Integrating the Level of Pension System in China—Insights from Predatory-Prey Model*

Yuhao.Li† Yifan.Yang ‡ Taixi.Xiao §

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†Barcelona Graduate School of Economics

‡Southwest Jiaotong University

§Maryland University,College Park

Abstract

In this paper, the author used a Predator-Prey Model to study how the pension reform in China(increasing the integrated level of pension system) can influence the relationship between governments and individuals. We separate governments as central government and local governments. The central government play a role of intelligent designer while the local governments play as predator and the firms are considered to be preys. We find that to increase the level of integrate of the pension system is not only necessary to build a solid social security, but also to accelerate the economy. While during the reform, a destabilization may happen and require extra attention.

Key words: Evolutionary game, Pension, Experiment

JEL Classification C73 H55

1 Introduction

China has now precociously evolved into an aging society. A significant amount of people remain financially vulnerable even when they are about to retire. As an important social financial support, the pension insurance is now facing a lot of revolutionary challenges. The problems of limited coverage, low level of protection, historical and hidden debt, unfairness of the system, and imperfection of legal system become even more prominent. Therefore, it is urgent to formulate a promising environment for the revolution and development of Chinas national pension scheme, by taking advantage of a low-cost labor market and the rise of Chinas current economy.

China had, until the late 1980s, maintained an urban- and enterprise-based PAYGO pension system covering mainly state owned enterprises and some large collective enterprises. This SOE-backed system was extremely fragmented and provided relative generous benefits to pensioners. Although it adequately served China planning economy for four decades, the conflict between enterprises social functions and their role as market players has become more and more acute as economic reforms hardened their budget constraints and forced many of them into financial distress.

China started to reform the SOE-based pension system in the late 1980s. In 1986, pooling was established on a limited basis across state enterprises at the municipal level, and an individual contribution scheme was implemented for contractual workers within the SOEs. Contributions began to be pooled but enterprises retained the responsibility for making pension payments. Since then, pooling was extended to workers in collectively owned enterprises in many cities.

The State Council decreed three important documents, the State Councils Document No. 33 (1991), No. 26 (1995), No.26 (1997), providing the guideline and the framework for the new pension system.

In 1991 the State Councils Document No. 33 required individual contributions by all workers, in addition to enterprise contributions, and initiated the experiment of individual accounts. This document also called for an expansion of pooling and the establishment of a three-tier system: a basic pension plan by mandatory enterprise and individual contributions, a supplementary pension plan funded by enterprises that in sound financial conditions, and individual savings.

In 1995, the State Council issued Document No. 26 which proposed two plans for the basic pension plan. The circular permitted municipal and prefecture governments to select a reform plan and provincial governments were given the right to approve the choice by lower level governments. This led to a highly fragmented system in which provincial and local governments and line-ministries selected various combinations of the two plans.

In 1997, the State Councils Document No. 26 decided on a unified multi-tier pension system combining social pooling with individual accounts. The system separates a basic pension plan (pillar 1, social pooling) which aims to set a floor of benefits,

from a supplementary pension plan (pillar 2, individual accounts) which is linked to accumulated contributions. According to the document, contributions to [Pillar 1] were to be pooled initially at the provincial level and later at the national level. Unfortunately, the 1997 system largely failed as funds in most individual accounts were "borrowed" to finance the benefits payments of the basic pension plan. As a result, the entire pension system remained effectively a PAYG system. Following the central guideline, the cities/counties all over the country instituted the new urban pension program featured by "the combination of social pooling with personal saving accounts." The new program gradually extended its coverage from employees of SOEs and rural collective enterprises to enterprises of other ownership, employment in the informal sector and self-employed.

In implementation, the pension rate for employee has floated around 8% and been unique among the national wide. In contrast, the counterpart for employers are various in different areas, different industries and different types of firms till now. It seems a bargaining process among some agents rather than a policy executing. Since 1997, the central government of China has published several guiding documents to control this process.

