10	0.285433447	0.540127504(***)
Simulation experiment 11	0.813787881(***)	0.922949559(***)
Simulation experiment 12	0.442237397(***)	0.894868299(***)
Simulation experiment 13	0.078442607	0.619470152(***)
Simulation experiment 14	0.074772869	0.628528825(***)
Simulation experiment 15	0.339461527(***)	0.738737025(***)
Simulation experiment 16	0.241624236	0.739900166(***)
Simulation experiment 17	0.474385474(***)	0.53770889(***)
Simulation experiment 18	0.474385474(***)	0.53770889(***)
Simulation experiment 19	0.571387327(***)	0.866480258(***)
Simulation experiment 20	0.604210948(***)	0.900787968(***)

Figure 3: Histogram of example 2 and example3



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