Macroeconomics Is Still Useful and Necessary: A Mechanism to Explain the Condition when Strict Convexity is Unsatisfied

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A Mechanism to Explain the Condition when Strict Convexity is Unsatisfied

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Abstract

Macroeconomics has been often criticized for being useless particularly since the Great Recession. In this paper, I show that macroeconomics is still important, useful, and needed on the basis of the concept of a “Nash equilibrium of a Pareto-inefficient path” (NEPIP). On a NEPIP, the condition of strict convexity is not satisfied and thus the price adjustment process malfunctions, which can generate an event like the Great Depression and Great Recession. Microeconomics cannot explain the generation of such an event. Macroeconomics, as the branch of economics that deals with the NEPIP concept, can explain these kinds of events and is therefore also necessary and useful in the field of economics. In addition, macroeconomics is as important and useful as microeconomics because only macroeconomics can justify fiscal policies.

JEL Classification code: D00, D50, E00, E12, E32

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1 INTRODUCTION

Although macroeconomics has long been taught to almost all undergraduate economics majors, it is still difficult to find a definition of macroeconomics that most economists agree on. Undergraduate textbooks of macroeconomics usually consist of the elements of Keynesian economics (e.g., the IS-LM model). A common explanation for studying macroeconomics is that microeconomics deals with disaggregates and macroeconomics deals with aggregates. However, the mechanism of why disaggregates and aggregates move in fundamentally different ways is not usually discussed, probably because it is difficult to explain.

The concept of the representative household is often assumed in studies of macroeconomics, but this concept implicitly means that all households can be represented by the average household. Therefore, it requires the assumption that aggregates are simple or simply weighted sums of the corresponding disaggregates, which implies there is no fundamental difference between their movements. Because it is difficult to show a fundamental difference between aggregates and disaggregates, macroeconomics may not be necessary, and furthermore it may be merely an arbitrary collection of various fields in economics and the collection differs among economists.

On the other hand, there are very important questions that economics must answer; for example, why do events such as the Great Depression and Great Recession occur? Although the causes of economic depressions and severe recessions have 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 has yet been reached. Microeconomics cannot answer the question because persistent generation of huge amounts of unutilized economic resources contradicts microeconomic predictions.

An important nature of economic depressions (severe recessions) such as the Great Depression and Great Recession is the persistent generation of huge amounts of unutilized economic resources (e.g., persistent very high unemployment rates) (Temin, 1989; Martin et al., 2015; Hall, 2016; Fernald et al., 2017). In this paper, I define unutilized economic resources as economic resources that are not utilized by any agent even though Pareto efficiency could improve if they were utilized. In this case, an explanation is needed not only for why they are generated to begin with but also why they are persistently generated.

Because microeconomics cannot answer this question, another kind of economics is needed. Keynesian economics, broadly speaking macroeconomics, was born after the Great Depression. It particularly emphasizes the importance of friction (rigidity) in the price adjustment process, and many kinds of models have been proposed in which this process is hindered by friction (rigidity). However, it does not explain the persistent generation of large-scale unutilized economic resources that was actually observed during the Great Depression and Great Recession. On the other hand, Harashima (2016a) 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 discussed in other contexts by Harashima (2004b, 2009[1], 2012b[2], 2016a, 2016b[3], 2017a, 2018b, 2019b), and it provides 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 Decession and Great Repression can be generated.

Furthermore, the NEPIP phenomenon is numerically simulated by Harashima (2004b) on the basis of the concept of maximum degree of comfortability (MDC) where MDC indicates the state at which a household feels most comfortable with its combination of income and assets. Simulation results indicate that a NEPIP can indeed persistently generate large-scale unutilized economic resources. Because it is not easy to perform a numerical simulation of the path to a steady state in dynamic economic growth models in which households behave by generating their own rational expectations, Harashima (2022c) presented a completely different way to perform this simulation by using the MDC concept. Using this simulation method, Harashima (2022c, 2023a, 2023b, 2023f, 2004b) simulated not only the NEPIP mechanism but also the path to reach a steady state, the effect of economic rents, the mechanism of increases in economic inequality, and the mechanism for endogenous growth in economies and a balanced growth path.

The MDC concept is important not only for numerical simulations but also for the NEPIP concept itself. Usually, it is assumed that households behave by generating their own rational expectations to reach a steady state, but Harashima (2018a[4]) showed an alternative procedure with which households maintain their capital-wage ratio (CWR) at MDC to reach a steady state. Household behavior under this MDC-based procedure is equivalent to that of households who base their behavior on rational expectations. That is, it is equivalent to the behavior under a procedure based on the rate of time preference (RTP) (Harashima 2018a, 2021, 2022a[5]), although under the MDC-based procedure, households are not required to do anything equivalent to computing a complex model, unlike the case of the RTP-based procedure. Hence, the NEPIP concept can be equivalently explained on the basis of behaviors of households under both the MDC- and RTP-based procedures (Harashima, 2020a[6]).

In this paper, I examine whether macroeconomics is still important, useful, and

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[1] Harashima (2009) is also available in Japanese as Harashima (2018b).

[2] Harashima (2012b) is also available in Japanese as Harashima (2019c).

[3] Harashima (2016b) is also available in Japanese as Harashima (2020c).

[4] Harashima (2018a) is also available in Japanese as Harashima (2019a).

[5] Harashima (2022a) is also available in Japanese as Harashima (2022b).

[6] Harashima (2020a) is also available in Japanese as Harashima (2023e).

needed on the basis of the NEPIP concept. I first examine various existing ideas about distinguishing macroeconomics from microeconomics and show that it is difficult to distinguish them unless the causes of events such as the Great Depression and Great Recession are uncovered. I next examine the causes of these events on the basis of the NEPIP concept, and I show that on a NEPIP, the condition of strict convexity of a household's preference is broken and the price adjustment process therefore malfunctions. As a result, huge amounts of unutilized economic resources are persistently generated, which is a very important characteristic of the Great Depression and Great Recession. Taking the results of this examination into consideration, I then define macroeconomics such that it is a field of economics that deals with situations in which the condition of strict convexity is not satisfied; more specifically, macroeconomics deals with situations when households strategically select a NEPIP. This includes both infrequent large-scale NEPIPs like the Great Depression and Great Recession and the more frequent small-scale recessions. Finally, I discuss the importance of macroeconomics, particularly as it relates to the need for fiscal policy.

2 WHAT DIVIDES MICRO- AND MACROECONOMICS?

2.1 Aggregates or disaggregates

The most popular explanation for the distinction between microeconomics and macroeconomics is that microeconomics deals with disaggregate economic phenomena and macroeconomics deals with aggregated ones. The terms "micro" and "macro" originate from this understanding of the distinction between them. However, this understanding is problematic because it is difficult to show that the mechanisms that govern the movements of disaggregates and aggregates are fundamentally different. Both micro- and macroeconomics commonly use the same concepts such as the household or firm, production, consumption, and capital, which also makes it difficult to discern them.

In macroeconomics, the representative household is often assumed to be the average household, which is the entity that represents all households (i.e., the aggregate of households). Furthermore, it is often assumed that all households are identical. These assumptions implicitly mean that aggregates are the simple (weighted) sum of disaggregates, which makes it meaningless to distinguish microeconomics and macroeconomics.

2.2 Static or dynamic analysis

In many graduate school textbooks of macroeconomics, growth theory is taught first because phenomena around the steady state in dynamic models are a focal point in these textbooks. In this sense, the boundary between microeconomics and macroeconomics is that microeconomics mainly deals with static analyses and macroeconomics mainly deals with dynamic analyses.

However, there are different ways to define and understand static and dynamic analyses. For example, one of the most simple and direct is that static analyses deal with states in a period and dynamic analyses deal with states in many periods. However, there are many analyses in microeconomics that deal with states in many periods. In this paper, nevertheless, I simply define the difference between static and dynamic analyses such that capital is given exogenously and constant in static analyses, but it can change endogenously and temporally in dynamic analyses. Under this definition, macroeconomics may be distinguished from microeconomics because generally microeconomics does not include a theory of capital accumulation. On the other hand, there is a field of economics that specifically deals with the mechanism of capital accumulation (i.e., growth theory).

Nevertheless, if the distinction between microeconomics and macroeconomics is only whether growth theory is directly incorporated or not, the concept of macroeconomics becomes somewhat meaningless because this distinction means that what is needed is not microeconomics and macroeconomics but microeconomics and growth theory.

2.3 Equilibrium or steady state

Considerations of the differences between static and dynamic analyses suggest another possible difference between them—analyses of equilibrium or those of a steady state. In general, the concept of equilibrium usually includes that of the steady state, but in this paper, I use the term “equilibrium” in a narrow sense, that is, an equilibrium in the price-quantity space. I also use the term “steady state” in a narrow sense, i.e., a steady state for temporally moving quantities without price.

In many cases, microeconomics deals with phenomena around an equilibrium, and macroeconomics deals with those around a steady state, but this difference can be seen also as the difference between microeconomics and growth theory. In this sense, this distinction also does not seem to be essential enough to support the necessity of macroeconomics.

2.4 Price or quantity adjustments

The difference between equilibrium and steady state suggests the importance of another element—price. For an equilibrium to be achieved, price is essential, but for a steady state to be achieved, price is not necessarily needed given the above definitions. That is, there is an essential difference between the ways to reach an equilibrium and the steady state.

The former is mainly achieved through price adjustments, but the latter is achieved through quantity adjustments. This difference in mechanisms may have the potential to distinguish micro- and macroeconomics.

Price and quantity adjustments can coexist, complement each other, and be implemented simultaneously. Nevertheless, in every period, a household first adjusts and determines the quantity of consumption (in other words, how much money it allocates for consumption) considering the steady state it will reach (i.e., it first employs quantity adjustments). Next, on the basis of the adjusted and determined quantity of consumption (money allocated for consumption) in each period, it adjusts its instantaneous demand functions in the price-quantity space in that period. Finally, with these instantaneous demand functions, it fine tunes the amount of goods and services it purchases in that period considering price adjustments made in markets.

In the sense that instantaneous demand functions are indeterminate unless households employ quantity adjustments to reach a steady state and thus price adjustments cannot properly function, quantity adjustments dominate over price adjustments. This means that if quantity adjustments malfunction, price adjustments cannot function and an economy cannot reach an equilibrium, but even if price adjustments do malfunction, quantity adjustments function and thus an economy can reach a steady state.

Considering the difference between quantity and price adjustments, we may define macroeconomics such that macroeconomics deals with quantity adjustments and microeconomics deals with price adjustments. However, microeconomics also deals with quantity adjustments (i.e., the Marshallian quantity adjustment process). Usually, the Walrasian price adjustment process is implicitly assumed to be the main adjustment process in microeconomics, so microeconomics may be regarded to deal with only price adjustments, but it does not explicitly exclude the quantity adjustment process. Hence, it is still difficult to distinguish micro- and macroeconomics only from the aspect of price and quantity adjustments.

2.5 Fluctuations

Microeconomics and growth theory predict that persisting large-scale fluctuations will not occur because an equilibrium and steady state are naturally maintained. Even if short-period fluctuations occur due to exogenously given shocks, an equilibrium and steady state will be soon be re-established through well-functioning price and quantity adjustments.

Conversely, if a persistent large-scale deviation from equilibrium and steady state actually occurs, it cannot be explained by microeconomics and the growth theory. Unfortunately, such large-scale deviations actually have occurred (e.g., the Great

Depression and Great Recession), pointing to the necessity of a completely different kind of economics from microeconomics.

3 THE GREAT DEPRESSION AND RECESSION

3.1 The Great Depression and macroeconomics

3.1.1 Keynes' original idea

Macroeconomics is regarded to have been initiated by Keynes (1936) and his followers (e.g., Hicks, 1937; Samuelson, 1947) after the Great Depression. They believed that the price adjustment process can malfunction in some cases and therefore a separate branch of economics was necessary. However, Keynes' (1936) original aim was not to establish macroeconomics but to solve the enigma of the unprecedented and persistently generated large-scale unutilized economic resources (e.g., very high unemployment rates) observed during the Great Depression.

