A Theory of Inflation: The Law of Motion for Inflation under the MDC-based Procedure

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Abstract

In this paper, I construct an inflation model in an economy where the government and households behave under a procedure based on the maximum degree of comfortability (MDC) to reach steady state. MDC indicates the state at which the combination of revenues and assets is felt most comfortable. I show that, if MDCs of the government and households are not consistent, inflation accelerates (or decelerates) because the government behaves to match the rate of increase of its real obligations with its MDC, but households and firms behave to match the real interest rate with household's MDC. This inconsistency or contradiction must be resolved by acceleration (or deceleration) of inflation. To control inflation, therefore, a truly independent central bank is needed because MDC is a type of preference. The central bank can control the government's MDC by forcing the government to increase its real obligations and thereby control inflation.

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Keywords: Capital-wage ratio; Deflation; Inflation acceleration; Law of motion for inflation; Monetary policies

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1 INTRODUCTION

There are two competing inflation models: those based on the New Keynesian Phillips curve (NKPC) and those based on the fiscal theory of the price level (FTPL). However, neither of them seems to be sufficiently compelling because both possess important problems. First, the pure NKPC has a serious problem in that it is not consistent with the observed persistence of inflation (e.g., Fuhrer and Moore, 1995; Galí and Gertler, 1999; Mankiw, 2001). Since Galí and Gertler (1999), a modified version of NKPC (i.e., the hybrid NKPC) that includes lagged inflation has been intensely studied. The hybrid NKPC captures the persistent nature of inflation well, but the question remains of why rational agents behave in a backward-looking manner, even if only partially. Galí, Gertler, and López-Salido (2005) argued that a more coherent rationale for the role of lagged inflation needs to be addressed in the hybrid NKPC. Furthermore, Fuhrer (2006) concluded that inflation in the hybrid NKPC inherits relatively little persistence from its driving process.

Proponents of FTPL argue that a problem with conventional NKPC inflation theory is that it largely neglects the importance of the government's borrowing behavior in inflation dynamics (e.g., Leeper 1991; Sims 1994, 1998, 2001; Woodford 1995, 2001; Cochrane 1998a, 1998b, 2005). They say that, if a government borrows money without limits, inflation will eventually explode (e.g., Sargent and Wallace 1981). The FTPL implies that, if a government's borrowing behavior is modeled well, the mechanism of severely deviated inflation paths can be explained without assuming ad hoc frictions or irrationality. Most FTPL models have not, however, explicitly modeled the behavior of government in detail. Hence, some critics contend that the theory is fallacious (e.g., Kocherlakota and Phelan 1999; McCallum 2001, 2003; Buiter 2002, 2004; Niepelt 2004).

Harashima (2004, 2005, 2006, 2007a, 2007b, 2007c, 2008, 2013a, 2013b, 2016a, 2018c) has presented an alternative inflation model that can explain the persistent nature of inflation without an ad hoc assumption that households behave in a backward-looking manner and that explicitly incorporates the government's borrowing behavior. That is, this model can solve the main problems of the inflation models based on NKPC and FTPL. In this alternative model, a trend in inflation is naturally generated as a result of heterogeneity in the rate of time preference (RTP) between households and the government.

Similar to most other recent economic models, Harashima's alternative inflation model is constructed in the framework of the rational expectations hypothesis. However, the rational expectations hypothesis has been criticized for imposing substantial demands on economic agents. To generate rational expectations, households have to do something equivalent to computing complex, large-scale, non-linear, dynamic macro-econometric models, but can a household routinely do such a thing in its daily life? Evans and Honkapohja (2001) have argued that this problem can be solved by introducing a learning mechanism (see also, e.g., Marcet and Sargent, 1989; Ellison and Pearlman, 2011), but this solution is not necessarily regarded as being sufficiently successful because arbitrary learning rules have to be assumed.

Harashima (2018a, 2019) has presented an alternative procedure for households to reach steady state as a substitute for the conventionally assumed procedure, under which rational expectations are generated with the RTP-based procedure. Under the alternative procedure, the capital-wage ratio (CWR) at the "maximum degree of comfortability" (MDC) plays the crucial role (hereafter, the MDC-based procedure). The MDC-based procedure is very simple. A household has only to act on its feelings about whether the combination of its labor income and capital (wealth) is comfortable or not; that is, households behave targeting only their own CWR at their own MDC. The steady state reached under the MDC-based procedure can be interpreted to be equivalent to the one reached under the RTP-based procedure (i.e., the one that is rationally expected). Because the MDC-based procedure is far easier for households to use than the RTP-based procedure and leads households to the same steady state, it is much more likely that households actually use the MDC-based procedure rather than the RTP-based procedure.

