A Pareto Inefficient Path to Steady State in Recession

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Abstract

In this paper, I focus on the concept of Nash equilibrium of a Pareto inefficient path (NEPIP) to examine the nature of the transition path to steady state after a shock that generates a severe recession. Risk-averse and non-cooperative households strategically and rationally choose a NEPIP if a shock that widely shifts the steady state downwards occurs. Because NEPIPs are not Pareto efficient, an infinite number of transition paths can be NEPIPs, but a unique NEPIP is eventually selected from among many possible NEPIPs by households through a tug of war between their preference to avoid a worst-case scenario and the expected utility.

JEL Classification: D10, E21, E32

Keywords: Great Depression; Great Recession; Pareto inefficiency; Recession; Transition path

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1 INTRODUCTION

Severe recessions like the Great Recession and the Great Depression persist for several years or more (Temin, 1989; Martin et al., 2015; Hall, 2016; Fernald et al., 2017), probably because it takes time to reach the posterior steady state after a shock that changed the steady state and generated the severe recession. Although the cause of severe recessions has long been studied from various points of view (Temin, 1989; Hall, 2011; Eggertsson and Krugman, 2012; Mian and Sufi, 2012; Christiano et al., 2015; Martin et al., 2015; Guerrieri and Lorenzoni, 2017), no consensus about the cause has yet been reached. Because the cause remains unresolved, discussions about severe recessions have generally focused only on the cause, whereas the nature of the transition path to the posterior steady state during a severe recession has hardly been studied. Because the nature of the transition path will differ greatly, depending on the cause, researchers may have thought it would be fruitless to study the nature of the transition path in detail before knowing the cause.

Harashima (2016) showed a cause of the Great Recession that was based on the concept of a "Nash equilibrium of a Pareto inefficient path" (NEPIP). This concept is also shown in other papers by Harashima (2004, 2009, 2017, 2018a) and enables us to explain a mechanism for why a Pareto inefficient path is rationally chosen by households. If such a Pareto inefficient path is rationally chosen, phenomena like the Great Recession and Great Depression can be generated. An important feature of NEPIP is that it does not require a sudden huge technological regression or persisting rigidities in price adjustment processes to explain the generation of severe recessions.

In this paper, the nature of the transition path is examined on the basis of NEPIP. Risk-averse and non-cooperative households strategically and rationally choose a NEPIP if a shock that widely shifts the steady state downwards occurs. However, because NEPIP is not Pareto efficient—that is, because the constraint that Pareto efficiency should be kept does not exist—an infinite number of transition paths can be NEPIPs. The main purpose of this paper is to answer the question: How do households select a NEPIP from among many possible NEPIPs?

Households choose a NEPIP instead of the Pareto efficient saddle path strategically and rationally, by considering various possible options. A reason for not choosing the Pareto efficient saddle path in the first place is that a household dislikes, fears and avoids a worst-case scenario (hereafter, called "worst-case aversion"), and the selection of a NEPIP from among many possible NEPIPs will be also made considering this same household preference. In this paper, I show that households that possess worst-case aversion eventually select a unique NEPIP by calculating optimality on the basis of (1) the expected utility from consumption and (2) the expected probability that the foremost household (the household that first makes a decision) will be followed by all the other households.

As Harashima (2018b, 2019) showed, the NEPIP phenomenon can be equivalently explained on the basis of the concept of the MDC (maximum degree of comfortability)-based procedure. However, in this paper, I examine the nature of NEPIP on the basis of the model under the RTP (rate of time preference)-based procedure shown by Harashima (2004, 2009, 2017, 2018a).

2 NASH EQUILIBRIUM OF A PARETO INEFFICIENT PATH (NEPIP)

The mechanism and nature of NEPIP shown by Harashima (2004, 2009, 2017, 2018a) are briefly explained in this section.