The reason why large-scale unutilized economic resources were persistently generated during the Great Depression was not explained by economic theories at the time (e.g., Jensen, 1989). These theories are almost identical to microeconomics at present. Hence, economists living in the midst of the Great Depression were required to create a completely new theory that could explain this phenomenon, and Keynes' (1936) theory was one of the new theories presented. Considering the fact that Keynes' (1936) ideas would later be developed into what we now know as macroeconomics, the essence of macroeconomics lies in the phenomenon of persistent large-scale unutilized economic resources generated during the Great Depression.

3.1.2 Possible causes of persistent unutilized economic resources

There are three possible sources of persistent generation of large-scale unutilized economic resources: friction or rigidity (e.g., menu cost or sticky information) (see e.g., Rotemberg, 1982; Calvo, 1983; Mankiw, 1985, 2001; Galí and Gertler, 1999; Christiano et al., 2005), partial irrationality (e.g., near rationality or bounded rationality) (see e.g., Akerlof and Yellen, 1985), and a Nash equilibrium that consists of persistent unutilized economic resources (Harashima, 2004b, 2009, 2012b, 2016a, 2016b, 2017a, 2018b, 2019b).

Frictions, particularly adjustment costs, hinder price adjustments and thus may cause unutilized economic resources. However, it is difficult to explain the persistence and scale of their generation in a depression solely on the basis of frictions (rigidities). In addition, although it is easy to theoretically show the persistent generation of unutilized economic resources under the assumption of irrationality, it is difficult to show the mechanism of why most rational people suddenly became simultaneously irrational as the Great Depression suddenly began. In any case, most unexplainable phenomena could be made explainable if irrationality were assumed.

The third possibility is a Nash equilibrium that consists of persistent unutilized economic resources. A Nash equilibrium can coexist with Pareto inefficiency and therefore also with persistent large-scale unutilized economic resources. Harashima (2004b, 2009, 2012b, 2016a, 2016b, 2017a, 2018b, 2019b) showed that such a Nash equilibrium can be selected strategically by most households in some cases. The mechanism of generation of this Nash equilibrium is explained in Section 4.

3.2 Malfunctioning price adjustment due to friction (rigidity)

Among the three possibilities discussed in the previous section, friction (rigidity) or more specifically, a malfunctioning price adjustment process due to friction (rigidity) has attracted the most attention and been most intensely studied; many studies have been made under the name of various kinds of Keynesian economics. Under the assumption of malfunctioning price adjustments, Keynes introduced the concept of a consumption function that is indifferent to prices and placed it in the center of his theory, contrary to microeconomics, which puts prices in the center.

In keeping with the tradition of Keynes' assumption, in a broad sense, Keynesian economics has focused on frictions (rigidities) in price movements as the origin of malfunctioning price adjustments. However, the assumption of friction (rigidity) has been criticized for being introduced *ad hoc* and lacking a micro-foundation. Therefore many Keynesian economists have worked to uncover what kind of friction (rigidity) makes price adjustments malfunction and the related mechanism even though people are sufficiently rational.

One of the most important ways to solve this problem is to introduce the assumption of menu cost. It partially succeeds in explaining malfunctioning price adjustments in small-scale economic fluctuations, but not the persistent economy-wide malfunctioning that was actually observed in the Great Depression. Mankiw (2001) argued that the so-called New-Keynesian Phillips curve is ultimately a failure and is not consistent with the standard stylized facts about the dynamic effects of monetary policy (see also, e.g., Fuhrer and Moore, 1995; Galí and Gertler, 1999).

Price adjustments may be indeed hindered by frictions (rigidities) in the short-run to some extent, but if people are rational, they will soon find a way to bypass these frictions (rigidities). It is highly unlikely that most people will be suddenly, greatly, and simultaneously hindered from changing prices or responding to changes in prices by a friction (rigidity) and continue to do so for several years by the same friction (rigidity). In this sense, the effort made by Keynesian economics to explain the persistent malfunctioning of price adjustments by introducing frictions (rigidities) has not yet succeeded.

3.3 Strict convexity

With microeconomics, a general equilibrium exists, and this existence requires satisfying the condition of strict convexity in household preference. This condition means that, if the price of a good approaches zero, its demand approaches infinity. That is, however huge the amounts of excess supply of some goods and services are, general equilibrium can be achieved by making their prices decrease, even to near zero. Of course, infinite demand does not actually exist, but the condition of strict convexity usually can be generally satisfied with the help of quantity adjustments (i.e., the Marshallian quantity adjustment process).

As long as the condition of strict convexity is satisfied, price adjustments function well and persistent large-scale unutilized economic resources will not be generated because an equilibrium is always achieved through price adjustments. Conversely, if this condition suddenly becomes unsatisfied simultaneously for most people, great quantities of unutilized economic resources can be generated. The question is, what can make this condition become suddenly and simultaneously unsatisfied for most rational people?

4 STRATEGIC NON-CONVEXITY

In this section, I explain the mechanism of why the condition of strict convexity can become suddenly and simultaneously unsatisfied for most rational households on the basis of the NEPIP concept presented in Harashima (2004b, 2009, 2012b, 2016a, 2016b, 2017a, 2018b, 2019b), the MDC-based procedure developed in Harashima (2018a, 2021, 2022a), and the sustainable heterogeneity (SH) concept presented in Harashima (2010[7], 2012a[8], 2014a). These concepts and procedures are briefly summarized in Appendixes 1, 2, and 3.

4.1 Strategic selection of a Pareto-inefficient path

4.1.1 Dominance of quantity adjustments over price adjustments

As shown in Section 2.4, quantity adjustments to reach a steady state dominate over price adjustments to reach an equilibrium. This means that what a household first has to do in each period is to guess or expect the steady state that an economy will eventually reach;

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[7] Harashima (2010) is also available in Japanese as Harashima (2017b).

[8] Harashima (2012a) is also available in Japanese as Harashima (2020b).

next, it adjusts its behaviors in that period so as to make them consistent with this expectation or guess (i.e., it adjusts its instantaneous demand functions). After its instantaneous demand functions are determined, prices then begin to play an important role to reach the equilibrium in that period. The same is true for firms and their supply functions.

If instantaneous demand functions determined by these quantity adjustments satisfy the condition of strict convexity, an equilibrium must be always achieved with well-functioning price adjustments. As mentioned in Section 3.3, this condition will generally be satisfied, and general equilibrium is also usually achieved. However, the experiences during the Great Depression and Great Recession strongly imply that there is a possibility that there are periods when this condition is not satisfied. That is, there are periods when instantaneous demand functions derived from quantity adjustments do not satisfy the condition of strict convexity. Even in such a situation, households can still manage economic activities by depending on quantity adjustments because quantity adjustments dominate over price adjustments.

4.1.2 NEPIP

The presence of a persistently large amount of unutilized resources not only indicates that price adjustments malfunction but also that the economy is not persistently Pareto-efficient on a large scale. Pareto inefficiency usually cannot be maintained for a long period, but a Nash equilibrium can conceptually coexist with Pareto inefficiency. If a Nash equilibrium that consists of strategies generating Pareto inefficient payoffs is selected, unutilized resources as large and persistent as those observed in a depression may exist. Harashima (2004b, 2009, 2012b, 2016a, 2016b, 2017a, 2018b, 2019b) showed that a depression at such a Nash equilibrium—that is, a Nash equilibrium consisting of strategies of choosing a Pareto-inefficient transition path of consumption to the steady state (i.e., NEPIP)—is generated even in a frictionless economy if—and probably only if—RTP shifts upwards. In addition, Harashima (2020a) showed that the NEPIP phenomenon after an upward MDC shock under the MDC-based procedure is equivalent to that after an upward RTP shock under the RTP-based procedure. The concept of an MDC shock is explained in Section 4.2.2.

An essential reason for the generation of NEPIP is that households are intrinsically risk averse and not cooperative. In a strategic environment, this generates the possibility that, if consumption needs to be substantially and discontinuously increased to maintain Pareto efficiency, a non-cooperative household’s strategy to deviate from the Pareto-efficient path gives a higher expected utility than the strategy of choosing the Pareto-efficient path.

Suppose that an upward shift of the entire economy’s guessed CWR at MDC (or the expected representative household’s RTP) occurs (see Section 4.2.2). All households will be knocked off the Pareto-efficient path on which they have proceeded until the shift occurred. At that moment, each household must decide on a direction in which to proceed. Because they are no longer on a Pareto-efficient path, households choose a path strategically considering other households’ choices. This situation can be described by a non-cooperative mixed strategy game, and there is a NEPIP in this game.

4.2 NEPIP generation mechanism

4.2.1 Fundamental shock

It is highly likely that an economic depression (severe recession) is caused by a shock that largely changes the steady state because otherwise an economy would soon come back to the previous steady state and be stable again. This means that such a shock should be a sudden change in a deep parameter that has the potential to largely change the steady state. However, the choices for such deep parameters are very limited. Technology is one of them, but it will not be the cause of a depression because it will not change largely in a very short period, and furthermore, it will never regress largely and suddenly across an entire economy. Another important deep parameter is RTP under the RTP-based procedure (equivalently, CWR at MDC under the MDC-based procedure). If the expected representative household’s RTP (equivalently, the entire economy’s guessed CWR at MDC) suddenly shifts upwards, a depression can occur because consumption at the posterior steady state is lower than that at the prior steady state. Furthermore, this shock can lead to households’ selection of a NEPIP (Harashima, 2004b, 2009, 2012b, 2016a, 2016b, 2017a, 2018b, 2019b).

However, although RTP (or CWR at MDC) is a deep parameter, RTP has not been regarded as a source of shocks for economic fluctuations, possibly because RTP is thought to be constant and not to shift suddenly. There is also a practical reason, however. Models with a permanently constant RTP exhibit excellent tractability (see Samuelson, 1937). However, RTP has been naturally assumed and actually observed to be time-variable. The concept of a time-varying RTP has a long history (e.g., Böhm-Bawerk, 1889; Fisher, 1930). Parkin (1988) showed that RTP is as volatile as technology and leisure preference. Lawrance (1991) and Becker and Mulligan (1997) showed that people do not inherit permanently constant RTPs by nature and that economic and social factors affect its formation.

Harashima (2004a, 2009) presented a model of RTP under an RTP-based procedure, in which RTP can change largely and suddenly if surrounding economic situations change. This model predicts that a sudden and large upwards shift of RTP can be generated (e.g., when uncertainty about the economic situation largely increases). Furthermore, Harashima (2018a, 2021, 2022a) showed that an MDC shock can also occur under the MDC-based procedure, and it is equivalent to an RTP shock under the RTP-based procedure.

4.2.2 MDC (RTP) shock

Harashima (2018a, 2021, 2022a) showed that in a heterogeneous population, all households are linked at a state where sustainable heterogeneity (SH) is achieved, where SH indicates the state where all optimality conditions of all heterogeneous households are simultaneously achieved. It cannot be easily achieved naturally but can be achieved with appropriate government interventions. At a SH, each household determines its behavior so as to be consistent with the behaviors of the other households. Particularly, households are linked via "the representative household's RTP" under the RTP-based procedure and via "the entire economy's CWR at MDC at approximate SH ($\tilde{S}_{MDC,SH,ap}$)" under the MDC-based procedure.

On the other hand, Harashima (2018a, 2021, 2022a) showed that $\tilde{S}_{MDC,SH,ap}$ crucially depends on the guessed values of a few variables, in particular, the entire economy's CWR at MDC ($\Gamma(\tilde{S}_{MDC,SH})$), the amount of net government transfers (T), and the adjusted CWR (Γ_R). Because these values are generally guessed with incomplete information, $\tilde{S}_{MDC,SH,ap}$ is vulnerable to various shocks and can occasionally fluctuate widely. Vulnerabilities will emerge because of various factors, including limitations on the amount of information a household can access, difficulty in distinguishing between permanent and temporary incomes, and misconceptions about the difference in the natures of capital and wealth.

Because of these vulnerabilities, households will occasionally revise their guessed values of $\Gamma(\tilde{S}_{MDC,SH})$, T, and Γ_R when new pieces of information arrive or some kinds of shocks are recognized. In some cases, the value of $\Gamma(\tilde{S}_{MDC,SH})$ guessed by many households may be simultaneously revised. This revision generates a MDC shock. Harashima (2015, 2022d[9], 2023d) showed that disinformation disseminated by malicious people through large-scale speculations in financial markets can greatly influence people's guessed values of $\Gamma(\tilde{S}_{MDC,SH})$ and can then occasionally generate a large MDC (RTP) shock.