2 Literature Reviews

Most literatures regarding pension assume that the public pension system follow a Pay-As-You-Go(PAYG) principle and most of them put their attention to find out the optimal conditions for the participants. For example, Martin and Jeffery(2002)established a model with complete myopia, they assume individuals live two periods, in the first period people will go to work with full employment, earn income and pay tax(pension contribution), and in the next period individuals are going to retire and receive pension benefits. The size of the labor force grows at a constant rate n, i.e. $L_t = (1+n)\times L_{t-1}$. At time t, young individuals pay tax of $T_t = \theta\times w_t\times L_t$, the PAYG implies that the total taxes at time t is equal to the total benefit paid i.e. $T_t = B_t = b_t \times L_{t-1}$, that is $b_t = \theta \times w_t \times (1+n)$. Next they represent social utility as the combination of the sum of identical working individuals utilities as well as the sum of retirees utilities, i.e. $W_t = L_t \times u[(1-\theta)w_t] + L_{t-1}v[\theta w_t(1+n)$. he first order condition $\frac{dW_t}{d\theta}$ implies that $u' = v'$ which further implies $(1-\theta^*)w_t = \theta^* w_t(1+n)$ or $\theta^* = (2+n)^{-1}$. This means that the optimal ratio of benefits to the average wage is given by $\beta^* = b^*/w = (1+n)/(2+n)$.

Furthermore, Martin and Jeffery extended the previous model to allow individuals to save an amount s_t during the first period of the life. The first period consumption is therefore $C_{1,t} = (1-\theta)w_t - s_t$ while the second period is $C_(2,t) = s_t(1+\rho)+b_(t+1)$. They argue that the rationale for Social Security in this model is that individuals should do some precaution savings and can be represented by assuming that the individual may choose s_t to maximize $u[C_{1,t}] + \lambda v[C^a_{2,t+1}]$ where individuals anticipated retirement period consumption $C^a_{2,t+1} = s_t(1+\rho)+_{t+1}$, in which equation, α indicates that individual may anticipate less than full amount of benefit. Then the government select the Social Security tax level to maximize the ex

post utility:$maxW_t = L_t u[(1-\theta)w_t - s_t] + (1+n)^{-1} v[s_{t-1}(1+\rho) + b_t]$ subject to $b_t = \theta w_t(1+n)$ and to s_t being chose to maximize $u[C_{1,t} + \lambda v[C^a_{2.t+1}]$ subject to $C^a_{2,t+1} = s_t(1+\rho)+_{t+1}$.

If we specify the utility as $u[C_{i,t}] = lnC_{i,t}$ and $\alpha = 0$, the optimal tax rate would be:

$$\theta^* = \frac{(1+\lambda)(1+\gamma)-\lambda(1+\rho)(2+n)}{(1+\lambda)(1+\gamma)(2+n)-\lambda(1+\rho)(2+n)}$$

where λ is the degree of myopia, social security contributions are denoted by γ. Generally, we take the derivative of θ^* with respect to λ we can get $\frac{d\theta^*}{d\lambda} < 0$, which means an increase in myopia raises the optimal size of social security; we can also show that $\frac{d\theta^*}{d\gamma} > 0$, meaning an increase in social security contributions also increase the cost of such program and thus reduce the optimal size of that.

However, most literatures used representative individuals models to discuss their issues. When we apply individual level utility maximization to aggregate level utility maximization we always want a unique and stable equilibrium. However, one can only assure 3 properties that carry over from individual level to aggregate level, that is continuous, homogeneous degree of zero and Walras Law, and none of them can guarantee such desired equilibrium. It is useful to introduce some degree of heterogeneous.

Another reason is that public pension is less like other publicly provided good, it is less synchronized. Hu(1982) pointed out that under the pay-as-you-go system, false representation of preferences by current taxpayers could be brought about by the expectations of revoting opportunities.

Selfish young and middle-aged agents are not willing to sustain a social security system if they don not expect the system to remain in place when they are retired. Some early literature,such as Browning (1975) ,handle this question by simply assuming there exits an one-shot voting. Later contributions such as Hu (1982)have tried to amend these unrealistic features by considering that elections take place every period, and that previous policies can be changed at zero cost. Sjoblom (1985) extended Hammonds (1975) seminal idea of implicit contracts among successive generations of individuals to a repeat ed voting environment. The idea is simple. The voting game givers rise to a social contract, which implicitly defines a system of rewards and punishments. Young voters may agree to transfer resources to current retirees because they expect to be awarded with a corresponding transfer in their old age. If they fail to do such transfer, they will receive punishment of no pension in the future.