2.1 The model

Households are assumed to be non-cooperative, risk averse, and infinitely living. They are also assumed to be identical in the sense that their preferences, labor incomes, and initial financial assets are identical. In addition, there is assumed to be a sufficiently large number of them. Each household maximizes its expected utility

$$E\int_0^\infty u(c_t)\exp(-\theta t)dt$$

subject to

$$\frac{dk_t}{dt} = f'(A, k_t) - c_t$$

where c_t, k_t, and y_t are consumption, capital, and production per capita in period t, respectively; A is technology; θ (> 0) is the rate of time preference (RTP); u is the utility function; $y_t = f(A, k_t)$ is the production function; and E is the expectation operator.

Suppose that there is a shock that makes the RTP of a household shift upward (i.e., increase) in period $t = 0$. After the shock, the steady state is changed from the prior (original) one to the posterior one. There are two options for each household with regard to consumption just after the shock. The first is a jump option **J**, in which a household's consumption jumps upwards and then proceeds on the posterior Pareto efficient saddle path to the posterior steady state. The second is a non-jump option **NJ**, in which a household’s consumption does not jump but instead gradually decreases from the prior steady state to the posterior steady state. This transition path is not Pareto efficient. The household that chose the **NJ** option reaches the posterior steady state in period s ($\geq$0). The difference in consumption between the two options in period t is b_t ($\geq$ 0). The existence of b_t indicates that unutilized resources and excess capital exist, and they have to be somehow eliminated.

The probability that households choose option **NJ** will not necessarily be low because option **J** requires a discontinuous large and sudden increase in consumption, but risk-averse households intrinsically dislike this type of discontinuous change in consumption and want to smooth the stream of consumption. The expected utility of a household after the shock depends on whether the household chooses option **J** or **NJ**. Let **Jalone** indicate that a household chooses the **J** option but other households choose the **NJ** option, **NJalone** indicate that the household chooses the **NJ** option but other households choose the **J** option, **Jtogether** indicate that all households choose the **J** option, and **NJtogether** indicate that all households choose the **NJ** option. Let p ($0 \leq p \leq 1$) be the subjective probability of a household that the other households choose the **J** option. With p, the expected utility of the household when it chooses option **J** is

$$E(J) = pE(Jtogether) + (1-p)E(Jalone) ,$$

and when it chooses option NJ is

$$E(NJ) = pE(NJalone) + (1-p)E(NJtogether) ,$$

where $E(Jalone)$, $E(NJalone)$, $E(Jtogether)$, and $E(NJtogether)$ are the expected utilities of the household when choosing **Jalone**, **NJalone**, **Jtogether**, and **NJtogether**, respectively. A household determines whether to choose option **J** or **NJ** by strategically considering other households’ choices.

2.2 The existence of NEPIP

Harashima (2009, 2018a) proved that, under reasonable conditions, there is a p^* ($0 \leq p^* \leq 1$) such that if $p = p^*$, $E(J) - E(NJ) = 0$, and if $p < p^*$, $E(J) - E(NJ) < 0$. That is, it is possible that a Pareto inefficient path (i.e., a NEPIP) can be rationally chosen by households.

Suppose that there are $H (\in N)$ identical households in the economy and H is sufficiently large. Households’ strategic choices between options **J** and **NJ** are well described by a H-dimensional symmetric mixed strategy game. Let q_η ($0 \leq q_\eta \leq 1$) be the probability that a household $\eta (\in N)$ chooses option **J**. Harashima (2009, 2018a) showed that strategy profiles

$$(q_1, q_2, \ldots, q_H) = \{(1,1,\ldots,1), (p^*, p^*, \ldots, p^*), (0,0,\ldots,0)\}$$

are Nash equilibria of this game.

2.3 The preference of worst-case aversion

As shown by Harashima (2009, 2018a), refinements of the Nash equilibrium are required to determine which Nash equilibrium, **NJtogether** (0,0,…,0) or **Jtogether** (1,1,…,1), is dominant, and these refinements necessitate additional criteria. If households are worst-case averse in the sense that they prefer to avoid options that include the worst-case scenario when its probability is not known, they suppose a very low p and select the **NJtogether** (0,0,…,0) equilibrium (i.e., a NEPIP), because **Jtogether** is the best choice in the sense of the amount of payoff, followed by **NJalone** and **NJtogether**, whereas **Jalone** is the worst. The outcomes of choosing option **J** are more dispersed than those of choosing option **NJ**. If households are worst-case averse in the above-mentioned sense, a household will prefer option **NJ** that does not include the worst-case scenario **Jalone**, because it fears the worst-case scenario that, after the shock, it alone will substantially increase consumption while the other households will substantially decrease consumption. This behavior is rational because it is consistent with the household's preference.