Harashima (2014b) similarly showed the generation mechanism of an RTP shock under the RTP-based procedure.

4.2.3 Model of NEPIP

In this section, I briefly explain the generation mechanism of NEPIP after an upward RTP shock under the RTP-based procedure following Harashima (2009, 2012b, 2016a, 2016b,

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[9] Harashima (2022d) is also available in Japanese as Harashima (2023c).

2017a, 2018b, 2019b). It is also explained in detail in Appendix 1. The generation mechanism of NEPIP after an upward MDC shock under the MDC-based procedure is shown in Harashima (2020a). The mechanisms under the RTP- and MDC-based procedures are basically equivalent.

4.2.3.1 Model

Households are assumed to be non-cooperative, risk averse, and infinitely living, and behave under the RTP-based procedure. They are also assumed to be identical in the sense that their preferences, labor incomes, and initial financial assets are identical. 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 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 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 (≥ 0). The difference in consumption between the two options in period t is b_t (≥ 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.

4.2.3.2 Existence of NEPIP

Harashima (2009) 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) 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.

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 NEPIP is Pareto inefficient and excess capital and b_t exist, unutilized resources are successively generated and eliminated—that is, a recession, in some cases a depression, is generated.

4.3 Non-convexity: strategically disregarded price adjustments

On a NEPIP, households strategically never increase consumption even if prices approach zero. This means that demand does not respond to price. Figure 1 indicates the comparative statics of this situation; the downward sloping bold solid and dotted curves, respectively, indicate the demand curve before the shock and that on a NEPIP after the shock.

The nearly vertical part in the downward sloping part of the demand curve on a NEPIP after the shock indicates that there is an upper limit of consumption forced by the NEPIP. Consumption cannot increase beyond this upper limit even if the price approaches zero. For example, even if the supply curve is changed from curve 1 to curve 2 in Figure 1 by largely decreasing the price, the intersection only almost vertically shifts downwards from point E_1 to E_2 and therefore the quantity a household purchases on the NEPIP only increases by a small amount.

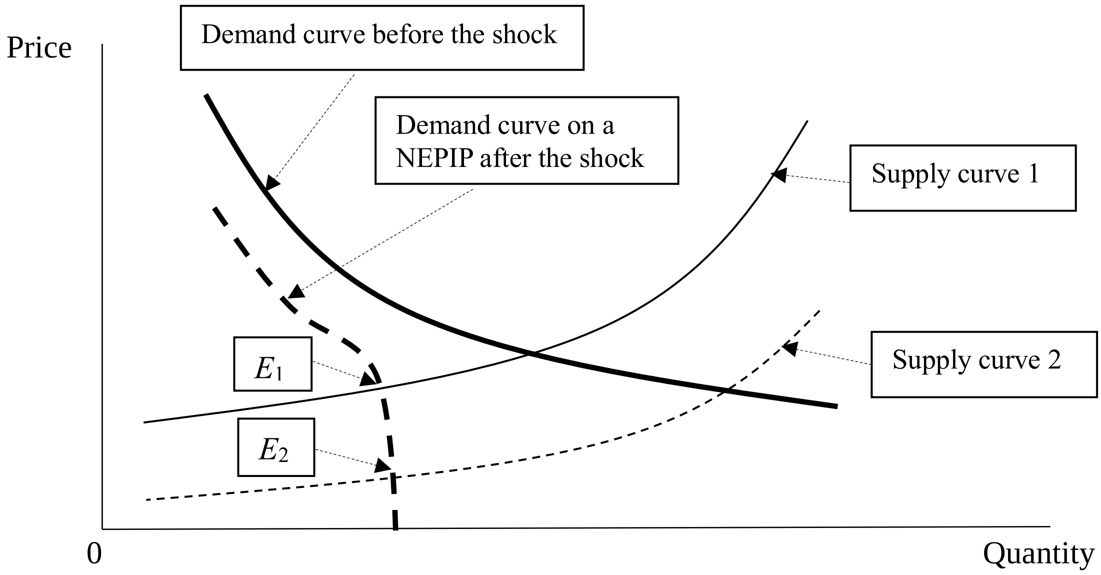

Figure 1: Demand curve before and after the shock, and the supply curves

This distorted demand curve clearly does not satisfy the condition of strict convexity, because even if the price approaches zero, the demand does not increase to an infinite quantity. The reason for the distortion is that households strategically disregard price adjustments after the shock and proceed toward the posterior steady state relying only on quantity adjustments. The household's strategic selection of a NEPIP and its consequent disregard of price adjustments make the condition of strict convexity break down.

Furthermore, it is highly likely that firms well know that price adjustments will not function if households select a NEPIP; therefore, they will not dare to largely decrease prices to meet the demand and supply (e.g., by cutting costs through decreasing wages). On a NEPIP, cutting wages to lower prices will be a less effective way for firms to maintain profits than simply firing "unutilized" idle workers generated by shrinking demand because lowering prices does not increase demand, but it does decrease profit. This implies that wages will not decrease largely on a NEPIP, but a large number of workers will become unemployed. As a result, wages and prices look like they are sticky and rigid.

4.4 Keynes' view and NEPIP

Keynes' (1936) intention behind the introduction of the concept of a "liquidity trap" was to explain the reason why persistent large-scale unutilized economic resources were generated during the Great Depression. Keynes realized that even if the price adjustment process malfunctioned, an equilibrium can be reached through the quantity adjustment process, except in the labor market. Because the labor supply cannot decrease largely, unlike supplies of other goods and services, the demand and supply of labor cannot easily be adjusted only through quantity adjustments. As a result, high unemployment rates will persist during a depression. The picture Keynes presented is thus similar to that predicted by a NEPIP, and the Keynesian view seems to capture many aspects of a NEPIP.

As mentioned in the Introduction, however, an explanation for the cause of an economic depression by Keynesian economics has not yet been sufficiently accepted. One reason is that households' strategic behaviors are not considered. Under the circumstances where the condition of strict convexity is satisfied and thus the general equilibrium can be achieved, households always select a Pareto-efficient path even after strategically considering other households' behaviors. Hence, Keynesian economics is usually indifferent to whether households behave strategically or not. In this sense, it is not surprising that the aspect of strategic behavior is usually ignored in Keynesian economics. However, strategic considerations do greatly matter in some cases, for example, in the case of the strategic selection of a NEPIP.

Keynes (1936) also emphasized the importance of "animal spirits" in economic activities. The concept of animal spirits is vague, and various interpretations exist because Keynes did not clearly define the term. Nevertheless, proponents of this idea commonly maintain that economic activities are largely governed by people's mood (e.g., optimistic or pessimistic). Animal spirits as a driving force of economic fluctuations may be reinterpreted as households' revising their guesses of the entire economy's CWR at MDC (the expected representative household's RTP), which can cause a change in steady state and cause a NEPIP to be selected.

5 IMPORTANCE OF MACROECONOMICS

5.1 Definition of macroeconomics

The examinations in the previous sections indicate that the key for a distinction between micro- and macroeconomics is whether the condition of strict convexity is satisfied or not.

In that context, I define macroeconomics as follows: macroeconomics is a field of economics that deals with situations when the condition of strict convexity is not satisfied. More specifically, macroeconomics deals with situations when households strategically select a NEPIP.

5.2 Small-scale NEPIPs

In this paper, only upward MDC (RTP) shocks are considered as the origin of a NEPIP, but other kinds of shocks that can change a steady state may also generate a NEPIP. In addition, as shown in Harashima (2004b, 2009, 2012b, 2016a, 2016b, 2017a, 2018b, 2019b) and summarized in Appendix 1, households' selection of a NEPIP does not depend on the scale of the shock but on their degrees of risk aversion and, from the point of view of one household, the subjective probability that the other households choose the J option (i.e., p). Many scales of upward MDC (RTP) shock, even a small one, can occur depending on the scales of change in the entire economy's guessed CWR at MDC (the expected representative household's RTP). Because the scale of shock does not matter to the generation of the NEPIP, small-scale NEPIPs can be generated by various kinds of small shocks.

As discussed in Section 4.2.2, small-scale MDC (RTP) shocks seem to occur more frequently than expected because unexpected incidents like wars, political turmoil, natural disasters, pandemics, oil price hikes, or financial speculations always occur somewhere in the world. These unexpected incidents themselves may directly generate economic fluctuations, but they also can indirectly generate NEPIPs by making households change their guesses or expectations about the future economy; thus, the guess of the entire economy's CWR at MDC (the expected representative household's RTP) also changes.

Even if the scales of revisions of guesses or expectations are small, they can still generate NEPIPs. Because small-scale unexpected incidents will frequently occur, small-scale NEPIPs and unutilized economic resources can be frequently generated. This means that macroeconomics is needed to describe not only rare periods like the Great Depression and Great Recession but also many other relatively "ordinary" periods (i.e., during many "ordinary" small-scale recessions).

5.3 Only macroeconomics can justify fiscal policies

Even if macroeconomics can be defined as a fundamentally different branch of economics from microeconomics, the question arises: is it as important and useful as microeconomics? The answer is yes because without macroeconomics, fiscal policies cannot be justified. In the framework of microeconomics, fiscal policies cannot be justified because an equilibrium and steady state can be naturally achieved through price and quantity adjustments without government intervention. Even if there is a deviation from an equilibrium or steady state because of a shock, it will soon be restored through these adjustments. Hence, in microeconomics, fiscal policies only distort an economy and therefore are unnecessary.

Conversely, fiscal policies are indispensable in macroeconomics as defined above. Without them, unemployment rates can largely increase and stay at high levels on a NEPIP. Fiscal policies (probably only fiscal policies) and furthermore only voluminous fiscal policies in some cases can greatly restrain unemployment rate increases on a NEPIP (Harashima 2009, 2016b, 2017a). In other words, only macroeconomics can justify these important and indispensable fiscal policies, making macroeconomics as important and useful as microeconomics.

6 CONCLUDING REMARKS

The usual understanding that microeconomics deals with disaggregates and macroeconomics deals with aggregates is problematic because it is difficult to show why disaggregates and aggregates move fundamentally differently. In addition, the concept of the representative household implicitly means that aggregates are simple (weighted) sums of corresponding disaggregates. Hence, macroeconomics may be unnecessary and merely an arbitrary collection of various fields in economics and the collection differs among economists.

On the other hand, economists must answer important questions, such as why did the Great Depression and Great Recession occur? Although the cause of economic depressions (severe recessions) has long been studied from various points of view, no consensus about the cause has yet been reached. An important nature of economic depressions is the persistent generation of huge amounts of unutilized economic resources. Microeconomics cannot explain this nature, which means that another kind of economics is needed.

Keynesian economics emphasizes the importance of friction (rigidity), but it does not succeed in explaining the persistent generation of large-scale unutilized economic resources. On the other hand, Harashima (2004b, 2009, 2012b, 2016a, 2016b, 2017a, 2018b, 2019b) presented the NEPIP concept and showed that it can explain the generation of events such as the Great Depression and Great Recession without assuming any friction (rigidity). In this paper, I show that the condition of strict convexity of household preference breaks down on a NEPIP; thus, the price adjustment process malfunctions. As a result, huge amounts of unutilized economic resources are persistently generated, which is a very important characteristic of the Great Depression and Great Recession. Harashima (2024) numerically simulated an economic depression on the basis of the NEPIP concept. Many aspects of the simulated path of a NEPIP (e.g., persistent generation of huge amounts of unutilized economic resources) are similar to those actually observed during the Great Recession and Great Depression.

I define macroeconomics such that it is the field of economics that deals with situations in which strict convexity is not satisfied, and more specifically, deals with situations when households strategically select a NEPIP. Because small-scale NEPIPs will be generated frequently, macroeconomics will be needed not only to explain periods of large-scale NEPIPs like the Great Depression and Great Recession but also for other relatively "ordinary" periods. In addition, macroeconomics is as important and useful as microeconomics because fiscal policies and only large fiscal policies in some cases can greatly restrain unemployment rates from increasing on a NEPIP (Harashima 2009, 2016b, 2017a), and only macroeconomics can justify these important and indispensable fiscal policies.