Now consider two period overlapping generations model to enforce such contracts. An action at time t for a young player is a tax rate, $a^y_t \in [0,1]$. Similarly we have the action of a old player's action, $a^o_t \in [0,1]$. At time t, the public history of the game is given by the sequence of tax rates:$h_t = (\tau_0, \tau_1, \tau_2, ...\tau_{t-1}) \in [0,1]^t$.Strategy for a young voter is a mapping from the history into action space, $\sigma^y_t = h_t \to [0,1]$,or an old player is $\sigma^o_t = h_t \to [0,1]$. In a majority voting game, the political outcome has to be preferred to any other outcome by a majority of voters. We assume

the young constitute a majority of the voters, thus, the political outcome is determined by the action of the young,$\tau_t = a_t^y$. For a given sequence of actions profiles, $(a_0^y, a_0^o, ..., a_t^y, a_t^o)$, and corresponding outcomes $(\tau_0^y, \tau_0^o, ..., \tau_t^y, \tau_t^o)$, the payoff function of a young voter at time t is a indirect utility function $v_t^y(\tau_t, \tau_{t+1})$. We use subgame perfection as equilibrium concept.

Consider any strategy profile $(\sigma_s^{y^*}, \sigma_s^{o^*})$ such that :

$$\sigma_s^{y^*} = \{^{\tau_s^*, if \tau_{s-i} = \tau_{s-i}^*}_{0, others}$$

and call $(v_s^*)_{s=t}^{\infty}$ the resulting payoffs for the young since only the young decide the desired equilibrium. The young will vote for v_s^* if the sequence of tax rates $(v_i^*)_{i=1}^{s-1}$ has been played, and to vote a zero tax rate otherwise. This strategy is an equilibrium if on one has an incentive to deviate it. Then the payoff from this equilibrium strategy is v_s^*. Thus if $v_s^* > v_s(0,0)$, a young agent will never deviate. Therefore, a strategy profile $(\sigma_s^{y^*}, \sigma_s^{o^*})$ is a subgame perfect if and only if $v_s^* > v_s(0,0)$.

However if we introduce game theory, this approach will generate a high degree of indeterminacy and will be lack of clear consensus on the equilibrium.

3 Facts about the pension system in China

It is very useful to first introduce some basic facts about the Chinese pension system before discussing our model and findings, since it is critical to make a clearer understanding why we choose such model.

Unlike any other industrial countries, the pension system in China is complex and changeable. In fact, there exist various kinds of pension systems, a national scale pension system specifically for civil servants, a very basic pension project for rural residents(New Corporation Medical System) and two pension programs for residents in urban area,one for those who have a job(Basic Endowment Insurance for the Urban Working Group) and one for those without a job or self-employed and yet lives in the city(Social Endowment Insurance for non-working Urban Residents). These pension programs are unrelated and unequally in terms of coverage and benefits. For example, the civil servants pension project settled a much higher level of benefit than rest of others, while the pension system aimed to rural residents can only guarantee a very basic need for retirees. These pension systems are usually financed by Local governments, employers and employees except for civil servants pension project and the rural residents pension program, these two are financed mainly by central government.

Since China changed her tax system from centralism to federalism, local governments are entitled to collect and modify a number of taxes including the contribution rate. The collected contribution is used to build a pension fund that is limited to local governments' jurisdiction. That is to say for most Chinese who lives in the urban does not enjoy a national pension coverage. Such institutional arrangement fits the reality of China in some degree, because China is popularity and not-equally-developed. However, a fragmentary system means, for example, a labour force from

Sichuan Province yet working in Shanghai can not access to Shanghai's pension project, thus hindering the mobility of labour force, which is become a more and more serious problem for Chinese economy growth.

Another obstacle that hinder the free movement of human resources is the so called dual-economy condition. More specifically, although even in urban areas there are kinds of pension plans, a more rapidly different is between the rural pension system and urban pension system. The older population in rural area did not be covered until 2003 by introducing the New Corporation Medical System(NCMS). And the NCMS is isolated by the urban plans.

4 The pension system from a evolutionary perspective

Before the authors develop the evolutionary institutionalist framework, it would be helpful to outline some nature of participants in the pension system. Since we mainly focus on the relationship between individuals and governments, we will not not discuss too much about the enterprises.

