Dynamic Game of Economic Growth with Quasi-Geometric Discounting and Consumption Externalities

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Abstract

This paper introduces quasi-geometric discounting into an endogenous growth model of common capital accumulation with consumption externalities. We examine how the existence of present bias affects the economic growth rates and the welfare properties. In this paper we consider two equilibrium concept: non-cooperative Nash equilibrium (NNE) and cooperative equilibrium (CE). We show that the growth rate in a NNE can be higher than that in a CE if individuals strongly admire the consumption of others regardless of the magnitude of present bias. Contrary to a time-consistent case, we show that in the initial period, the welfare in a NNE can be higher than that in a CE. However, in the later periods, this relationship can be reversed due to the difference of the speed of capital accumulation.

Keywords: Dynamic game, Quasi-geometric discounting, Consumption externalities
JEL classification: C73, E21, Q21

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1 Introduction

For the last several decades, many researchers have been discussed the common capital accumulation in the context of static or dynamic game model. In this research field, it is well known that the lack of individuals' commitment to their future decisions or each individual's cooperativeness to intra-temporal decisions could cause an overconsumption problem (see, for example, Gordon (1954), Levhari and Mirman (1980)). Recently, some studies examine the relationship between the common capital accumulation and consumption externalities. This reflects on the fact that in many empirical and experimental papers the importance of consumption externalities in the real world is shown (see, for example, Easterlin (1995), Kagel et al. (1996), and Zizzo and Oswald (2001)). In the theoretical literature, for example, Hori and Shibata (2010) incorporates consumption externalities into a dynamic game model. They show that the growth rate in a no-commitment case can be higher than that in a commitment case due to consumption externalities. Long and Wang (2009) incorporates status-consciousness of consumption into a dynamic game model. They show that the consumption externalities worsen the overconsumption problem. However, one of the key features of this literature is that most of the foregoing studies employ time-consistent preference models. Many laboratory and field studies on inter-temporal decision (see, for example, Frederick et al. (2002) and DellaVigna (2009)) support the hypothesis that discounting is not exponential but hyperbolic, which means discounting between two future periods gets steeper as time goes by.

In this paper, we examine how the existence of a present bias could affect the economic growth and welfare properties. For this purpose, we introduce quasi-geometric discounting[1] and into a dynamic game model of endogenous growth with consumption externalities. We consider two equilibrium concept: non-cooperative Nash equilibrium (NNE) and cooperative equilibrium (CE). We have the following results. First, we show that there is a unique equilibrium in the NNE and CE. Second, we show that the growth rate in the NNE can be higher than that in the CE if preferences exhibit strong administration to other consumption. Third, we show that when a present bias is high, the growth rates in the NNE and CE become lower. Finally, we numerically show that contrary to a time-consistent case, in the initial period, the welfare in the NNE can be higher than that in the CE. However, in the later periods, this relationship can be reversed due to the difference of the speed of a common capital accumulation between the NNE and the CE.

To the best of our knowledge, except for Nowak (2006), there are no studies that investigate the effect of a present bias in the framework of the time-inconsistent preference's dynamic game model. Nowak (2006) extend Levhari and Mirman (1980) to the multigenerational framework. He assume that agents have time-inconsistent preferences. He investigates the effects of the time-inconsistent preferences on equilibrium. Contrary to our model, he adopts more general frameworks. He does not consider consumption externalities. Moreover, he does not examine welfare analysis.

The remainder of the paper is organized as follows. Section 2 sets up the dynamic game model with quasi-geometric discounting and consumption externalities. Section 3 characterizes the Non-cooperative Nash Equilibrium and the Cooperative Equilibrium and examines the effect of the present bias on the two equilibrium. Section 4 discusses the welfare properties. Our conclusions are summarized in Section 5.

2 Model

We consider the following dynamic game model. Following Krusell et al. (2002) and Hori and Shibata (2010), we introduce quasi-geometric discounting into the dynamic game model of common capital accumulation with consumption externalities. Contrary to Hori and Shibata (2010), time is discrete and is denoted by $t \in [0, \infty)$.