APPENDIX 1:

Nash equilibrium of a Pareto-inefficient path (NEPIP)

A1.1 Model with non-cooperative households

The model describes the utility maximization of households after an upward RTP shock.

A1.1.1 Households

Households are not intrinsically cooperative. Except in a strict communist economy, households do not coordinate themselves to behave as a single entity when consuming goods and services. The model in this paper assumes non-cooperative, identical and infinitely living households and that the number of households is sufficiently large. Each of them equally maximizes the expected utility

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

subject to

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

where y_t, c_t, and k_t are production, consumption, and capital per capita in period t respectively; A is technology; u is the utility function; $y_t = f(A,k_t)$ is the production function; $\theta\,(>0)$ is RTP; and E is the expectation operator. y_t, c_t, and k_t are monotonic, continuous and differentiable in t, and u and f are monotonic and continuous functions of c_t and k_t, respectively. All households initially have an identical amount of financial assets equal to k_t, and all households gain the identical amount of income $y_t = f(A,k_t)$ in each period. It is assumed that $\frac{du(c_t)}{dc_t} > 0$ and $\frac{d^2u(c_t)}{dc_t^2} < 0$; thus, households are risk averse. For simplicity, the utility function is specified to be the constant relative risk aversion (CRRA) utility function

$$u(c_t) = \frac{c_t^{1-\gamma}}{1-\gamma} \qquad \text{if } \gamma \neq 1$$

$$u(c_t) = \ln(c_t) \qquad \text{if } \gamma = 1,$$

where $0 < \gamma < \infty$. In addition, $\frac{\partial f(A, k_t)}{\partial k_t} > 0$ and $\frac{\partial^2 f(k_t)}{\partial k_t^2} < 0$. Technology A and labor supply are assumed to be constant.

The effects of an upward shift in RTP are shown in Figure A1.1 Suppose first that the economy is at steady state before the shock. After the upward RTP shock, the vertical line $\frac{dc_t}{dt} = 0$ moves to the left (from the solid line to the dashed line in Fig 1).

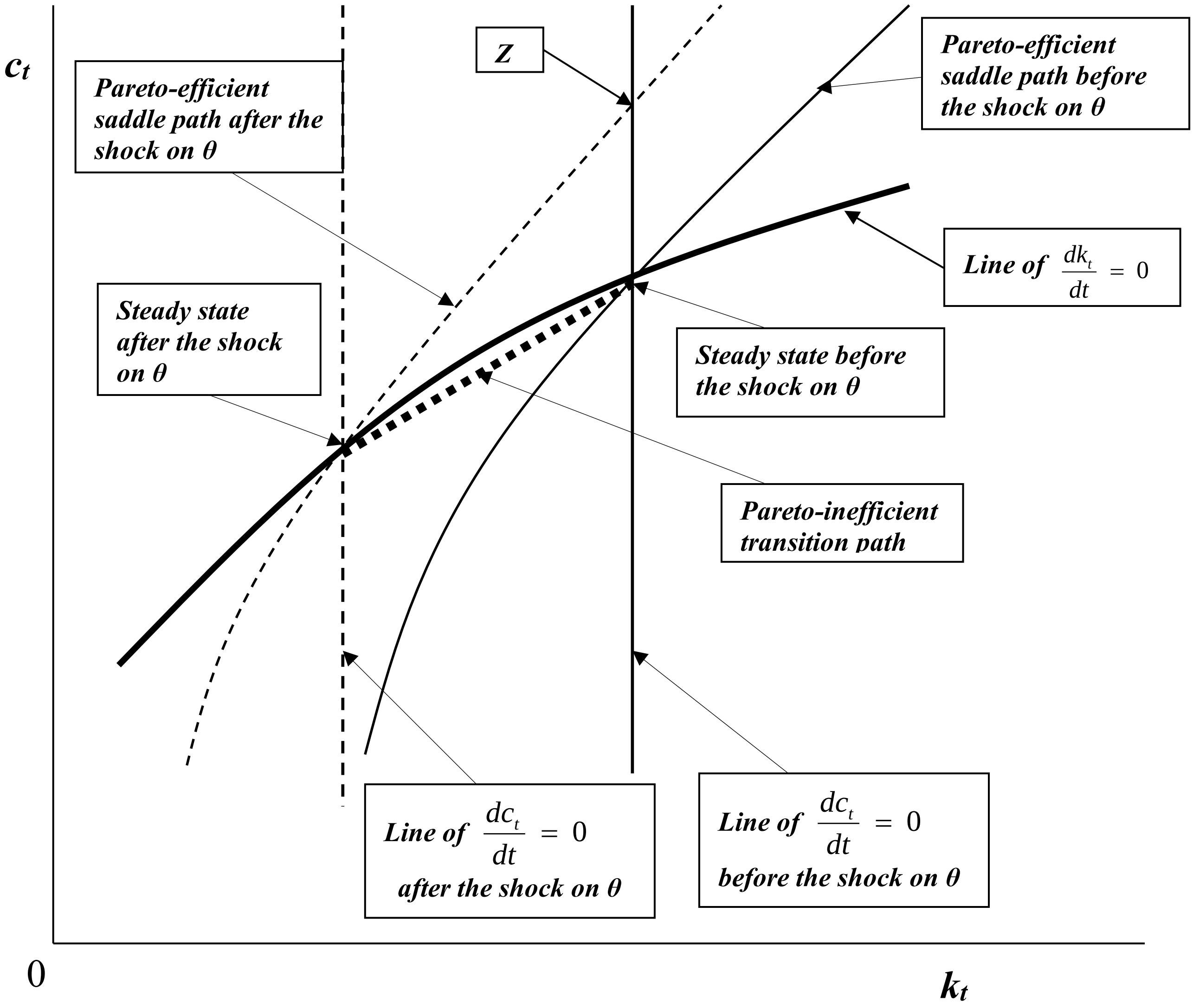

Figure A1.1: An RTP shock

To keep Pareto efficiency, consumption needs to jump immediately from the steady state before the shock (the prior steady state) to point *Z*. After the jump, consumption proceeds on the Pareto-efficient saddle path after the shock (the posterior Pareto-efficient saddle path) from point *Z* to the lower steady state after the shock (the posterior steady state). Nevertheless, this discontinuous jump to *Z* may be uncomfortable for risk-averse households that wish to smooth consumption and not to experience substantial fluctuations. Households may instead take a shortcut and, for example, proceed on a path on which consumption is reduced continuously from the prior steady state to the posterior steady state (the bold dashed line in Fig. 1), but this shortcut is not Pareto-efficient.

Choosing a Pareto-inefficient consumption path must be consistent with each household's maximization of its expected utility. To examine the possibility of the rational choice of a Pareto-inefficient path, the expected utilities between the two options need be compared. For this comparison, I assume that there are two options for each non-cooperative household with regard to consumption just after an upward RTP shift. The first is a jump option "***J***", in which a household's consumption jumps to *Z* 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, as shown by the bold dashed line in Figure A1.1. The household that chose the ***NJ*** option reaches the posterior steady state in period $s\left(\geq 0\right)$. The difference in consumption between the two options in each period t is b_t ($\geq$ 0). Thus, b_0 indicates the difference between *Z* and the prior steady state. b_t diminishes continuously and becomes zero in period s. The ***NJ*** path of consumption (c_t) after the shock is monotonic, continuous and differentiable in t and $\frac{dc_t}{dt} < 0$ if $0 \leq t < s$. In addition,

$$\bar{c} < c_t < \hat{c}_t \qquad \text{if } 0 \leq t < s$$
$$c_t = \bar{c} \qquad \text{if } 0 \leq s \leq t,$$

where $\hat{c}_t$ is consumption when proceeding on the posterior Pareto-efficient saddle path and $\bar{c}$ is consumption in the posterior steady state. Therefore,

$$b_t = \hat{c}_t - c_t > 0 \qquad \text{if } 0 \leq t < s$$
$$b_t = 0 \qquad \text{if } 0 \leq s \leq t.$$

It is also assumed that, when a household chooses the option that is different from the option the other households choose, the difference in the accumulation of financial assets resulting from the difference in consumption (b_t) before period s between the household and the other households is reflected in consumption after period s. That is, the difference in the return on financial assets is added to (or subtracted from) the household's consumption in each period after period s. The exact functional form of the addition (or subtraction) is shown in Section A1.1.3.

A1.1.2 Firms

Unutilized products because of b_t are eliminated quickly in each period by firms because holding them for a long period is a cost to firms. Elimination of unutilized products is accomplished by discarding the goods or preemptively suspending production, thereby leaving some capital and labor inputs idle.[10] However, in the next period, unutilized products are generated again because the economy is not proceeding on the Pareto-efficient saddle path. Unutilized products are therefore successively generated and eliminated. Faced with these unutilized products, firms dispose of the excess capital used to generate the unutilized products. Disposing of the excess capital is rational for firms because the excess capital is an unnecessary cost, but this means that parts of the firms are liquidated, which takes time and thus disposing of the excess capital will also take time. If the economy proceeds on the *NJ* path (that is, if all households choose the *NJ* option), firms dispose of all of the remaining excess capital that generates b_t and adjust their capital to the posterior steady-state level in period s, which also corresponds to households reaching the posterior steady state. Thus, if the economy proceeds on the *NJ* path, capital k_t is

$$\begin{aligned} &\bar{k} < k_t \le \hat{k}_t &&\text{if } 0 \le t < s \\ &k_t = \bar{k} &&\text{if } 0 \le s \le t, \end{aligned}$$

where $\hat{k}_t$ is capital per capita when proceeding on the posterior Pareto-efficient saddle path and $\bar{k}$ is capital per capita in the posterior steady state.

The real interest rate i_t is

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[10] In this model, capital depreciation is implicitly assumed. Considering capital depreciation, increasing consumption by b_t when the economy is on the *J* path indicates that replenishing depleted capitals with investments is reduced, and eliminating b_t when it is on the *NJ* path indicates discarding the produced new capitals for investments or preemptively suspending investments, leaving some capital and labor inputs idle. If capital depreciation is not assumed, consuming b_t on the *J* path indicates that households consume some amount of the existing capitals, and eliminating b_t on the *NJ* path indicates disposing of some of the existing capitals.

$$i_t = \frac{\partial f(A, k_t)}{\partial k_t}.$$

Because the real interest rate equals RTP at steady state, if the economy proceeds on the ***NJ*** path,

$$\begin{aligned} \tilde{\theta} \le i_t < \theta \quad & \text{if } \ 0 \le t < s \\ i_t = \theta \quad & \text{if } \ 0 \le s \le t, \end{aligned}$$

where $\tilde{\theta}$ is RTP before the shock and θ is RTP after the shock. i_t is monotonic, continuous and differentiable in *t* if $0 \le t < s$.