Firstly, we have to separate governments as central government and local governments and assume the current central government of China is not predator, that is because the central leaders possess a sufficiently encompassing interest in the wealth of the country as a whole. Olsons stationary bandit theory(Olson,1993,2000) suggests that an invisible hand may push a self-interested dictator to perform like an altruist. A roving bandit has no interest in economic growth, because the roving bandit will not be able to collect the residuals of the investment in the next period. Therefore, he will extract all but the subsistence wealth that his subjects manage to accumulate. In contrast, a stationary bandit has an encompassing interest in economic growth, since his regime will last long enough to claim through taxation the longer-term surpluses derived from pro-growth investment policies. China's one-party central government, in rule for 60 years, could safely be defined as such a growth-oriented authoritarian government.

Secondly the local governments in China are potential predators on all eligible individuals. By adjusting the beneficial level, the local governments can infect the movement of individuals,or in the other words to say, can consume the individuals. Provincial and local leaders not only hold considerable discretionary power, but also enjoy information advantages over the central leaders. Each provincial and local government official has his or her own attitude toward predation. Moreover, when there is any degree of central government control, an increase in the value of the prey is expected to raise the amount of predations.

Thirdly, individuals are potential prey.

With a standard setting of a predatorprey model, provincial and local officials are defined as predators and individuals as prey, we are ready to build a framework of Predator-Prey model. Evolutionary game theory has developed a rich literature

analyzing the predatorprey relationship. This is an endogenous relationship with a cycle of flows: 'higher prey population→more predator→lower density of prey→less predation→higher prey population'.The relevant literature began with the Lotka-Volterra predatorprey Model (L-V model,hereafter) The model is a pair of first-order, nonlinear differential equations. It is frequently used to describe the dynamics of biological systems in which two species interact, one a predator and one its prey. These interactions will create a cycle of flow as aforementioned. In general, The L-V model is a part of evolutionary game theory.The L-V model assumes that the prey population has an exponential growth rate in the absence of predators. Later studies (e.g.Rosenzweig and MacArthur 1963) R-M model, hereafter,have corrected this unreasonable assumption, and replaced it with more reasonable logistic growth assumption.

We follow Zhang's(2012) method, modify this R-M model by introducing central government as neutral and intelligent designer.

5 Predator-Prey model

With the assumptions made above, a framework of the R-M predator-prey model is developed.

$$\dot{X} = gX(1 - \frac{X}{K}) - \mu \frac{X}{S+X} T$$

$$\dot{T} = \delta \frac{X}{S+X} T - \gamma T$$

In these equations,

- X:the density of working individuals
  T:a measurement that describe the retirement burden of individuals. More specifically, this retirement burden is the gap between pension benefits and the disposable income before retirement.
  XT:interaction term, which indicates the encounter rate of a random prey with a random predator.
- The density of individuals grow at a natural rate $g > 0$, where$g$ depends on how heavy the beneficial level given. It is natural to assume a higher beneficial level results in a higher g.
- μ is the coefficient of predation rate. When a beneficial level is given to incumbent individuals, such rate will affect some individuals' decision on whether to stay in or leave current place. The higher μ is, the more significant this effect will be.
- δ is the measurement of the efficiency of managing pension funds. A smaller value means a higher level of management, since at the next period, the local government is able to cut individuals' retirement burden by distributing more benefits while maintain a constant fiscal income.

- γ is the measurement that describes the influence of the national integrated pension plan on the beneficial level of individuals. The higher integrated level of this national pension(the higher value of γ), the more benefits an individual will receive. The reason is straightforward, even the value of pension benefits is unchanged, one can cash in such benefits in the whole nation instead of in one specific city.
- K is the maximum just maintainable density of prey, beyond k, the prey population will be over-crowed.
- S is a factor that describe the diversity of retirement income sources.
- The central government moderates the predator-prey relationship by adjusting the values of parameters g, μ, γ and δ.

Much attentions should be paid to two functions in these equations. The first one describe the growth rate of prey. $gX(1-\frac{X}{K})$ is a logistic growth function, which implies the prey (individuals) growth can not continue indefinitely. It slows as the number of individuals approach the carrying capacity. The second function describes the diversity of retirement income and is expressed as $\frac{X}{S+X}$. When the diversity factor S is relatively small compare to the density of X, predators are proficient in predation. In our case, a small S means that the main income of individuals after retirement is financed by government pension.