2.4 NEPIP and severe recessions

Because NEPIP is Pareto inefficient and excess capital and b_t exist, unutilized resources are successively generated and eliminated—that is, a recession is generated. In this situation, as Harashima (2012) showed, the unemployment rate rises by frictions in the job search and matching process. Note that Harashima (2014b) also showed the generation mechanism of the shock on RTP. The main underlying factor that generates this shock is that households need to generate an expected RTP under sustainable heterogeneity, as shown by Harashima (2014a, 2014b).

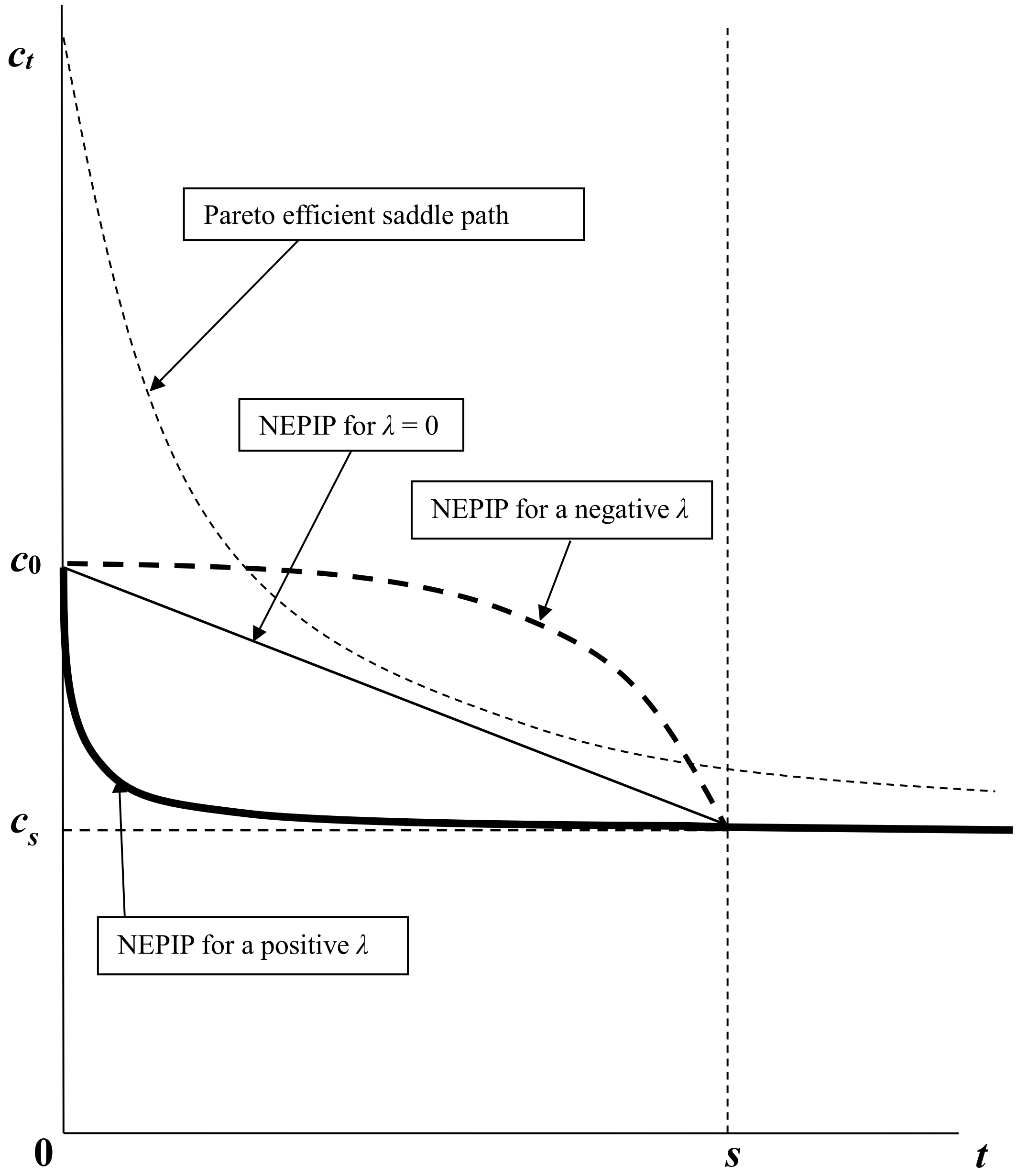
3 SELECTION OF A NEPIP

3.1 Possible NEPIPs

Because NEPIPs are Pareto inefficient, an infinite number of possible ones can exist. On the other hand, it is highly likely that a NEPIP will not be a complex winding path but rather a simple monotonously decreasing path from the prior steady state to the posterior one, because risk-averse households dislike discontinuous change in consumption and prefer to smooth it.

Let λ be the value that determines the shape of a simple monotonously decreasing path from the prior steady state to the path of the posterior one, such that if $\lambda > 0$, consumption declines to greater extent in the early periods and then gradually approaches the level at the posterior steady state; if $\lambda = 0$, it declines in a straight line to posterior steady state consumption; and if $\lambda < 0$, it declines a smaller amount in the early periods and more as time passes. Figure 1 shows the shapes of NEPIPs for a positive, zero, and negative λ, as well as the likely shape of the Pareto efficient saddle path.

Figure 1: NEPIP paths



3.2 Features of NEPIP

3.2.1 Expected utility

Figure 1 indicates that, as the value of λ increases, consumption decreases in any period before s and therefore the expected utility decreases. Hence, as λ increases, households will be more hesitant to choose a NEPIP. Because all identical households equally become more hesitant and they all are aware of this tendency, they will equally suppose a higher p if λ increases from the point of view of expected utility.

3.2.2 Worst-case aversion

Since all households are identical and possess the preference of worst-case aversion, as discussed in Section 2.3, all households will equally suppose that they all prefer option **NJ** that does not include the worst-case scenario **Jalone**; therefore, all of them will suppose a low p and select the **NJtogether** (0,0,…,0) equilibrium, which is a NEPIP.