A1.1.3 Expected utility after the shock

The expected utility of a household after the shock depends on its choice of ***J*** or ***NJ***. Let ***Jalone*** indicate that the household chooses the ***J*** option but the other households choose the ***NJ*** option, ***NJalone*** indicate that the household chooses the ***NJ*** option but the 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 $p(0 \le p \le 1)$ be the subjective probability of the household that the other households choose the ***J*** option (e.g., $p = 0$ indicates that all the other households choose option ***NJ***). With *p*, the expected utility of the household when it chooses option ***J*** is,

$$E(J) = pE(Jtogether) + (1-p)E(Jalone) \ , \tag{A1.1}$$

and when it chooses option ***NJ*** is

$$E(NJ) = pE(NJalone) + (1-p)E(NJtogether), \tag{A1.2}$$

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. With the properties of ***J*** and ***NJ*** shown in Sections A1.1.1 and A1.1.2,

$$\begin{aligned} E(J) = pE\left[\int_0^s \exp(-\theta t) u(c_t + b_t) dt + \int_s^\infty \exp(-\theta t) u(\hat{c}_t) dt\right] \\ + (1-p)E\left[\int_0^s \exp(-\theta t) u(c_t + b_t) dt + \int_s^\infty \exp(-\theta t) u(\bar{c} - \bar{a}) dt\right], \end{aligned} \tag{A1.3}$$

and

$$E(NJ) = pE\left[\int_0^s \exp(-\theta t) u(c_t)\,dt + \int_s^\infty \exp(-\theta t) u(\hat{c}_t + a_t)\,dt\right]$$
$$+ (1-p)E\left[\int_0^s \exp(-\theta t) u(c_t)\,dt + \int_s^\infty \exp(-\theta t) u(\bar{c})\,dt\right], \qquad \text{A1.4)}$$

where

$$\bar{a} = \theta \int_0^s b_r \exp \int_r^s i_q \, dq \, dr \,, \qquad \text{(A1.5)}$$

and

$$a_t = i_t \int_0^s b_r \exp \int_r^s i_q \, dq \, dr \,, \qquad \text{(A1.6)}$$

and the shock occurred in the period t = 0. Figure A1.2 shows the paths of ***Jalone*** and ***NJalone***. Because there is a sufficiently large number of households and the effect of an individual household on the whole economy is negligible, then in the case of ***Jalone*** the economy almost proceeds on the ***NJ*** path, and in the case of ***NJalone*** it almost proceeds on the ***J*** path. If the other households choose the ***NJ*** option (***Jalone*** or ***NJtogether***), their per capita consumption after s is constant as $\bar{c}$ and capital is adjusted to $\bar{k}$ by firms in the period s. In addition, a_t and i_t are constant after s such that a_t equals $\bar{a}$ and i_s equals θ, because the economy is at the posterior steady state. Nevertheless, during the transition period before s, the value of i_t changes from the value of the prior RTP to that of the posterior. If the other households choose option ***J*** (***NJalone*** or ***Jtogether***), however, their per capita consumption after s is $\hat{c}_t$ and capital is not adjusted to $\bar{k}$ by firms in the period s and remains at $\hat{k}_t$.

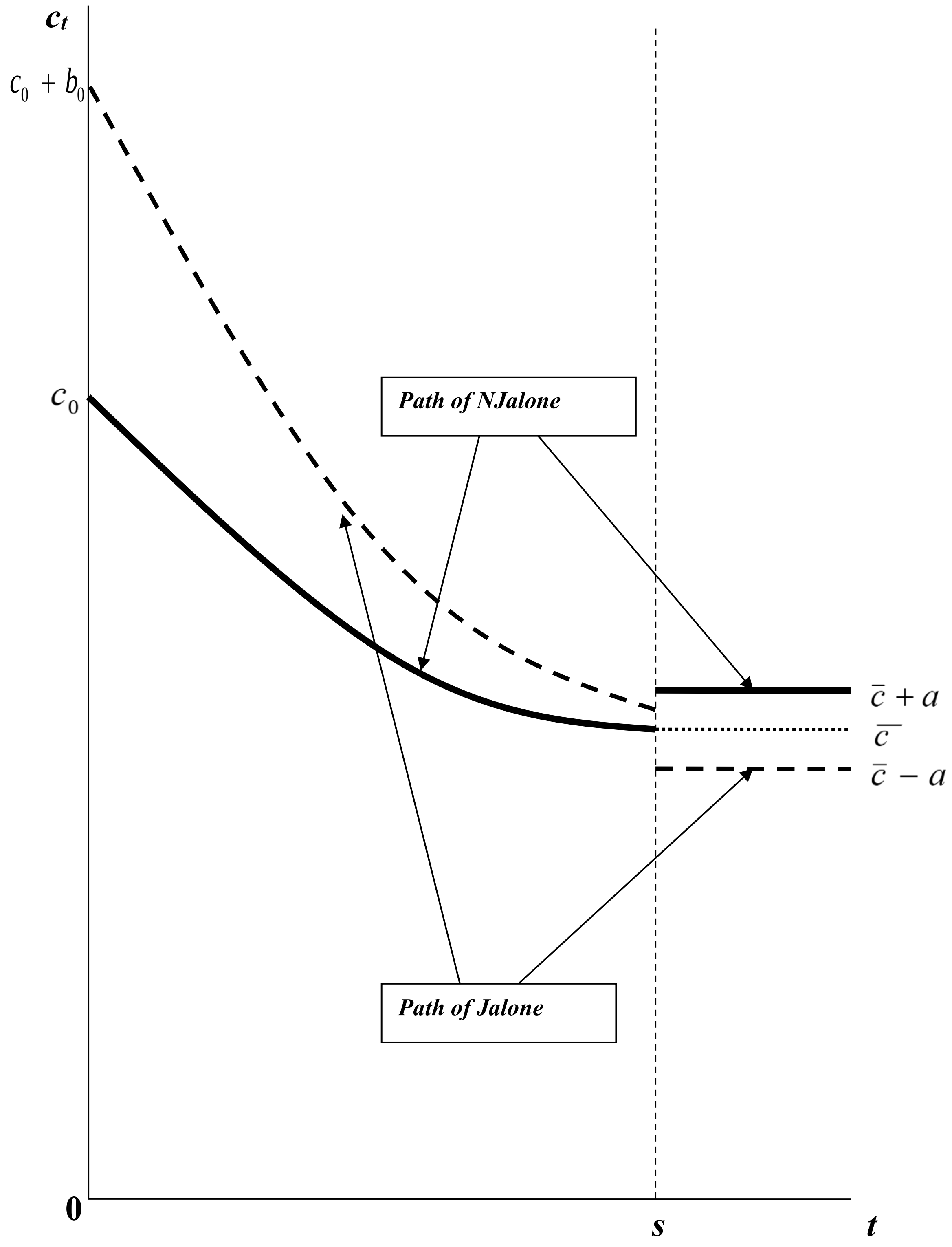

Figure A1.2: Paths of *Jalone* and *NJalone*

As mentioned in Section A1.1.1, the difference in the returns on financial assets for the household from the returns for each of the other households is added to (or subtracted from) its consumption in each period after period *s*. This is described by a_t and $\bar{a}$ in equations (A1.3) and (A1.4), and equations (A1.5) and (A1.6) indicate that the accumulated difference in financial assets due to b_t increases by compound interest between the period *r* to *s*. That is, if the household takes the ***NJalone*** path, it accumulates more financial assets than each of the other ***J*** households, and instead of immediately consuming these extra accumulated financial assets after period *s*, the household consumes the returns on them in every subsequent period.

If the household takes the ***Jalone*** path, however, its consumption after *s* is $\bar{c} - \bar{a}$, as shown in equation (A1.3). $\bar{a}$ is subtracted because the income of each household $y_t = f(A, k_t)$, including the ***Jalone*** household, decreases equally by b_t. Each of the other ***NJ*** households decreases consumption by b_t at the same time, which compensates for the decrease in income; thus, its financial assets (i.e., capital per capita; k_t) are kept equal to $\hat{k}_t$. The ***Jalone*** household, however, does not decrease its consumption, and its financial assets become smaller than those of each of the other ***NJ*** households, which results in the subtraction of $\bar{a}$ after period *s*.

A1.2 Pareto-inefficient transition path [11]

A1.2.1 Rational Pareto-inefficient path

A1.2.1.1 Rational choice of a Pareto-inefficient path

Before examining the economy with non-cooperative households, I first show that, if households are cooperative, only option ***J*** is chosen as the path after the shock because it gives a higher expected utility than option ***NJ***. Because there is no possibility of ***Jalone*** and ***NJalone*** if households are cooperative, then $E(J) = E(Jtogether)$ and $E(NJ) = E(NJtogether)$. Therefore,

$$\begin{aligned}
&E(J) - E(NJ) = \\
&\quad E\left[\int_0^s \exp(-\theta t)u(c_t + b_t)dt + \int_s^\infty \exp(-\theta t)u(\hat{c}_t)dt\right] - E\left[\int_0^s \exp(-\theta t)u(c_t)dt + \int_s^\infty \exp(-\theta t)u(\bar{c})dt\right] \\
&\quad = E\left\{\int_0^s \exp(-\theta t)[u(c_t + b_t) - u(c_t)]dt + \int_s^\infty \exp(-\theta t)[u(\hat{c}_t) - u(\bar{c})]dt\right\} > 0
\end{aligned}$$

since $c_t < c_t + b_t$ and $\bar{c} < \hat{c}_t$.

Next, I examine the economy with non-cooperative households. First, the special case with a utility function with a sufficiently small γ is examined.

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[11] The idea of a rationally chosen Pareto inefficient path was originally presented by Harashima (2004b).

Lemma 1: If $\gamma(0<\gamma<\infty)$ is sufficiently small, then $E(Jalone)-E(NJtogether)>0$.

Proof: $\lim_{\gamma\to 0}[E(Jalone)-E(NJtogether)]$

$$= E\int_0^s \exp(-\theta t)\lim_{\gamma\to 0}[u(c_t+b_t)-u(c_t)]dt + E\int_s^\infty \exp(-\theta t)\lim_{\gamma\to 0}[u(\bar{c}-\bar{a})-u(\bar{c})]dt$$

$$= E\int_0^s \exp(-\theta t)b_t\,dt - E\int_s^\infty \exp(-\theta t)\bar{a}\,dt$$

$$= E\int_0^s \exp(-\theta t)b_t dt - E\theta\left[\int_0^s\left(b_r \exp\int_r^s i_q\,dq\right)dr\right]\int_s^\infty \exp(-\theta t)dt$$

$$= E\int_0^s \exp(-\theta t)b_t dt - E\exp(-\theta s)\int_0^s\left(b_r \exp\int_r^s i_q\,dq\right)dr$$

$$= E\exp(-\theta s)\int_0^s b_t\left\{\exp[\theta(s-t)]-\exp\int_t^s i_q\,dq\right\}dt>0,$$

because, if $0\le t< s$, then $i_t<\theta$ and $\exp[\theta(s-t)]>\exp\int_t^s i_q\,dq$. Therefore, because $\exp[\theta(s-t)]>\exp\int_t^s i_q\,dq$, $E(Jalone)-E(NJtogether)>0$ for sufficiently small γ. ■

Second, the opposite special case (i.e., a utility function with a sufficiently large γ) is examined.

Lemma 2: If $\gamma(0<\gamma<\infty)$ is sufficiently large and if $0<\lim_{\gamma\to\infty}\frac{\bar{a}}{\bar{c}}<1$, then $E(Jalone)-E(NJtogether)<0$.

Proof: Because $0<b_t$, then for any period $t(<s)$,

$$\lim_{\gamma\to\infty}\frac{1-\gamma}{\bar{c}^{\,1-\gamma}}[u(c_t+b_t)-u(c_t)]=\lim_{\gamma\to\infty}\left[\left(\frac{c_t+b_t}{\bar{c}}\right)^{1-\gamma}-\left(\frac{c_t}{\bar{c}}\right)^{1-\gamma}\right]=0.$$

On the other hand, because $0<\bar{a}$, then for any period $t(<s)$, if $0<\lim_{\gamma\to\infty}\frac{\bar{a}}{\bar{c}}<1$,

$$\lim_{\gamma\to\infty}\frac{1-\gamma}{\bar{c}^{\,1-\gamma}}[u(\bar{c}-\bar{a})-u(\bar{c})]=\lim_{\gamma\to\infty}\left[\left(1-\frac{\bar{a}}{\bar{c}}\right)^{1-\gamma}-1\right]=\infty.$$

Hence,

$$\lim_{\gamma\to\infty}\frac{1-\gamma}{\bar{c}^{\,1-\gamma}}\left[E(Jalone)-E(NJtogether)\right]=\lim_{\gamma\to\infty}\frac{1-\gamma}{\bar{c}^{\,1-\gamma}}\int_0^s \exp(-\theta t)\lim_{\gamma\to\infty}\left[u(c_t+b_t)-u(c_t)\right]dt+$$
$$\lim_{\gamma\to\infty}\frac{1-\gamma}{\bar{c}^{\,1-\gamma}}\int_s^\infty \exp(-\theta t)\lim_{\gamma\to\infty}\left[u(\bar{c}-\bar{a})-u(\bar{c})\right]dt=0+\infty>0.$$

Because $\frac{1-\gamma}{\bar{c}^{\,1-\gamma}}<0$ for any $\gamma(1<\gamma<\infty)$, then if $0<\lim_{\gamma\to\infty}\frac{\bar{a}}{\bar{c}}<1$, $E(Jalone)-E(NJtogether)<0$ for sufficiently large $\gamma(<\infty)$ ■

The condition $0<\lim_{\gamma\to\infty}\frac{\bar{a}}{\bar{c}}<1$ indicates that path ***NJ*** from c_0 to $\bar{c}$ deviates sufficiently from the posterior Pareto-efficient saddle path and reaches the posterior steady state $\bar{c}$ not too late. Because steady states are irrelevant to the degree of risk aversion (γ), both c_0 and $\bar{c}$ are irrelevant to γ.