Now let us examine some characteristics of these equations. At first, assume only the logistic growth $gX(1-\frac{X}{K})$ is taken into consideration, while the saturation function remains linear as μX. The prey locus(i.e.,$\frac{dX}{dt}=0$) has a negative slope, whereas the predator locus(i.e.,$\frac{dT}{dt}=0$) is a vertical line, as shown in figure 1. It has a stabilization effect.

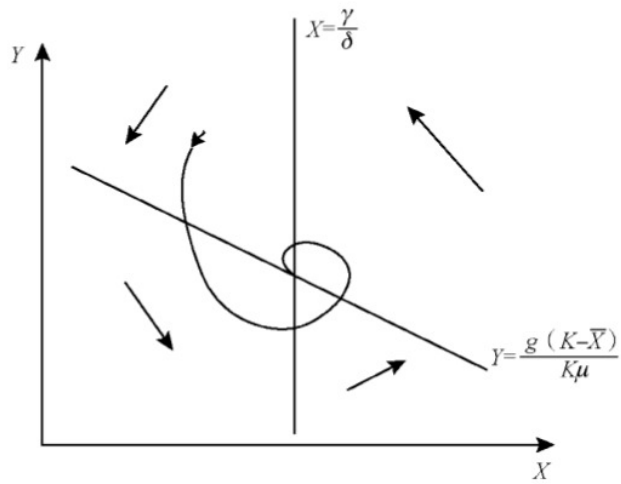

Figure 1: Logistic growth for the prey.

If now we hold the growth function as linear as gX but introduce the saturation

function $\frac{X}{S+X}$, then the prey locus(i.e.,$\frac{dX}{dt} = 0$) has a positive slope, whereas the predator locus(i.e.,$\frac{dT}{dt} = 0$),$X = \frac{\gamma S}{\delta - \gamma}$ remains a vertical line, as shown in figure 2. And now it has a destabilizing effect.

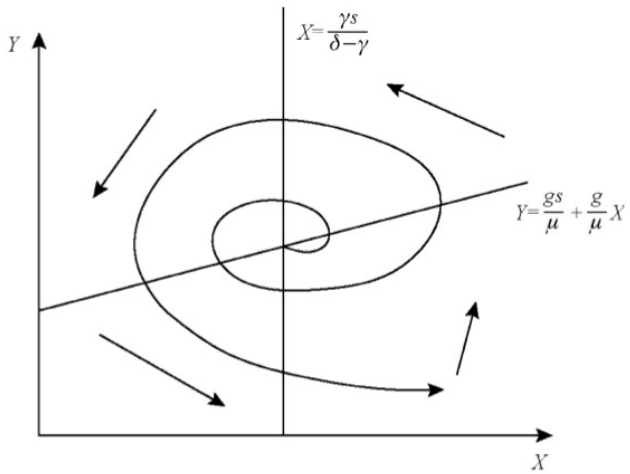

Figure 2: Take saturation into consideration

Finally let us take both logistic growth function and saturation function into consideration, which completes our model. It is clear that this model simultaneously contains both stabilizing and destabilizing effects as shown in figure 3 [1].