[1] This present-bias preferences was developed by Strotz (1956), and Phelps and Pollak (1968), and was rejuvenated by Laibson (1997).

2.1 Individuals

There exists N homogeneous individuals in an economy. We assume that in time 0 individual i's preference is given by the following utility function:

$$U_{i0} = u_{i0} + \beta \sum_{t=1}^{\infty} \delta^t u_{it}, \ \ i = 1, \cdots, N, \tag{1}$$

where u_{it} denotes the instantaneous utility function of individual i in period $t \geq 0$. Then, $\delta \in (0,1)$ represents the long-run discount factor and $\beta \in (0,1]$ represents present bias. When $\beta = 1$, individuals have time-consistent and geometric preferences: the discount factor is always δ. In contrast, when $0 < \beta < 1$, they face a problem of time-inconsistency: at time 0, the discount factor between time 1 and time 2, δ is different from at time 1, $\beta\delta$. These preferences are called quasi-geometric preferences.

Here, in the same manner as in Hori and Shibata (2010), the instantaneous utility function, u_{it} is specified as

$$u_{it} = \frac{\eta}{\eta - 1}(c_{it} \cdot (\bar{c}_{-it})^{-\alpha})^{1-\frac{1}{\eta}}, \ \ i = 1, \cdots, N, \tag{2}$$

where $\bar{c}_{-it} = \frac{1}{N-1}\sum_{j \neq i} c_{jt}, \alpha < 1, \eta > 0$ and $\eta \neq 1$. c_{it} is the consumption of individual i in period t and $\bar{c}_{-it}$ is the average level of consumption of the other individuals in period t. Each individual's consumption affects the utility level of the other individuals. The parameter α means the attitude against the consumption of the others and the magnitude of this external effects. According to Dupor and Liu (2003), we can define the consumption externalities as follows:

Definition 1 *We call the attitude of the consumption externality as (1) jealousy if* $\partial u_i / \partial \bar{c}_i < 0$ $(\alpha > 0)$ *and administration if* $\partial u_i / \partial \bar{c}_i > 0$ $(\alpha < 0)$*. (2) "keeping up the Joneses" (KUJ) if* $\partial^2 u_i / \partial c_i \partial \bar{c}_i > 0$ $(\alpha(1-\eta) > 0)$ *and "running away from the Joneses" (RAJ) if* $\partial^2 u_i / \partial c_i \partial \bar{c}_i < 0$ $(\alpha(1-\eta) < 0)$.

If the utility of an individual decreases as the average level of others' consumption increases, we can say that her preferences exhibit jealousy. In contrast, if the utility of an individual increases as the average level of others' consumption increases, we can say that her preferences exhibit administration.

If the marginal utility increases as the average level of others' consumption increases, we can say that her preferences exhibit KUJ, and if not,we can say that her preference exhibits RAJ. KUJ (RAJ) means that an individual wants (does not want) to consume in the same way as others.

2.2 Production

Each individual owns a physical capital and the other $N - 1$ individuals can access the capital. Therefore we can define this capital as the common capital such as oil or fish. N individuals produce a good by using the capital and divide it into their consumption and common capital accumulation. The capital is assumed to fully depreciate in one period. The production function takes the Ak technology and the dynamics of the capital becomes

$$k_{t+1} = Ak_t - \sum_{i=1}^{N} c_{it}. \tag{3}$$

3 Equilibrium

We first derive a non-cooperative Nash equilibrium (NNE) and a cooperative equilibrium (CE), respectively. We assume that in the following, the current individual cannot commit to the decisions of the future individuals. Moreover, we assume that the individual is aware of her preferences for change and makes the current decision taking this into account; that is, she is sophisticated. Next, we obtain the economic growth rates of the NNE and the CE and compare these rates. We show that regardless of present bias, only the existence of consumption externalities affects this relationship between the two growth rates.