By Lemmas 1 and 2, it is proved that $E(Jalone)-E(NJtogether)<0$ is possible.

Lemma 3: If $0<\lim_{\gamma\to\infty}\frac{\bar{a}}{\bar{c}}<1$, then there is a $\gamma^*(0<\gamma^*<\infty)$ such that if $\gamma^*<\gamma<\infty$, $E(Jalone)-E(NJtogether)<0$.

Proof: If $\gamma(>0)$ is sufficiently small, then $E(Jalone)-E(NJtogether)>0$ by Lemma 1, and if $\gamma(<\infty)$ is sufficiently large and if $0<\lim_{\gamma\to\infty}\frac{\bar{a}}{\bar{c}}<1$, then $E(Jalone)-E(NJtogether)<0$ by Lemma 2. Hence, if $0<\lim_{\gamma\to\infty}\frac{\bar{a}}{\bar{c}}<1$, there is a certain $\gamma^*(0<\gamma^*<\infty)$ such that, if $\gamma^*<\gamma<\infty$, then $E(Jalone)-E(NJtogether)<0$. ■

However, $E(Jtogether)-E(NJalone)>0$ because both ***Jtogether*** and ***NJalone*** indicate that all the other households choose option ***J***; thus, the values of i_t and k_t are same as those when all households proceed on the posterior Pareto-efficient saddle path. Faced with these i_t and k_t, deviating alone from the Pareto-efficient path (***NJalone***) gives a lower expected utility than ***Jtogether*** to the ***NJ*** household. Opposite to ***Jtogether*** and ***NJalone***, both ***Jalone*** and ***NJtogether*** indicate that all the other households choose option ***NJ*** and i_t and k_t are not those of the Pareto-efficient path. Hence, the sign of $E(Jalone)-E(NJtogether)$ varies depending on the conditions, as Lemma 3 indicates.

By Lemma 3 and the property $E(Jtogether)-E(NJalone)>0$, the possibility of the choice of a Pareto-inefficient transition path, that is, $E(J)-E(NJ)<0$, is shown.

Proposition 1: If $0 < \lim_{\gamma \to \infty} \frac{\bar{a}}{\bar{c}} < 1$ and $\gamma^* < \gamma < \infty$, then there is a $p^* \left(0 \le p^* \le 1\right)$ such that if $p = p^*$, $E(J) - E(NJ) = 0$, and if $p < p^*$, $E(J) - E(NJ) < 0$.

Proof: By Lemma 3, if $\gamma^* < \gamma < \infty$, then $E(Jalone) - E(NJtogether) < 0$ and $E(Jtogether) - E(NJalone) > 0$. Here, $E(J) - E(NJ) = p[E(Jtogether) - E(NJalone)]$ $+ (1-p)[E(Jalone) - E(NJtogether)]$ by equations (A1.1) and (A1.2). Thus, if $0 < \lim_{\gamma \to \infty} \frac{\bar{a}}{\bar{c}} < 1$ and $\gamma^* < \gamma < \infty$, $\lim_{p \to 0} E(J) - E(NJ) = E(Jalone) - E(NJtogether) < 0$ and $\lim_{p \to 1} E(J) - E(NJ) = E(Jtogether) - E(NJalone) > 0$. Hence, by the intermediate value theorem, there is $p^* \left(0 \le p^* \le 1\right)$ such that if $p = p^*$, $E(J) - E(NJ) = 0$ and if $p < p^*$, $E(J) - E(NJ) < 0$. ■

Proposition 1 indicates that, if $0 < \lim_{\gamma \to \infty} \frac{\bar{a}}{\bar{c}} < 1$, $\gamma^* < \gamma < \infty$, and $p < p^*$, then the choice of option ***NJ*** gives the higher expected utility than that of option ***J*** to a household; that is, a household may make the rational choice of taking a Pareto-inefficient transition path. The lemmas and proposition require no friction, and a Pareto-inefficient transition path can be chosen even in a frictionless economy. This result is very important because it offers counter-evidence against the conjecture that households never rationally choose any Pareto-inefficient transition path in a frictionless economy.

A1.2.1.2 Conditions for a rational Pareto-inefficient path

The proposition requires several conditions. Among them, $\gamma^* < \gamma < \infty$ may appear rather strict. If γ^* is very large, option ***NJ*** will be rarely chosen. However, if path ***NJ*** is such that consumption is reduced sharply after the shock, option ***NJ*** gives the higher expected utility than option ***J*** even though γ is very small. For example, for any $\gamma \left(0 < \gamma < \infty\right)$,

$$\begin{aligned}
&\lim_{s \to 0} \frac{1}{s} [E(Jalone) - E(NJtogether)] \\
&= \lim_{s \to 0} \frac{1}{s} \int_0^s \exp(-\theta t)[u(c_t + b_t) - u(c_t)]dt + \lim_{s \to 0} \frac{1}{s} \int_s^\infty \exp(-\theta t)[u(\bar{c} - \bar{a}) - u(\bar{c})]dt \\
&= u(c_0 + b_0) - u(c_0) - \frac{1}{\theta} \lim_{s \to 0} \frac{u(\bar{c}) - u(\bar{c} - s\theta b_0)}{s} = u(c_0 + b_0) - u(c_0) - b_0 \frac{du(\bar{c})}{d\bar{c}}
\end{aligned}$$

$$= \frac{(c_0+b_0)^{1-\gamma} - c_0^{1-\gamma}}{1-\gamma} - b_0\bar{c}^{\,-\gamma} = \bar{c}^{\,-\gamma}\left\{\bar{c}^{\,\gamma}\left[\frac{(c_0+b_0)^{1-\gamma}}{1-\gamma} - \frac{c_0^{1-\gamma}}{1-\gamma}\right] - b_0\right\} < 0\,,$$

because

$$\lim_{\gamma\to 1}\bar{c}^{\,\gamma}\left[\frac{(c_0+b_0)^{1-\gamma}}{1-\gamma} - \frac{c_0^{1-\gamma}}{1-\gamma}\right] = \bar{c}\left[\ln(c_0+b_0) - \ln(c_0)\right] = \bar{c}\ln\left(1+\frac{b_0}{c_0}\right) < b_0$$

and

$$\lim_{\gamma\to\infty}\bar{c}^{\,\gamma}\left[\frac{(c_0+b_0)^{1-\gamma}}{1-\gamma} - \frac{c_0^{1-\gamma}}{1-\gamma}\right] = \lim_{\gamma\to\infty}\bar{c}^{\,\gamma}c_0^{1-\gamma}\left[\frac{\left(1+\frac{b_0}{c_0}\right)^{1-\gamma} - 1}{1-\gamma}\right] = 0$$

due to $\bar{c} < c_0$. That is, for each combination of path ***NJ*** and *γ*, there is $s^*(>0)$ such that, if $s < s^*$, then $E(Jalone) - E(NJtogether) < 0$.

Consider an example in which path ***NJ*** is such that b_t is constant as $b_t = \bar{b}$ before *s* (Figure A1.3); thus $E\int_0^s b_t = s\bar{b}$. In this ***NJ*** path, consumption is reduced more sharply than it is in the case shown in Figure A1.2. In this case, because $\bar{a} > E\theta\int_0^s b_t = \theta s\bar{b}$, $0 < \gamma$, and $c_s < c_t$ for $t < s$, then

$$\begin{aligned}&E\int_0^s \exp(-\theta t)\left[u(c_t+b_t) - u(c_t)\right]dt \\ &< E\int_0^s \exp(-\theta t)dt\left[u(c_s+\bar{b}) - u(c_s)\right] = E\,\frac{1-\exp(-\theta s)}{\theta}\left[u(c_s+\bar{b}) - u(c_s)\right],\end{aligned}$$

and in addition,

$$\begin{aligned}&E\int_s^\infty \exp(-\theta t)\left[u(\bar{c}-\bar{a}) - u(\bar{c})\right]dt = E\int_s^\infty \exp(-\theta t)dt\left[u(\bar{c}-\bar{a}) - u(\bar{c})\right] = E\,\frac{\exp(-\theta s)}{\theta}\left[u(\bar{c}-\bar{a}) - u(\bar{c})\right] \\ &< E\,\frac{\exp(-\theta s)}{\theta}\left[u(\bar{c}-\theta s\bar{b}) - u(\bar{c})\right].\end{aligned}$$

Hence,

$$
\begin{aligned}
&E(Jalone) - E(NJtogether) \\
&\qquad = E\int_0^s \exp(-\theta t)\left[u(c_t + b_t) - u(c_t)\right]dt + E\int_s^\infty \exp(-\theta t)\left[u(\bar{c} - \bar{a}) - u(\bar{c})\right]dt \\
&\qquad < E\,\frac{1-\exp(-\theta s)}{\theta}\left[u\left(c_s + \bar{b}\right) - u(c_s)\right] + E\,\frac{\exp(-\theta s)}{\theta}\left[u\left(\bar{c} - \theta s\bar{b}\right) - u(\bar{c})\right] \\
&\qquad = E\,\frac{1-\exp(-\theta s)}{\theta}\left\{\left[u\left(c_s + \bar{b}\right) - u(c_s)\right] - \frac{\exp(-\theta s)}{1-\exp(-\theta s)}\left[u(\bar{c}) - u\left(\bar{c} - \theta s\bar{b}\right)\right]\right\}.
\end{aligned}
$$

As γ becomes larger, the ratio $\dfrac{u\left(c_s + \bar{b}\right) - u(c_s)}{u(\bar{c}) - u\left(\bar{c} - \theta s\bar{b}\right)}$ becomes smaller; thus, larger values of s can satisfy $E(Jalone) - E(NJtogether) < 0$. For example, suppose that $\bar{c} = 10$, $c_s = 10.2$, $\bar{b} = 0.3$, and $\theta = 0.05$. If $\gamma = 1$, then $s^* = 1.5$ at the minimum, and if $\gamma = 5$, then $s^* = 6.8$ at the minimum. This result implies that, if option ***NJ*** is such that consumption is reduced relatively sharply after the shock (e.g., $b_t = \bar{b}$) and $p < p^*$, option ***NJ*** will usually be chosen. Choosing option ***NJ*** is not a special case observed only if γ is very large, but option ***NJ*** can normally be chosen when the value of γ is within usually observed values. Conditions for generating a rational Pareto-inefficient transition path therefore are not strict. In a depression, consumption usually declines sharply after the shock, which suggests that households have chosen the ***NJ*** option.