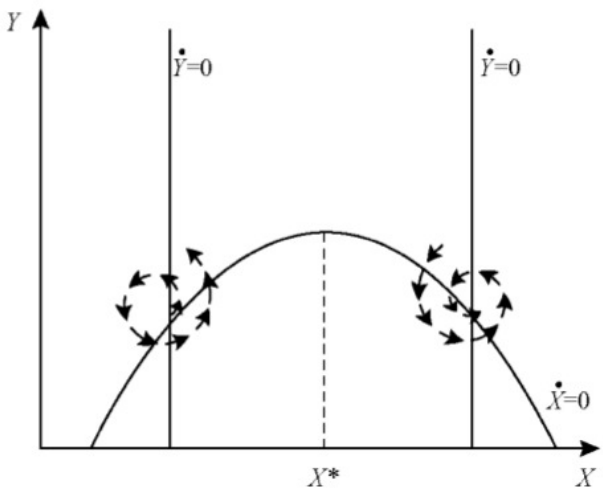

Figure 3: Take both functions into consideration

There are more that we can find in figure 3. Notice that although the predator

[1]figure 1-3 came from Zhang's(2012) paper

locus is the same as the what we described in figure 2, the prey locus is no longer a linear, it begins with positive slope while ends with negative slope when the prey is over-crowed. Therefore a hump will be formed. The $\frac{dX}{dt} = 0$ locus satisfies the equation $T = \frac{gK-gX}{K}\frac{S+X}{\mu}$. The slop of this prey locus is the partial derivative of T with respect to X: $\frac{dT}{dX} = \frac{g(K-S)}{K\mu} - 2gX$ with a critical value of $X^* = \frac{K-S}{2K\mu}$.

The stability of the system depends on whether the predator locus locates on the left side of critical value or right side of the critical value as shown in figure 3. A destabilized system leads to the extinction of prey.

We also run a simulation in computer, figure 4 shows the results. The Y-Coordinate represents how strong the beneficial level is while the X-Coordinate represents the density of the enterprises. The exact numbers in both coordinate means nothing but ordinal numbers. We begin with a contribution strong rate of 400 and a density rate of 600,as the motion shows,at first the density of firms grows to some point and then the local government begin to raise a significantly higher contribution rate and the density of enterprises gradually fall to some point where the government lay down the contribution rate significantly. This cycle continues as converging to one specific point.

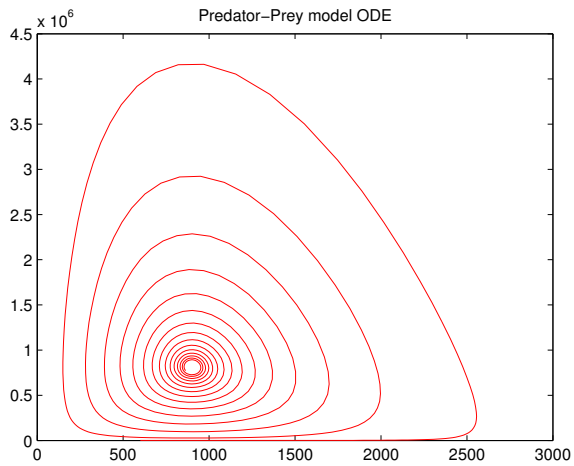

Figure 4: Predator-Prey model, with $K = 3000$,$S = 2000$,$g = 0.4$,$\mu = 0.001$,$\delta = 0.001$ and $\gamma = 0.9$

Before analysis the implications of the R-M model, we have to consider how would the retirement burden change if the central government decide to increase the overall level(i.e., create a national pension system while keep or not keep the local pension funds). Since China is diverse in terms of everything, development may various in different provinces. Some provinces are rich,such as Beijing, Shanghai and Guangdong,etc, while some are extremely poor such as Qinghai,Xinjiang and Tibetan,etc. We assume that the retirement burden of an uniform national pension should not be heavier than previous in rich provinces and should be lighter than previous in poor provinces.

The R-M Predator-Prey model could have various economy implications.

1. The R-M model indicate that an incremental increase of overall level is much more desirable than a radical increase of such level. Two parameters γ and δ largely determine the location of the predator locus. The movement of such locus has to be incremental rather than radical since the whole system is limited by the carrying capacity K. If the central government decide to raise the level of overall(i.e., increase the γ), while the market can not adjust its carrying capacity simultaneously to a correspond level, then it would lead to a destabilization situation. In figure 3, if the government decide to move the predator locus to the very right where the predator locus and prey locus have no intersection, then a policy failure will be incurred. Another implication related to the overall level is that a higher overall level(i.e., a higher value of γ) shifts the predator locus to the right, such shift will not only increase the number of prey(i.e.,the number of enterprises), but also will stabilize the economy.

2. A lower national retirement burden will attract more immigrants, which as a result, increase the carrying capacity(K). However, such increase may lead to a bad situation known as the "paradox of enrichment". Figure 5 describe such phenomenon. As the carrying capacity increases from K to $k^{'}$,so as the critical value. As a result of such increase of critical value, the predator locus may locate at the left side of the critical value, making the economy destabilized. To avoid such situation, the predator locus must move to the right. Mathematically there are two ways to do so, increase the S or decrease the δ. From a view of policy making, increasing the S means that the individuals has to finance relatively more from other sources rather than government pension benefit. One very possible way to do so is to encourage commercial insurance institutes to engage more aggressively,while decreasing the δ means to improve the efficient of managing the pension fund.