As λ increases, the NEPIP deviates more from the Pareto efficient saddle path (option **J**), and the worst-case scenario **Jalone** becomes even worse. Hence, as λ increases, households will have a greater preference for option **NJ** that does not include the worst-case scenario **Jalone**. Therefore, as λ increases, households will equally suppose a lower p from the point of view of worst-case aversion.

3.2.3 The foremost household and followers

Even though all households are identical, as assumed in Section 2.1, they behave strategically by considering and expecting the other households' possible actions and outcomes. Therefore, the choice of transition path after the shock may not necessarily be made simultaneously by all households. A household may wait to make its decision until observing other households' decisions, where a decision here means choosing of a value of λ. However, at the same time, households cannot postpone decisions for a long period—they need to make a decision relatively soon after the shock. While each household is considering the others' possible actions, a very small exogenous factor that is unrelated to preferences and heterogeneous to households will push one of the households forward. That is, a household (possibly even by accident) makes a decision (i.e., chooses a value of λ) and exhibits its decision to other households before any other household does. I call this household the "foremost household."

All of the other households will make decisions by considering and evaluating the foremost household's decision. I call these households "followers." A follower will choose the same value of λ as that of the foremost household if it expects that many of the other followers will also make the same choice. From Section 3.2.1, we know that, from the point of view of expected utility, as the value of λ that the foremost household chooses increases, the probability that all followers will choose the same value decreases.[1] On the other hand, from Section 3.2.2, we know that, from the point of view of the worst-case aversion, as the foremost household's value of λ increases, the probability that all followers will choose the same value of λ as the foremost household will also increase. That is, expected utility and worst-case aversion act in opposite directions. Whether followers choose the same value as that of the foremost household therefore depends on the relative difference in the strengths of these two opposing forces.