3.1 Non-cooperative Nash Equilibrium

The current individual i maximizes the following taking the strategies, $h_j^n(k)$ ($j \neq i$) of the other individuals that include the strategies of the future selves of the other individuals. The individual also takes decisions of her own future individuals' decisions $h_i^n(k)$ as given.

$$V_{i0}^n(h_i^n(k), \overline{H}_{-i}^n(k)) = \max_{c_i} \left[\frac{\eta}{\eta - 1} (c_i \cdot (\overline{h}_{-i}(k))^{-\alpha})^{1-\frac{1}{\eta}} + \beta\delta V_i^n(k') \right], \tag{4}$$

subject to $k' = Ak - c_i - \sum_{j\neq i} h_j^n(k)$.
Here, function V is the value function of this problem. k' represents the capital of the next period, and $\overline{H}_{-i}^n(k) \equiv \{h_j^n(k)\}_{j\neq i}$. We denote the solution of this problem as $\widehat{h}_i^n(k)$. The value function $V_i^n(k)$ satisfies the following relationship:

$$V_i^n(k) = \frac{\eta}{\eta - 1} \left(h_i^n(k) \cdot \left[\frac{1}{N-1} \sum_{j\neq i} h_j^n(k) \right]^{-\alpha} \right)^{1-\frac{1}{\eta}} + \delta V_i^n(\widetilde{k}'), \tag{5}$$

where $\widetilde{k}' = Ak - \sum_{j=1}^N h_j^n(k)$.
We can define a NNE as follows:

Definition 2 *Strategies $\{h_i^{n*}(k)\}_{i=1}^{i=N}$ constitute a non-cooperative Nash equilibrium if and only if (1) each individual's strategy satisfies $\widehat{h}_i^n(k) = h_i^{n*}(k)$. (2) for every possible states, the following is satisfied: $V_{i0}^n(h_i^{n*}(k), \overline{H}_{-i}^{n*}(k)) \leq V_{i0}^n(h_i^n(k), \overline{H}_{-i}^{n*}(k))$ for all i where $\overline{H}_{-i}^{n*}(k) \equiv \{h_j^{n*}(k)\}_{j\neq i}$.*

The equilibrium can be solved by using a dynamic programming technique. The first order condition of becomes $(c_i)^{-\frac{1}{\eta}} \cdot (\overline{h}_{-i}^n(k))^{-\alpha(1-\frac{1}{\eta})} = \beta\delta V_i^{n\prime}(k')$.
We use the following guesses for the value function of individual i: $V_i^n(k) = E_i^n + F_i^n \psi^{-1} k^\psi$, where $\psi \equiv (1-\alpha)(1 - 1/\eta) < 1$. We further assume the symmetric equilibrium and linear strategies; that is, $h_i^n(k) = \gamma^n k$, $V_i^n(k) = V^n(k)$, $E_i^n = E^n$ and $F_i^n = F^n$. We can finally obtain

$$\gamma^n = \frac{(\beta\delta F^n)^{\frac{1}{\psi-1}} A}{1 + (\beta\delta F^n)^{\frac{1}{\psi-1}} N}. \tag{6}$$

Using (5) and the guess of the linear strategy, we obtain $F^n = \frac{\eta\psi}{\eta-1}\gamma^{n\psi} + \delta F^n(A - \gamma^n N)^\psi$.
Substituting (6) into this, we obtain

$$\left[\frac{1 + (\beta\delta F^n)^{\frac{1}{\psi-1}} N}{A} \right]^\psi = \frac{\eta\psi}{\eta - 1} (\beta\delta)^{\frac{\psi}{\psi-1}} F^{n\frac{1}{\psi-1}} + \delta. \tag{7}$$

From (6) and (7), we assume $x^n \equiv (F^n)^{\frac{1}{\psi-1}}$ and denote $\delta^\star \equiv g(0)$ when $f'(x^n) = g'(x^n)$ where $f(x^n)$ is the left hand side of (7) and $g(x^n)$ is the right hand side of (7). We can derive the following lemma:

Lemma 1 *There exists a unique non-cooperative Nash equilibrium if (1) $A^{-\psi} > \delta$ when $0 < \eta < 1$ or (2) $A^{-\psi} > \delta$ or $\delta = \delta^\star$ when $\eta > 1$ are satisfied.*

3.2 Cooperative Equilibrium

We next consider a CE. We assume that individuals maximize total sum of their utilities. The cooperative individuals take decisions of their own future decisions $h_i^c(k)$ as given. When the individuals cooperate, they maximize

$$V_0^c(k) = \max_{\{c_i\}_{i=1}^{i=N}} \left[\frac{1}{N} \sum_{i=1}^{N} \frac{\eta}{\eta - 1} (c_i \cdot (c_{-i})^{-\alpha})^{1-\frac{1}{\eta}} + \beta\delta V^c(k') \right], \tag{8}$$

subject to $k' = Ak - \sum_{j=1}^{N} c_j$.

We denote the solution of this problem as $\widehat{h}_i^c(k)$. The value function $V^c(k)$ satisfies the following relationship:

$$V^c(k) = \frac{1}{N} \sum_{i=1}^{N} \frac{\eta}{\eta - 1} \left(h_i^c(k) \cdot \left[\frac{1}{N-1} \sum_{j \neq i} h_j^c(k) \right]^{-\alpha} \right)^{1-\frac{1}{\eta}} + \delta V^c(\widetilde{k}'), \tag{9}$$

where $\widetilde{k}' = Ak - \sum_{j=1}^{N} h_j^c(k)$.

We can define a CE as follows:

Definition 3 *Strategies $\{h_i^{c*}(k)\}_{i=1}^{i=N}$ constitute a cooperative equilibrium if and only if their strategies satisfy $\widehat{h}_i^c(k) = h_i^{c*}(k)$.*

As in the case of the NNE, we derive the CE by using a dynamic programming technique. The first order condition of becomes $\frac{1}{N} \left[(c_i)^{-\frac{1}{\eta}} (\overline{c}_{-i})^{-\alpha(1-\frac{1}{\eta})} - \frac{1}{N-1} \sum_{j \neq i} (c_j)^{1-\frac{1}{\eta}} \alpha (\overline{c}_{-j})^{-\alpha(1-\frac{1}{\eta})-1} \right] = \beta\delta V^{c\prime}(k')$.

We use the following guess for the value function: $V_i(k) = E^c + F^c \psi^{-1} k^{\psi}$. We further assume the symmetric equilibrium and linear strategies; that is, $h_i(k) = \gamma^c k$. Due to these guesses, the first order condition becomes

$$\gamma^c = \frac{(\frac{N}{1-\alpha})^{\frac{1}{\psi-1}} (\beta\delta F^c)^{\frac{1}{\psi-1}} A}{1 + (\frac{N}{1-\alpha})^{\frac{1}{\psi-1}} (\beta\delta F^c)^{\frac{1}{\psi-1}} N}. \tag{10}$$

Substituting this into (9), we obtain $F^c = \frac{\eta\psi}{\eta-1} (\gamma^c)^{\psi} + \delta F^c (A - \gamma^c N)^{\psi}$.

Substituting (10) into this and rearranging, we obtain

$$\left[\frac{1 + (\frac{N}{1-\alpha})^{\frac{1}{\psi-1}} (\beta\delta F^c)^{\frac{1}{\psi-1}} N}{A} \right]^{\psi} = \left(\frac{N}{1-\alpha} \right)^{\frac{\psi}{\psi-1}} \frac{\eta\psi}{\eta - 1} (\beta\delta)^{\frac{\psi}{\psi-1}} (F^c)^{\frac{1}{\psi-1}} + \delta. \tag{11}$$

To satisfy the second order condition for this problem, we impose the following assumption.