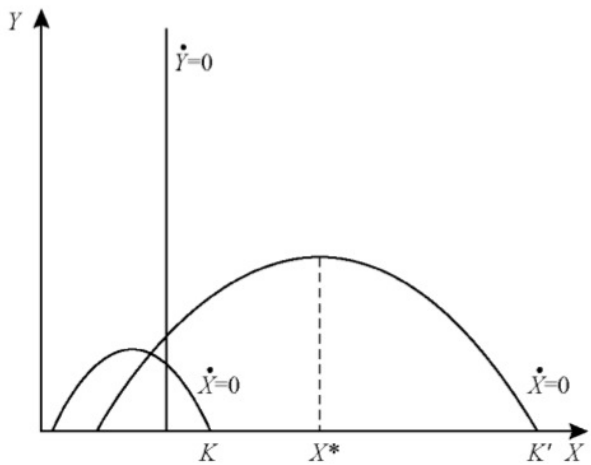

Figure 5: "paradox of enrichment"

3. The parameters g and μ do not have significant impact on economy stability, since the stability of the predatorprey interactions is largely dependent on the position of the vertical predator locus; a position which does not incorporate some economy environment indicators such as protect of private property rights that may affect g and μ. However, g and μ are still important determinants of the magnitudes of rotation trajectories. For example, considering only the logistic growth of prey, the slope of the prey curve is $\frac{-g}{K\mu}$. Therefore, better economic environment will increase the absolute slope of the prey curve, and thus will more quickly compress the rotating trajectory.

Now we make some simulations to test how parameters change could affect the economy. Particularly, we are interested in γ, δ and S. But first of all, let's check what would happen if nothing changed while the population aging continues.

Since X represents the density of working generation, a lower g reflects the population aging. As shown in figure 6, the economy is still stable, but the working population decrease dramatically, and the retirement burden also increase significantly. This is easily understood, a relatively small working generation has to feed a big percentage retirement generation thus a higher retirement burden is necessary to balance the account.

The increase of γ represents a higher level of integrating. The simulation(figure 7)

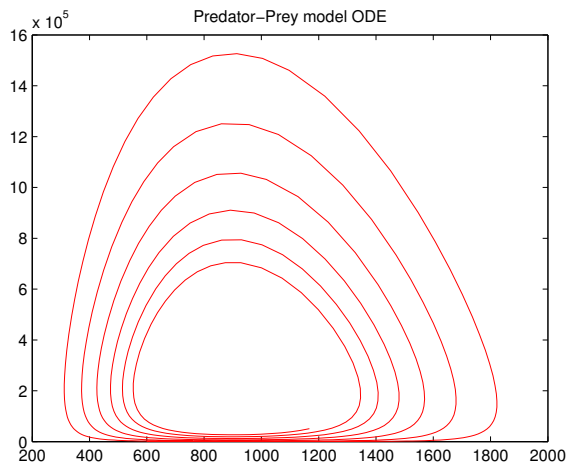

Figure 6: Holding other parameters status quo, $= 0.1g$

shows a faster speed to converge to the steady state, which could be translated to a higher economy growth. The reason, we believe, is that since a higher overall level makes labour force move more freely and reduce the potential cost. Besides, a higher overall level means a lower national retirement burden (especially for less develop areas), which accelerate the booming of the enterprise, and thus making economy growth faster. Another remarkable finding is that the variance of contribution rate setted by the local governments is much smaller compare to that of figure 4.

δ is the measurement of the efficiency of managing such contributions. A lower

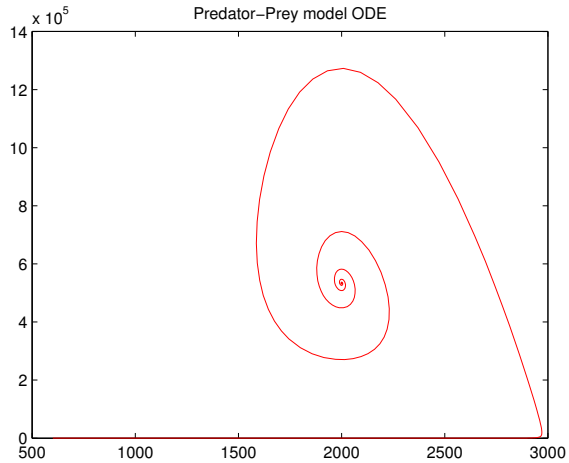

Figure 7: Holding other parameters status quo, $\gamma = 2.0$

value means a higher level of management, since at the next period, the local government require less contributions to maintain such balance. If we increase the value of δ (a lower efficiency,figure 8) and compare the result to that of figure 4, one can see that a higher management efficiency means faster converge rate, which as before, means a faster economy growth.