3.2.4 The expected probability of following the NJ

Taking the argument in Section 3.2.1 into consideration, the expected probability that all followers will make the same choice as that of the foremost household from the point of view of the expected utility can be most simply described by

$$\Pi_U = \exp\left(-\mu\tilde{\lambda}\right) \tag{1}$$

where $\tilde{\lambda}$ is the λ that the foremost household chose, and μ (> 0) is a constant. Equation (1) indicates that, as the value of $\tilde{\lambda}$ increases, Π_U decreases. On the other hand, taking the argument in Section 3.2.2 into consideration, the expected probability that all followers will make the same choice as that of the foremost household from the point of view of worst-case aversion can be most simply described by

$$\Pi_R = 1 - \exp\left(-\nu\tilde{\lambda}\right) \tag{2}$$

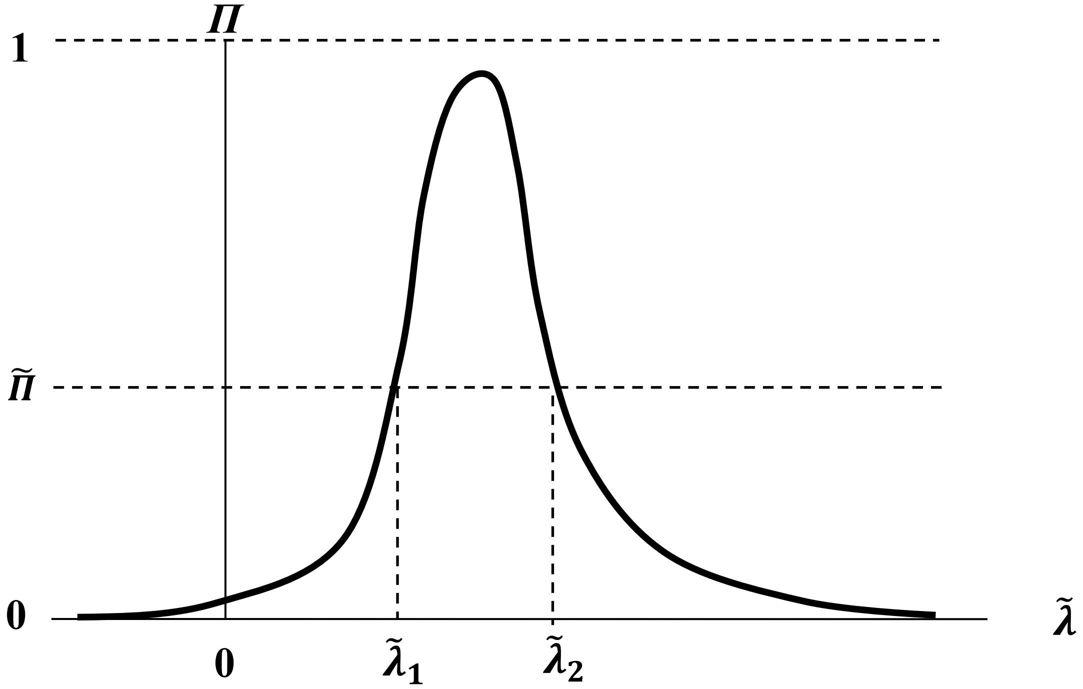
where ν (> 0) is a constant. Equation (2) indicates that, as the value of $\tilde{\lambda}$ increases, Π_R decreases. By equations (1) and (2), therefore, the combined expected probability that all followers will make the same choice as that of the foremost household from both points of view (Π) is

$$\Pi = \Pi_U \Pi_R = \exp\left(-\mu\tilde{\lambda}\right) - \exp\left[-(\mu+\nu)\tilde{\lambda}\right] \ . \tag{3}$$

Π indicates the initial expected probability that all other households make the same choice as the foremost household (Figure 2). The term "initial" is added because followers make their final decisions after considering not only equation (3) but also other related factors, as will be discussed below.

[1] Under the MDC-based procedure shown by Harashima (2018b, 2019), as the value of λ chosen by the foremost household increases, the probability that all followers will choose the same value of λ decreases because of the higher level of discomfort caused by the destruction of resources, not because of lower expected utilities.