Assumption 1 $\frac{1}{\eta} - \alpha \left\{ \alpha \left(1 - \frac{1}{\eta} \right) + 1 \right\} > 0$

From (10) and (11), we assume $x^c \equiv (F^c)^{\frac{1}{\psi-1}}$ and denote $\delta^{\star\star} \equiv m(0)$ when $k'(x^c) = m'(x^c)$ where $k(x^c)$ is the left hand side of (11) and $m(x^c)$ is the right hand side of (11). We can derive the following lemma:

Lemma 2 *Under Assumption 1, there exists a unique Cooperative Equilibrium if (1) $A^{-\psi} > \delta$ when $0 < \eta < 1$ or (2) $A^{-\psi} > \delta$ or $\delta = \delta^{\star\star}$ when $\eta > 1$ are satisfied.*

3.3 Comparison of the Growth Rates in Non-cooperative and Cooperative Equilibrium

From (3) and (6), the growth rate in the NNE is given by

$$G^n \equiv \frac{k^{n\prime}}{k^n} = A - N\gamma^n = \frac{A}{1 + (\beta\delta F^n)^{\frac{1}{\psi-1}} N}. \tag{12}$$

On the other hand, from (3) and (10), the growth rate in the CE is given by

$$G^c \equiv \frac{k^{c\prime}}{k^c} = A - N\gamma^c = \frac{A}{1 + \left(\frac{N}{1-\alpha}\right)^{\frac{1}{\psi-1}} (\beta\delta F^c)^{\frac{1}{\psi-1}} N}. \tag{13}$$

We can derive the following proposition:

Proposition 1 *$G^c \gtreqless G^n$ if and only if $N \gtreqless 1 - \alpha$*

The intuition of Proposition 1 is explained as follows. The presence of jealousy shows that when others increase their consumption, the utility of individuals decreases. This implies that the presence of jealousy has a effect raising their current consumption and reducing their contribution to the accumulation of common capital. On the other hand, the presence of administration shows that when others increase their consumption, their utility increases. this implies that the presence of administration has a effect reducing their current consumption and raising their contribution to the accumulation of common capital. In the CE, a planner can decide each agent's consumption simultaneously. From the intertemporal optimization, the total sum of each individual's consumption is unchanged if preferences change. This shows that the growth rate is also unchanged. On the other hand, in the NNE, individuals can decide their consumption taking into account that others' consumption is given. This shows that the total sum of their consumption and the growth rate are changed if preferences change. In that reason, the growth rate in the NNE becomes higher than that in the CE if the degree of administration is strong, that is, $N < 1 - \alpha$.

3.4 The Effect of the Present Bias on the Growth Rates

In this subsection we explore the effect of the present bias on the two growth rates. We can obtain the following proposition.

Proposition 2 *Both G^c and G^n are increasing in β.*

Proposition 2 indicates that the larger present bias each individual has (the smaller β is), the lower the two growth rates become. This implies that the rate of consumption, γ^i is decreasing in β. Intuitively, because of the large present bias, individuals prefer consume now to do later. Since the common capital accumulation becomes decrease, the growth rates also become decrease.

4 Welfare Analysis

In this section, we examine the welfare implications of the NNE and the CE in our dynamic game model. We first define the welfare evaluation function. Then, we compare the NNE and the CE in terms of resulting welfare.

4.1 Welfare evaluation function

we define the welfare evaluation function: $W^i(k_t) = \frac{\eta}{\eta-1}(\sigma^i k_t)^\psi \left[1 + \frac{\beta\delta(A-N\sigma^i)^\psi}{1-\delta(A-N\sigma^i)^\psi}\right]$, $i = n, c$.
This function is obtained by evaluating the individual's utility function when $c = \sigma^i k$ and $k' = (A - N\sigma^i)k$. Moreover, we can show the relationship between the welfare in period t and that in period 0 as follows: $W^i(k_t) = [(A - N\sigma^i)^\psi]^t W^i(k_0)$ $i = n, c$. The welfare in period t, $W^i(k_t)$ can divide these two parts: $W^i(k_0)$ (Initial Effect) and $[(A - N\sigma^i)^\psi]^t$ (Long run Effect).