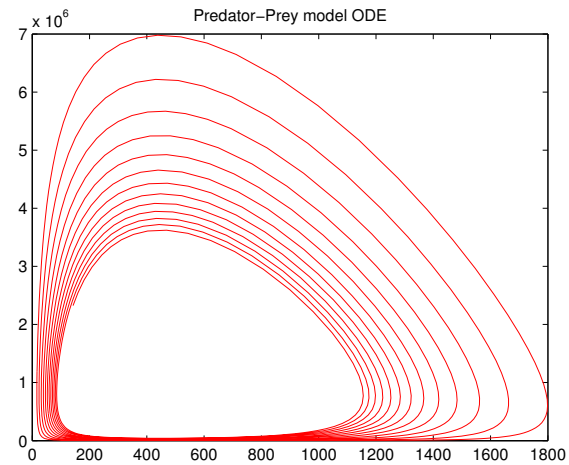

Figure 8: Holding other parameters status quo, $\delta = 0.002$

S represents other finance sources such as commercial pension projects and after retirement working income,etc rather than government pension benefits. As stated before, one doable option for central government to increase the value of S is to encourage commercial insurance companies to participate. The simulation results (figure 9) also show that such action could accelerate the economy growth. Such acceleration may happen because government pension benefits can not compensate too much due to its wide range and the ability of national fiscal support. That is if the income source after retirement is restricted, the consumption ability of pension-

ers is also restricted. By introducing commercial pension projects, one may have a higher income after the retirement and thus accelerate the economy by increasing consumption.

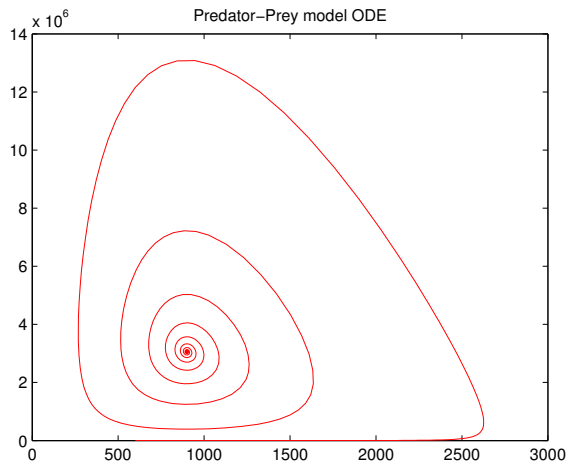

Figure 9: Holding other parameters status quo, $S = 10000$

6 Conclusion

In this paper, we introduce the evolutionary game theory into pension study by building a Predator-Prey model which is based on R-M modification. Through the analysis, we find that increase the level of integrating of pension system is necessary and will accelerate the economy growth. However the way to integrate the system should be cautioned, we find that a rapid integration would excess the carrying capacity of the market, which will lead to a policy failure. The best way to rise such level is to be incremental. Step by step the central government will build a national pension system while leaving local governments and individuals enough time to study and adjust to such change. During the period of changing, economy could be destabilization as a result of so called "paradox of enrichment". To avoid such paradox, two possible ways may be implemented. The first one is to increase the efficiency of managing the pension funds, another way is to reduce the dependency level of government pension plan, which means the individuals can finance retirement benefits not through public pension plan, but by investing commercial pension products. Another finding is that although a better economic environment does not directly influence the stability of the system, it could accelerate the speed to converge to a steady state.

By various simulations, we observed that a higher level of integrating and of efficiency can accelerate the economy growth. We also believe that if the central government collect more profits from SOEs, not only the pension system will be more stable by balancing the huge deficits, but also the economy will be more aggressively grow.

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