Figure 2: The initial expected probability that all followers will choose the same λ as the foremost household



A following household initially considers whether it should follow the foremost household on the basis of the initial expected probability (i.e., equation [3]). There will be a unique value of Π, $\tilde{\Pi}$, such that, if $\Pi > \tilde{\Pi}$, a follower always chooses the same value of λ as the foremost household ($\tilde{\lambda}$). In Figure 2, therefore, if $\tilde{\lambda}$ is located between $\tilde{\lambda}_1$ and $\tilde{\lambda}_2$, a follower will always make the same choice as the foremost household. An important point is that the decisions of all followers eventually become identical, because all households are identical in the sense that they have identical preferences although they behave strategically, non-cooperatively, and independently. Hence, the consequence after the foremost household chooses $\tilde{\lambda}$ is either that all followers choose it or no follower does. Hence, the "eventual" expected probability that all followers make the same choice as the foremost household is

$$\Pi = 1 \qquad \text{if } \tilde{\lambda}_1 \leq \tilde{\lambda} \leq \tilde{\lambda}_2$$
$$\Pi = 0 \qquad \text{if } \tilde{\lambda} < \tilde{\lambda}_1 \text{ or } \tilde{\lambda}_2 < \tilde{\lambda} \ . \tag{4}$$

If $\tilde{\lambda}_1 \leq \tilde{\lambda} \leq \tilde{\lambda}_2$, therefore, the NEPIP that the foremost household chose is selected as the

Nash equilibrium in an economy.

3.3 Determination of a NEPIP

Because all households are identical, they all generate the same eventual expected probability (equation [4]). Hence, any foremost household will choose $\tilde{\lambda}$, giving sufficient consideration to equation (4). Because no household will follow the foremost household unless $\tilde{\lambda}_1 \leq \tilde{\lambda} \leq \tilde{\lambda}_2$, any $\tilde{\lambda}$ outside $\tilde{\lambda}_1 \leq \tilde{\lambda} \leq \tilde{\lambda}_2$ will be harmful for any foremost household. Hence, any foremost household will choose only a $\tilde{\lambda}$ between $\tilde{\lambda}_1$ and $\tilde{\lambda}_2$.

In addition, among the values of $\tilde{\lambda}$ located between $\tilde{\lambda}_1$ and $\tilde{\lambda}_2$, the NEPIP with $\tilde{\lambda}_1$ gives the highest expected utility to the foremost household. Because any foremost household anticipates these consequences, it will generally choose $\tilde{\lambda}_1$ as $\tilde{\lambda}$. As a result, the NEPIP with $\tilde{\lambda}_1$ will be generally chosen as the NEPIP in an economy.

3.4 Simultaneous determination of the transition period

In the previous sections, the transition period s is given exogenously, but it may be determined endogenously and simultaneously with $\tilde{\lambda}$. It seems likely that households want to arrive at the posterior steady state as soon as possible. However, as s becomes shorter, μ in equation (1) will increase because the expected utility decreases as s decreases for any given value of λ. In other words, if the value of s is sufficiently small, there will be no value of $\tilde{\lambda}$ that makes $\Pi > \tilde{\Pi}$ because of the corresponding larger value of μ. Therefore, there will be the critical value of s, $\tilde{s}$, such that if $\tilde{s} \leq s$, then $\Pi > \tilde{\Pi}$ for at least one value of $\tilde{\lambda}$. That is, when $s = \tilde{s}$, the curve of the initial expected probability that all followers will follow the foremost household comes in contact with the line of $\tilde{\Pi}$, as shown in Figure 3.

Because all households are identical, all households know the value of $\tilde{s}$. In addition, because it seems likely that households want to arrive at the posterior steady state as soon as possible, any foremost household will choose $\tilde{s}$ as s. As a result, the NEPIP with $\tilde{s}$ and $\tilde{\lambda}_1$ will be generally chosen as the NEPIP in an economy.