4.2 Welfare comparison: time-consistent case

Before we compare the welfare in the NNE and the CE when $0 < \beta < 1$, we investigate the welfare comparison of the time-consistent case; that is, $\beta = 1$. Firstly, we consider the Initial Effect. In this time-consistent case, the CE coincides the social optimum. Therefore, when the initial capital stock of the two equilibrium are the same, $W^c(k_0) > W^n(k_0)$ for all k_0. Next, we consider the Long run Effect. Since this effect increases exponentially, the Long run Effect dominates the Initial Effect in the later period. From (12) and (13), the Long run Effect can rewrite as follows: $\left[(G^i)^{(1-\alpha)(1-\frac{1}{\eta})}\right]^t$, $i = n, c$.

From $\alpha < 1$, $\eta > 0$, when $\eta > 1$ (or $0 < \eta < 1$), the relationship between the Long run Effect and the growth rate (G^i) is negative (or positive). Intuitively, η is a parameter which means the intertemporal elasticity of substitution. When $0 < \eta < 1$, that is, the elasticity is low, individuals prefer a fluctuation of consumption which means larger growth rate. On the other hand, when $\eta > 1$, that is, the elasticity is high, they dislike the fluctuation of it and prefer smaller growth rate. Note that the relative magnitude of the two growth rates is derived from Proposition 1. We summarize the results as follows:

Lemma 3 *Suppose that the initial capital stock of NNE and CE are the same. Under the time-consistent case, we obtain the following:*

1. *When $N < 1 - \alpha$ and $0 < \eta < 1$, or $N > 1 - \alpha$ and $\eta > 1$, the welfare in CE is always higher than that of NNE.*

2. *When $N < 1 - \alpha$ and $\eta > 1$, or $N > 1 - \alpha$ and $0 < \eta < 1$, in the initial period, the welfare in CE is higher than that of NNE. However, in the later period, the welfare in NNE is higher than that of CE.*

4.3 Welfare comparison: time-inconsistent case

In this welfare comparison, depending on the magnitude of $N > 0$ and $\eta > 0$, there are four possible cases: Case (a) $N < 1 - \alpha$ and $0 < \eta < 1$, Case (b) $N > 1 - \alpha$ and $\eta > 1$, Case (c) $N < 1 - \alpha$ and $\eta > 1$, Case (d) $N > 1 - \alpha$ and $0 < \eta < 1$. Since these growth rates are not derived analytically and explicitly, we examine the welfare levels numerically.We adopt the following parameter: $N = 2$, $\delta = 0.9$, and $A = 1$. To satisfy Assumption 1, we set the following: in Case (a), $\alpha = -5$, and $\eta = 0.9$, in Case (b), $\alpha = -0.3$, and $\eta = 1.1$, in Case (c), $\alpha = -3$, and $\eta = 1.1$, in Case (d), $\alpha = 0.8$, and $\eta = 0.3$.

Figure 1-4 show the welfare in NNE and CE for $\beta = 1$, 0.7, or 0.3 in period 0 to 50. From these figures, we obtain the following results.

Numerical Result 1 *In the initial period, when β becomes decrease,*

1. *the welfare in the NNE becomes higher than that in the CE in Case (a) and (c)*

2. *the welfare in the CE becomes higher than that in the NNE in Case (b) and (d).*

In the later periods, when β becomes decrease,

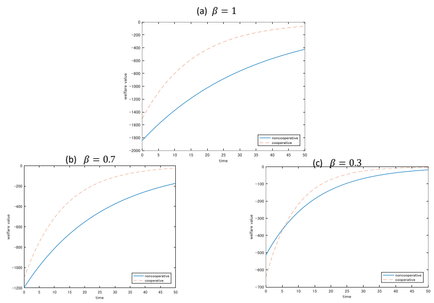

Figure 1: Welfare of Case (a)

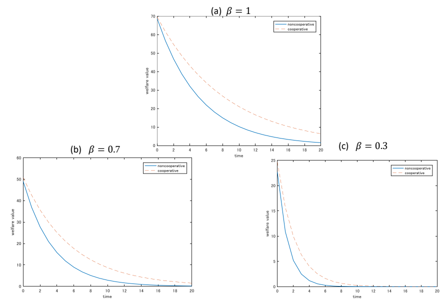

Figure 2: Welfare of Case (b)