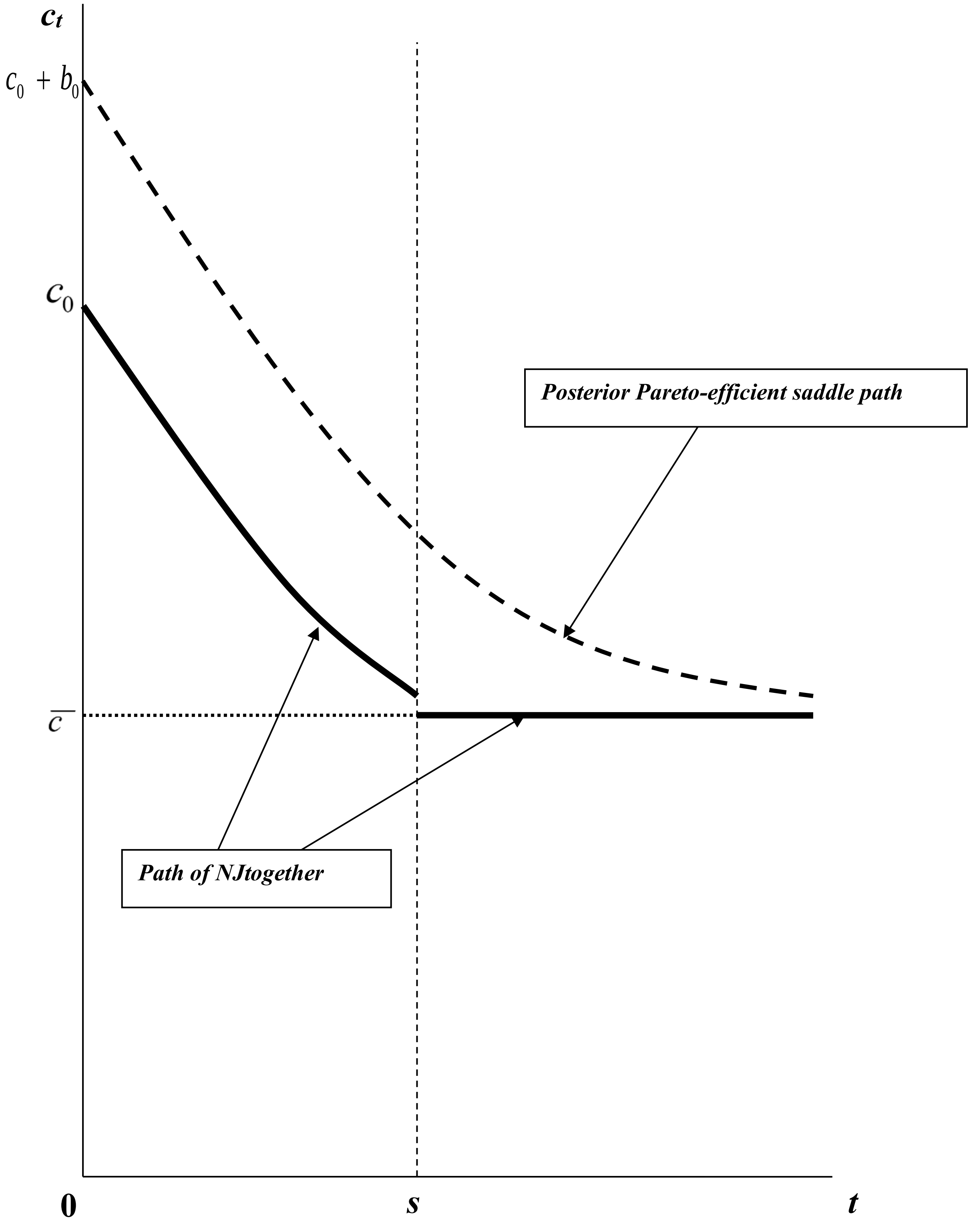

Figure A1.3: A Pareto-inefficient transition path

A1.3 Nash equilibrium

A1.3.1 A Nash equilibrium consisting of *NJ* strategies

A household strategically determines whether to choose the ***J*** or ***NJ*** option, considering other households' choices. All households know that each of them forms expectations about the future values of its utility and makes a decision in the same manner. Since all households are identical, the best response of each household is identical. Suppose that there are $H\ (\in N)$ identical households in the economy where H is sufficiently large (as assumed in Section A1.1.1). Let $q_\eta\ (0 \le q_\eta \le 1)$ be the probability that a household $\eta\ (\in H)$ chooses option ***J***. The average utility of the other households almost equals that of all households because H is sufficiently large. Hence, the average expected utilities of the other households that choose the ***J*** and ***NJ*** options are *E*(*Jtogether*) and *E*(*NJtogether*), respectively. Hence, the payoff matrix of the *H*-dimensional symmetric mixed strategy game can be described as shown in Table 1.

Table 1: The payoff matrix

		Any other household	
		J	***NJ***
A household	***J***	***E*(*Jtogether*), *E*(*Jtogether*)**	***E*(*Jalone*), *E*(*NJtogether*)**
	NJ	***E*(*NJalone*), *E*(*Jtogether*)**	***E*(*NJtogether*), *E*(*NJtogether*)**

Each identical household determines its behavior on the basis of this payoff matrix. In this mixed strategy game, strategy profiles

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

are Nash equilibria for the following reason. By Proposition 1, the best response of a household η is ***J*** (i.e., $q_\eta = 1$) if $p > p^*$, indifferent between ***J*** and ***NJ*** (i.e., any $q_\eta \in [0,1]$) if $p = p^*$, and ***NJ*** (i.e., $q_\eta = 0$) if $p < p^*$. Because all households are identical, the best-response correspondence of each household is identical such that $q_\eta = \{1\}$ if $p > p^*$, [0,1] if $p = p^*$, and {0} if $p < p^*$ for any household $\eta \in H$. Hence, the mixed strategy profiles (1, 1,…,1), $(p^*,p^*,\ldots,p^*)$, and (0,0,…,0) are the intersections of the graph of the best-response correspondences of all households. The Pareto-efficient saddle path solution (1,1,…,1; i.e., ***Jtogether***) is a pure strategy Nash equilibrium, but a Pareto-inefficient transition path (0,0,…,0; i.e., ***NJtogether***) is also a pure strategy Nash equilibrium. In addition, there is a mixed strategy Nash equilibrium ($p^*, p^*, ..., p^*$).

A1.3.2 Selection of equilibrium

Determining which Nash equilibrium, either ***NJtogether*** (0,0,…,0) or ***Jtogether*** (1,1,…,1), is dominant requires refinements of the Nash equilibrium, which necessitate additional criteria. Here, if households have the preference of worst-case aversion in the sense that they avoid options that include the worst-case scenario when its probability is not known, households suppose very low *p* and select the ***NJtogether*** (0,0,…,0) equilibrium. Because

$$
\begin{aligned}
&E(Jalone) - E(NJalone) = E\left\{\int_0^s \exp(-\theta t)\left[u(c_t + b_t) - u(c_t)\right]dt + \int_s^\infty \exp(-\theta t)\left[u(\bar{c} - \bar{a}) - u(\hat{c}_t + a_t)\right]dt\right\} \\
&\quad < E\left\{\int_0^s \exp(-\theta t)\left[u(c_t + b_t) - u(c_t)\right]dt + \int_s^\infty \exp(-\theta t)\left[u(\bar{c} - \bar{a}) - u(\bar{c})\right]dt\right\} \\
&\quad = E(Jalone) - E(NJtogether) < 0, \qquad \text{(A1.7)}
\end{aligned}
$$

by Lemma 3, then ***Jalone*** is the worst choice in the sense of the amount of payoff, followed by ***NJtogether***, and ***NJalone***, and ***Jtogether*** is the best. The outcome of choosing option ***J*** is more dispersed than that of option ***NJ***. If households have the preference of worst-case aversion in the above-mentioned sense and avoid options that include the worst-case scenario when they have no information on its probability, a household will prefer the less dispersed option (***NJ***), fearing the worst situation that the household alone substantially increases consumption while the other households substantially decrease consumption after the shock. This behavior is rational because it is consistent with preferences. Since all households are identical and know inequality (A1.7), all households will equally suppose that they all prefer the less dispersed ***NJ*** option; therefore, all of them will suppose a very low *p*, particularly $p = 0$, and select the ***NJtogether*** (0,0,…,0) equilibrium, which is the Nash equilibrium of a Pareto-inefficient path. Thereby, unlike most multiple equilibria models, the problem of indeterminacy does not arise, and animal spirits (e.g., pessimism or optimism) are unnecessary to explain the selection.

A1.4 Amplified generation of unutilized resources

A Nash equilibrium of a Pareto-inefficient path successively generates unutilized products because of b_t. They are left unused, discarded, or preemptively not produced during the path. Unused or discarded goods and services indicate a decline in sales and an increase in inventory for firms. Preemptively suspended production results in an increase in unemployment and idle capital. As a result, profits decline and some parts of firms need to be liquidated, which is unnecessary if the economy proceeds on the J path (i.e., the posterior Pareto-efficient path). If the liquidation is implemented immediately after the shock, unutilized products because of b_t will no longer be generated, but such a liquidation would generate a tremendous shock. The process of the liquidation, however, will take time because of various frictions, and excess capital that generates unutilized products because of b_t will remain for a long period. During the period when capital is not reduced to the posterior steady-state level, unutilized products are successively generated. In a period, unutilized products are generated and eliminated, but in the next period, another, new, unutilized products are generated and eliminated. This cycle is repeated in every period throughout the transition path, and it implies that demand is lower than supply in every period. This phenomenon may be interpreted as a general glut or a persisting disequilibrium by some definitions of equilibrium.

Because of the liquidation of firms, many employees are dismissed and capital is discarded. Note that a Nash equilibrium of a Pareto-inefficient path can be selected irrespective of frictions (as discussed in Section A1.2), and if the economy is frictionless, the liquidation will not raise the unemployment rate. However, if there are frictions on quantity and price adjustments, the unemployment rate will rise substantially as a result of the liquidation. Unemployment "naturally" exists even on a Pareto-efficient path because of frictions. The extra unemployment resulting from the liquidation caused by unutilized products is in addition to this natural unemployment. In this sense, unutilized products amplify the generation of unutilized resources. The extra unemployment and discarded capital can be huge and persistently generated during the Pareto-inefficient transition path, matching the observed magnitudes of unutilized resources in depressions.

APPENDIX 2:

The MDC-based procedure

A2.1 "Comfortability" of CWR

Let k_t and w_t be per capita capital and wage (labor income), respectively, in period t. Under the MDC-based procedure, a household should first subjectively evaluate the value of $\frac{\tilde{w}_t}{\tilde{k}_t}$ where $\tilde{k}_t$ and $\tilde{w}_t$ are household k_t and w_t, respectively. Let Γ be the subjective valuation of $\frac{\tilde{w}_t}{\tilde{k}_t}$ by a household and Γ_i be the value of $\frac{\tilde{w}_t}{\tilde{k}_t}$ of household i ($i = 1, 2, 3, \dots, M$). Each household assesses whether it feels comfortable with its current Γ (i.e., its combination of income and capital expressed by CWR). "Comfortable" in this context means "at ease," "not anxious," and other similar feelings.

Let the "degree of comfortability" (DOC) represent how comfortable a household feels with its Γ. The higher the value of DOC, the more a household feels comfortable with its Γ. For each household, there will be a most comfortable CWR value because the household will feel less comfortable if CWR is either too high or too low. That is, for each household, a maximum DOC exists. Let $\tilde{s}$ be a household's state at which its DOC is the maximum (MDC). MDC therefore indicates the state at which the combination of revenues and assets is felt most comfortable. Let $\Gamma(\tilde{s})$ be a household's Γ when it is at $\tilde{s}$. $\Gamma(\tilde{s})$ indicates the Γ that gives a household its MDC, and $\Gamma(\tilde{s}_i)$ is household i's Γ_i when it is at $\tilde{s}_i$.

A2.2 Homogeneous population

I first examine the behavior of households in a homogeneous population (i.e., all households are assumed to be identical).

A2.2.1 Rules

Household i should act according to the following rules:

Rule 1-1: If household i feels that the current Γ_i is equal to $\Gamma(\tilde{s}_i)$, it maintains the same level of consumption for any i.
Rule 1-2: If household i feels that the current Γ_i is not equal to $\Gamma(\tilde{s}_i)$, it adjusts its level of consumption until it feels that Γ_i is equal to $\Gamma(\tilde{s}_i)$ for any i.

A2.2.2 Steady state

Households can reach a steady state even if they behave only according to Rules 1-1 and

1-2. Let S_t be the state of the entire economy in period t and $\Gamma(S_t)$ be the value of $\frac{w_t}{k_t}$ of the entire economy at S_t (i.e., the economy's average CWR). In addition, let $\tilde{S}_{MDC}$ be the steady state at which MDC is achieved and kept constant by all households, and $\Gamma(\tilde{S}_{MDC})$ be $\Gamma(S_t)$ for $S_t = \tilde{S}_{MDC}$. Let also $\tilde{S}_{RTP}$ be the steady state under the RTP-based procedure; that is, it is the steady state in a Ramsey-type growth model in which households behave based on rational expectations generated by discounting utilities by θ, where θ (> 0) is the RTP of a household. In addition, let $\Gamma(\tilde{S}_{RTP})$ be $\Gamma(S_t)$ for $S_t = \tilde{S}_{RTP}$.