3.5 Nature of $\tilde{s}$

By equation (3), the maximal of Π is obtained at

$$\frac{\partial \Pi}{\partial \tilde{\lambda}} = \frac{\partial \exp\left(-\mu \tilde{\lambda}\right)}{\partial \tilde{\lambda}} - \frac{\partial \exp\left[-(\mu + \nu)\tilde{\lambda}\right]}{\partial \tilde{\lambda}} = 0$$

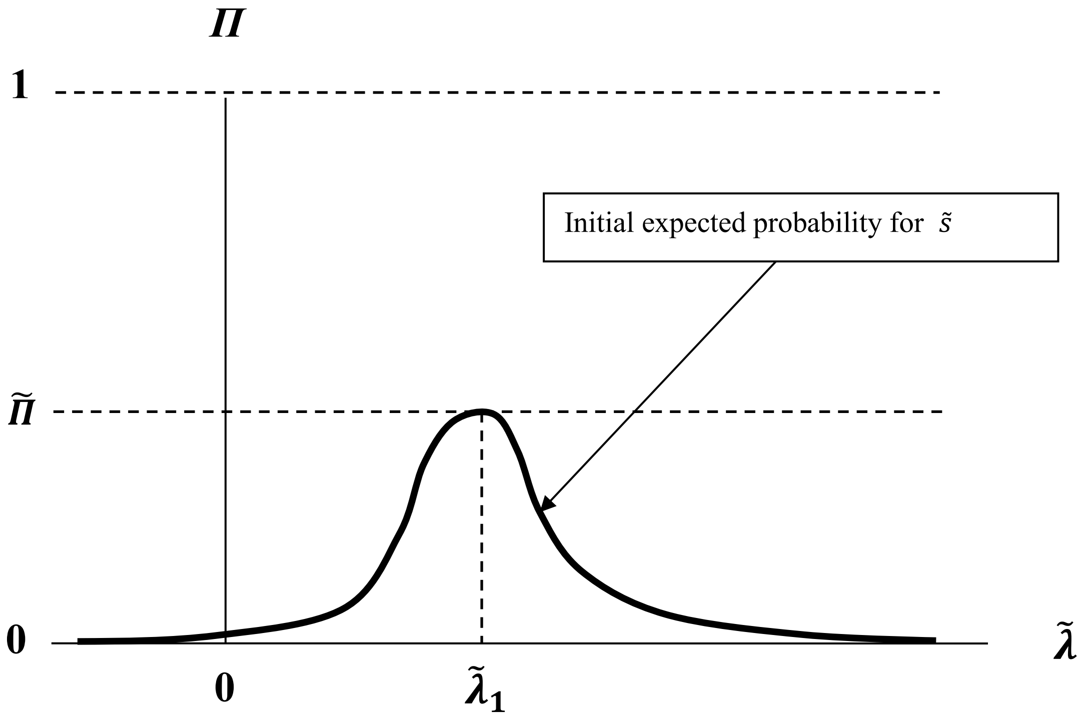
and thereby at

$$\tilde{\lambda} = -\frac{\ln\left(\frac{\mu}{\mu+\nu}\right)}{\nu} \ .$$

Hence, if $\frac{\partial \Pi}{\partial \tilde{\lambda}} = 0$ at $\tilde{\lambda}_1$, then

$$\tilde{\lambda}_1 = -\frac{\ln\left(\frac{\mu}{\mu+\nu}\right)}{\nu} \ . \tag{5}$$

Figure 3: $\tilde{\lambda}_1$ for $\tilde{s}$



If the curve of the initial expected probability comes in contact with the line of $\tilde{\Pi}$ at $\tilde{\lambda}_1$ as shown in Figure 3, then by equation (3),

$$\tilde{\Pi} = \exp(-\mu\tilde{\lambda}_1) - \exp[-(\mu+\nu)\tilde{\lambda}_1] \ , \tag{6}$$

and by equations (5) and (6),

$$\tilde{\Pi} = \left(\frac{\mu}{\mu+\nu}\right)^{\frac{\mu}{\nu}} - \left(\frac{\mu}{\mu+\nu}\right)^{\frac{\mu+\nu}{\nu}} . \tag{7}$$