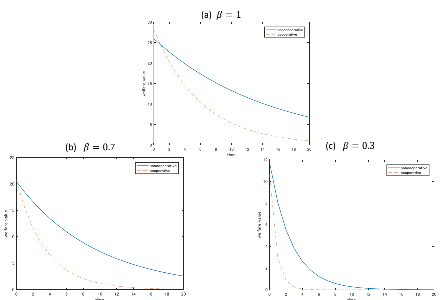

Figure 3: Welfare of Case (c)

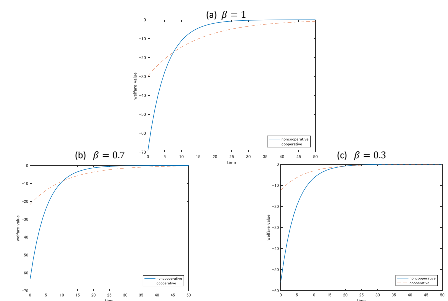

Figure 4: Welfare of Case (d)

1. *the welfare in the CE becomes higher than that in the NNE in Case (a) and (b)*
2. *the welfare in the NNE becomes higher than that in the CE in Case (c) and (d).*

Along the lines of discussions in section 4.1 and 4.2, there are two channels for a change in β to affect the welfare in the NNE and the CE. The first channel is via the Initial Effect. The second channel is via the Long run Effect.

First, we explain the intuition of the results in the later periods. In the periods the Long run Effect dominates the Initial Effect. The mechanism of this results is the same in the time-consistent case because from Proposition 1, β does not affect the relative magnitude of the growth rates of the NNE and the CE.

Next, we investigate the welfare in the initial period. The welfare in the NNE is higher than that in the CE in Case (a) and (c). The intuition of this result is explained as follows. In the initial period, only the Inital Effect affects the welfare. Let $\gamma^* \in (0,1)$ denotes the rate of consumption maximizing $W(k_0)$. γ^* is the solution when current individuals can commit their future decisions and cooperate each other. On the other hand, γ^c is the solution when they cannot commit their future decisions. Case (a) and (c) mean $N < 1 - \alpha$, that is, preferences exhibit strong administration to others. When individuals cannot commit, they take into account that they consume not so much in the future and do more now. Therefore, γ^c becomes higher than γ^* when β becomes decrease. As for γ^n, γ^n increases when β decreases from (13) and Proposition 2. As a result, γ^n becomes closer to γ^* than γ^c, that is, the welfare in the NNE becomes higher than that in the CE.

The welfare in the CE is higher than that in the NNE in Case (b) and (d). The intuition of this result is explained as follows. Case (b) and (d), that is, $N > 1 - \alpha$ can divide the two cases: (i) $0 > \alpha > 1 - N$, (ii) $\alpha > 0$. First, we consider the case of (i). This shows that preferences exhibit weak administration to others. As in Case (a) and (c), we obtain $\gamma^c > \gamma^*$. From Proposition 1, (12) and (13), we obtain $\gamma^n > \gamma^c$ when $N > 1 - \alpha$. From Proposition 2, (12) and (13), when β decreases, both γ^n and γ^c increase. Therefore, $\gamma^n > \gamma^c > \gamma^*$, that is, the welfare in the CE becomes higher than that in the NNE. Next, we consider the case of (ii). This shows that preferences exhibit jealousy to others. Contrary to Case (a) and (c), we obtain $\gamma^c < \gamma^*$. From Proposition 1, (12) and (13), we obtain $\gamma^n > \gamma^c$ when $N > 1 - \alpha$. Therefore, $\gamma^n > \gamma^* > \gamma^c$. From Proposition 2, (12) and (13), when β decreases, both γ^n and γ^c increase. As a result, γ^c becomes closer to γ^* than γ^n, that is, the welfare in the CE becomes higher than that in the NNE.

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