Proposition 1: If households behave according to Rules 1-1 and 1-2, and if the value of θ that is calculated from the values of variables at $\tilde{S}_{MDC}$ is used as the value of θ under the RTP-based procedure in an economy where θ is identical for all households, then $\Gamma(\tilde{S}_{MDC}) = \Gamma(\tilde{S}_{RTP})$.
Proof: See Harashima (2018a).

Proposition 1 indicates that we can interpret $\tilde{S}_{MDC}$ to be equivalent to $\tilde{S}_{RTP}$. This means that both the MDC-based and RTP-based procedures can function equivalently and that CWR at MDC can be substituted for RTP as a guide for household behavior.

A2.3 Heterogeneous population

In actuality, however, households are not identical—they are heterogeneous—and if heterogeneous households behave unilaterally, there is no guarantee that a steady state other than corner solutions exists (Becker 1980; Harashima 2010, 2012a). However, Harashima (2010, 2012a) has shown that SH exists under the RTP-based procedure. In addition, Harashima (2018a) has shown that SH also exists under the MDC-based procedure, although Rules 1-1 and 1-2 have to be revised, and a rule for the government should be added in a heterogeneous population.

Suppose that households are identical except for their MDCs (i.e., their values of $\Gamma(\tilde{s})$). Let $\tilde{S}_{MDC,SH}$ be the steady state at which MDC is achieved and kept constant by any household (i.e., SH in a heterogeneous population under the MDC-based procedure), and let $\Gamma(\tilde{S}_{MDC,SH})$ be $\Gamma(S_t)$ for $S_t = \tilde{S}_{MDC,SH}$. In addition, let Γ_R be a household's numerically adjusted value of Γ for SH based on its estimated value of $\Gamma(\tilde{S}_{MDC,SH})$ and several other related values. Specifically, let $\Gamma_{R,i}$ be Γ_R of household i, T be the net transfer that a household receives from the government with regard to SH, and T_i be the net transfer that household i receives ($i = 1,2,3, \dots, M$).

A2.3.1 Revised and additional rules

Household i should act according to the following rules in a heterogeneous population:

Rule 2-1: If household i feels that the current $\Gamma_{R,i}$ is equal to $\Gamma(\tilde{s}_i)$, it maintains the same level of consumption as before for any i.
Rule 2-2: If household i feels that the current $\Gamma_{R,i}$ is not equal to $\Gamma(\tilde{s}_i)$, it adjusts its level of consumption or revises its estimated value of $\Gamma(\tilde{S}_{MDC,SH})$ so that it perceives that $\Gamma_{R,i}$ is equal to $\Gamma(\tilde{s}_i)$ for any i.

At the same time, the government should act according to the following rule:

Rule 3: The government adjusts T_i for some i if necessary so as to make the number of votes cast in elections in response to increases in the level of economic inequality equivalent to the number cast in response to decreases.

A2.3.2 Steady state

Even if households and the government behave according to Rules 2-1, 2-2, and 3, there is no guarantee that the economy can reach $\tilde{S}_{MDC,SH}$. However, thanks to the government's intervention, SH can be approximately achieved. Let $\tilde{S}_{MDC,SH,ap}$ be the state at which $\tilde{S}_{MDC,SH}$ is approximately achieved (an approximate SH), and $\Gamma(\tilde{S}_{MDC,SH,ap})$ be $\Gamma(S_t)$ at $\tilde{S}_{MDC,SH,ap}$ on average. Here, let $\tilde{S}_{RTP,SH}$ be the steady state that satisfies SH under the RTP-based procedure, that is, in a Ramsey-type growth model in which households that are identical except for their θs behave generating rational expectations by discounting utilities by their θs. Furthermore, let $\Gamma(\tilde{S}_{RTP,SH})$ be $\Gamma(S_t)$ for $S_t = \tilde{S}_{RTP,SH}$.

Proposition 2: If households are identical except for their values of $\Gamma(\tilde{s})$ and behave unilaterally according to Rules 2-1 and 2-2, if the government behaves according to Rule 3, and if the value of θ_i that is calculated back from the values of variables at $\tilde{S}_{MDC,SH,ap}$ is used as the value of θ_i for any i under the RTP-based procedure in an economy where households are identical except for their θs, then $\Gamma(\tilde{S}_{MDC,SH,ap}) = \Gamma(\tilde{S}_{RTP,SH})$.
Proof: See Harashima (2018a).

Proposition 2 indicates that we can interpret $\tilde{S}_{MDC,SH,ap}$ as being equivalent to $\tilde{S}_{RTP,SH}$. No matter what values of T, Γ_R, and $\Gamma(\tilde{S}_{MDC,SH})$ are estimated by households, any $\tilde{S}_{MDC,SH,ap}$ can be interpreted as the objectively correct and true steady state. In addition, a government need not necessarily provide the objectively correct T_i for $\tilde{S}_{MDC,SH,ap}$ even though the $\tilde{S}_{MDC,SH,ap}$ is interpreted as objectively correct and true.

APPENDIX 3:
Sustainable heterogeneity

A3.1 SH

Here, three heterogeneities—RTP, degree of risk aversion (DRA), and productivity—are considered. Suppose that there are two economies (Economy 1 and Economy 2) that are identical except for RTP, DRA, and productivity. Each economy is interpreted as representing a group of identical households, and the population in each economy is constant and sufficiently large. The economies are fully open to each other, and goods, services, and capital are freely transacted between them, but labor is immobilized in each economy. Households also provide laborers whose abilities are one of the factors that determine the productivity of each economy. Each economy can be interpreted as representing either a country or a group of identical households in a country. Usually, the concept of the balance of payments is used only for international transactions, but in this paper, this concept and the associated terminology are used even if each economy represents a group of identical households in a country.

The production function of Economy i (= 1, 2) is

$$y_{i,t} = A_t^{\alpha} k_{i,t}^{1-\alpha} \ ,$$

where $y_{i,t}$ and $k_{i,t}$ are the production and capital of Economy i in period t, respectively; A_t is technology in period t; and α ($0 < \alpha < 1$) is a constant and indicates the labor share. All variables are expressed in per capita terms. The current account balance in Economy 1 is τ_t and that in Economy 2 is $-\tau_t$. The accumulated current account balance

$$\int_0^t \tau_s ds$$

mirrors capital flows between the two economies. The economy with current account surpluses invests them in the other economy. Since $\frac{\partial y_{1,t}}{\partial k_{1,t}} \left(= \frac{\partial y_{2,t}}{\partial k_{2,t}} \right)$ is returns on investments,

$$\frac{\partial y_{1,t}}{\partial k_{1,t}} \int_0^t \tau_s ds \ \text{ and } \ \frac{\partial y_{2,t}}{\partial k_{2,t}} \int_0^t \tau_s ds$$

represent income receipts or payments on the assets that an economy owns in the other economy. Hence,

$$\tau_t - \frac{\partial y_{2,t}}{\partial k_{2,t}} \int_0^t \tau_s ds$$

is the balance on goods and services of Economy 1, and

$$\frac{\partial y_{1,t}}{\partial k_{1,t}} \int_0^t \tau_s ds - \tau_t$$

is that of Economy 2. Because the current account balance mirrors capital flows between the economies, the balance is a function of capital in both economies such that

$$\tau_t = \kappa\left(k_{1,t}, k_{2,t}\right) .$$

This two-economy model can be easily extended to a multi-economy model. Suppose that a country consists of H economies that are identical except for RTP, DRA, and productivity (Economy 1, Economy 2, … , Economy H). Households within each economy are identical. $c_{i,t}$, $k_{i,t}$, and $y_{i,t}$ are the per capita consumption, capital, and output of Economy i in period t, respectively; and θ_i, $\varepsilon_q = -\frac{c_{1,t}u_i''}{u_i'}$, ω_i, and u_i are the RTP, DRA, productivity, and utility function of a household in Economy i, respectively (i = 1, 2, …, H). The production function of Economy i is

$$y_{i,t} = \omega_i A_t^{\alpha} k_{i,t}^{1-\alpha} \quad .$$

In addition, $\tau_{i,j,t}$ is the current account balance of Economy i with Economy j, where i, j = 1, 2, … , H and $i \neq j$.

Harashima (2010) showed that if, and only if,

$$\lim_{t\to\infty} \frac{\dot{c}_{i,t}}{c_{i,t}} = \left(\frac{\sum_{q=1}^{H} \varepsilon_q \omega_q}{\sum_{q=1}^{H} \omega_q}\right)^{-1} \left\{\left[\frac{\varpi\alpha \sum_{q=1}^{H} \omega_q}{Hm\nu(1-\alpha)}\right]^{\alpha} - \frac{\sum_{q=1}^{H} \theta_q \omega_q}{\sum_{q=1}^{H} \omega_q}\right\} \tag{A3.1}$$

for any i (= 1, 2, … , H), all the optimality conditions of all heterogeneous economies are satisfied, where m, ν, and ϖ are positive constants. Furthermore, if, and only if, equation (A2.1) holds,

$$\lim_{t\to\infty}\frac{\dot{c}_{i,t}}{c_{i,t}}=\lim_{t\to\infty}\frac{\dot{k}_{i,t}}{k_{i,t}}=\lim_{t\to\infty}\frac{\dot{y}_{i,t}}{y_{i,t}}=\lim_{t\to\infty}\frac{\dot{A}_t}{A_t}=\lim_{t\to\infty}\frac{\dot{\tau}_{i,j,t}}{\tau_{i,j,t}}=\lim_{t\to\infty}\frac{\frac{d\int_0^t\tau_{i,j,s}ds}{dt}}{\int_0^t\tau_{i,j,s}ds}$$

is satisfied for any *i* and *j* (*i* ≠ *j*). Because all the optimality conditions of all heterogeneous economies are satisfied, the state at which equation (A2.1) holds is SH by definition.

A3.2 SH with government intervention

As shown above, SH is not necessarily naturally achieved, but if the government properly transfers money or other types of economic resources from some economies to other economies, SH is achieved.

Let Economy 1+2+…+ ($H-1$) be the combined economy consisting of Economies 1, 2, …, and ($H-1$). The population of Economy 1+2+… + ($H-1$) is therefore ($H-1$) times that of Economy *i* (= 1, 2, 3, …, *H*). $k_{1+2+\cdots+(H-1),t}$ indicates the capital of a household in Economy 1+2+…+ ($H-1$) in period *t*. Let g_t be the amount of government transfers from a household in Economy 1+2+…+ ($H-1$) to households in Economy *H*, and $\bar{g}_t$ be the ratio of g_t to $k_{1+2+\cdots+(H-1),t}$ in period *t* to achieve SH. That is,

$$g_t=\bar{g}_t k_{1+2+\cdots,+(H-1),t}\ .$$

$\bar{g}_t$ is solely determined by the government and therefore is an exogenous variable for households.

Harashima (2010) showed that if

$$\lim_{t\to\infty}\bar{g}_t=\left(\frac{\sum_{q=1}^{H}\varepsilon_q\omega_q}{\omega_H}\right)^{-1}\left\{\frac{\varepsilon_H\sum_{q=1}^{H}\omega_q-\sum_{q=1}^{H}\varepsilon_q\omega_q}{\sum_{q=1}^{H-1}\omega_q}\left[\frac{\varpi\alpha\sum_{q=1}^{H}\omega_q}{Hmv(1-\alpha)}\right]^{\alpha}-\frac{\varepsilon_H\sum_{q=1}^{H}\theta_q\omega_q-\theta_H\sum_{q=1}^{H}\varepsilon_q\omega_q}{\sum_{q=1}^{H-1}\omega_q}\right\}$$

is satisfied for any *i* (= 1, 2, …, *H*) in the case that Economy *H* is replaced with Economy *i*, then equation (A2.1) is satisfied (i.e., SH is achieved by government interventions even if households behave unilaterally). Because SH indicates a steady state, $\lim_{t\to\infty}\bar{g}_t$= constant.

Note that the amount of government transfers from households in Economy 1+2+ … + ($H-1$) to a household in Economy *H* at SH is

$$(H-1)g_t=(H-1)\ k_{1+2+\cdots+(H-1),t}\lim_{t\to\infty}\bar{g}_t\ .$$

Note also that a negative value of g_t indicates that a positive amount of money or other type of economic resource is transferred from Economy H to Economy $1+2+\cdots+(H-1)$ and vice versa.

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