Here, as s decreases, the value of μ in equation (1) increases because, as s decreases, the expected probability that all followers will make the same choice as that of the foremost household from the point of view of the expected utility (Π_U) will decrease for any given value of $\tilde{\lambda}$. Hence, μ is a function of s such that

$$\mu = \hat{\mu}(s) \tag{8}$$

and

$$\frac{d\mu}{ds} < 0 . \tag{9}$$

By equations (7) and (8), $\tilde{s}$ should satisfy

$$\left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})}{\nu}} - \left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})+\nu}{\nu}} = \tilde{\Pi} . \tag{10}$$

If $\tilde{s}$ is too small, $\mu = \hat{\mu}(s)$ becomes too large by inequality (9), and

$$\lim_{\mu\to\infty}\left\{\left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})}{\nu}} - \left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})+\nu}{\nu}}\right\} = 0 < \tilde{\Pi} ,$$

and if $\tilde{s}$ is too large, $\mu = \hat{\mu}(\tilde{s})$ becomes too small by inequality (9), and

$$\lim_{\mu\to 0}\left\{\left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})}{\nu}} - \left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})+\nu}{\nu}}\right\} = 0 < \tilde{\Pi} .$$

Therefore, if $\tilde{s}$ is too small or too large, equation (10) is not satisfied. Hence, $\tilde{s}$ must be neither too small nor too large. If this condition is satisfied, $\mu = \hat{\mu}(\tilde{s})$ is also neither too small nor too large, and

$$\left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})}{\nu}} - \left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})+\nu}{\nu}} = \tilde{\Pi} > 0$$

can hold unless $\tilde{\Pi}$ is too large, because

$$0 < \frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu} < 1$$

and thereby

$$\left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})}{\nu}} > \left[\frac{\hat{\mu}(\tilde{s})}{\hat{\mu}(\tilde{s})+\nu}\right]^{\frac{\hat{\mu}(\tilde{s})+\nu}{\nu}} .$$

Therefore, unless $\tilde{\Pi}$ is too large, an $\tilde{s}$ that is neither too small nor too large exists.

Harashima (2009, 2018a) indicated that s is not too small or too large for reasonable parameter values in the model shown in Section 2. Hence, generally, $\tilde{\Pi}$ will not be too large, and thereby an $\tilde{s}$ that is not too small or too large will generally exist.

3.6 Government Intervention

Harashima (2017) showed that, if the government intervenes and utilizes b_t (e.g., by increasing government consumption), the transition period s is prolonged because the adjustment of excess capital is delayed. Each time the government intervenes, households will recalculate the values of $\tilde{s}$ and $\tilde{\lambda}_1$. Because the elimination of the excess capital is delayed by the government's intervention, $\tilde{s}$ will increase relative to the case when it does not intervene. Hence, if the government continues to intervene on a large scale for a long period, the eventual value of $\tilde{s}$ will become very large and the transition period will be much longer.

4 CONCLUDING REMARKS

Severe recessions like the Great Recession and the Great Depression probably persist for several years or more because it takes time to reach the posterior steady state after a shock. Because the cause of severe recessions remains unknown, the nature of the transition path during severe recessions has received little if any study. In this paper, the nature of the transition path was examined on the basis of the NEPIP. Because a NEPIP is not Pareto efficient, (i.e., the constraint that Pareto efficiency should be kept does not exist), an infinite number of transition paths can be NEPIPs. Here, I examined the mechanism by which households select a NEPIP from among an infinite number of possible choices.

Households do not randomly select a NEPIP. Rather, they do so strategically and rationally considering the characteristics of each NEPIP. A reason for not choosing the Pareto efficient saddle path in the first place is that a household dislikes, fears and avoids the worst-case scenario, and the selection of a NEPIP from among many possible NEPIPs is also governed by this same preference. Households' preferences for expected utility and worst-case aversion act in opposite directions in their selection of a NEPIP. A NEPIP is selected through a tug of war between these two opposite forces, and eventually a unique NEPIP will be selected by households. In addition, the length of the transition period will be uniquely determined endogenously and simultaneously, depending on the shape of the NEPIP.

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