Here, I modify Harashima's RTP-based inflation model so that households and the government behave based on this MDC-based procedure, rather than the originally proposed RTP procedure. The modified inflation model indicates that even under the MDC-based procedure, trend inflation is still naturally generated as a result of heterogeneity in preferences, in this case, inconsistency between MDCs of households and the government. The element of expectations is therefore irrelevant to the law of motion for inflation in this modified model, although households and the government still behave fully in forward-looking manners.

2 MDC-BASED PROCEDURE

In this section, the MDC-based procedure is explained briefly following Harashima (2018a, 2019).

2.1 "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 $\frac{\breve{w}_t}{\breve{k}_t}$ where $\breve{k}_t$ and $\breve{w}_t$ are household k_t and w_t, respectively. Let Γ be the subjective valuation of $\frac{\breve{w}_t}{\breve{k}_t}$ by a household and Γ_i be the value of $\frac{\breve{w}_t}{\breve{k}_t}$ of household i (i = 1, 2, 3, … , 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 $\tilde{s}_i$.

2.2 *Homogeneous population*

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

2.2.1 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.

2.2.2 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 $\Gamma\left(\tilde{S}_{MDC}\right)$ 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 $\Gamma\left(\tilde{S}_{RTP}\right)$ 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, 2019).

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.

2.3 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, 2012, 2017). However, Harashima (2010, 2012, 2017) has shown that a sustainable heterogeneity (SH) at which all optimality conditions of all heterogeneous households are simultaneously satisfied exists under the RTP-based procedure. In addition, Harashima (2018a, 2019) 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 ($i = 1,2,3, \dots, M$).

2.3.1 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.

2.3.2 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, and $\Gamma\left(\tilde{S}_{MDC,SH,ap}\right)$ 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 $\Gamma\left(\tilde{S}_{RTP,SH}\right)$ 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 $\Gamma\left(\tilde{S}_{MDC,SH,ap}\right) = \Gamma\left(\tilde{S}_{RTP,SH}\right)$.
Proof: See Harashima (2018a, 2019).

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 $\Gamma\left(\tilde{S}_{MDC,SH}\right)$ 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.

3 GOVERNMENT AND HOUSEHOLD MDC

Suppose for simplicity that technologies are exogenously given and constant (i.e., there is no technological progress).

3.1 The nature of the government's MDC

3.1.1 MDC

The value of

$$-\frac{g_t - x_t - s_t}{b_t}$$

is constant at steady state such that $\dot{g}_t = 0$, $\dot{x}_t = 0$, $\dot{s}_t = 0$, and $\dot{b}_t = 0$, where b_t is the nominal obligation of the government to pay for its accumulated bonds, g_t is the nominal government expenditure, x_t is the nominal tax revenue, and s_t is the nominal amount of seigniorage at time t, respectively. All variables are expressed in per capita terms. At this steady state, the MDC of government should be satisfied because it is the steady state that the government wants and has successfully managed to achieve. Let

$$\Gamma_G = -\frac{g_t - x_t - s_t}{b_t}\left(\frac{\alpha}{1-\alpha}\right) \tag{1}$$

at the government's MDC where α ($0 < \alpha < 1$) is a constant in the production function that is assumed to be $y_t = A^{\alpha} k_t^{1-\alpha}$, y_t is per capita output at time t, and A is technology. Because $-\frac{g_t - x_t - s_t}{b_t}$ at the MDC of government (i.e., at steady state) and α are constant, Γ_G is also constant. In addition, Γ_G indicates the most comfortable combination of net revenues ($g_t - x_t - s_t$) and debts (b_t) while MDC indicates the state at which the combination of revenues and assets is felt most comfortable. Hence, Γ_G can be seen as a parameter that indicates the preference of government concerning its MDC.

Let θ_G be the RTP of government. Harashima (2006, 2016a) has shown that in a Ramsey-type growth model in which a government maximizes its expected utility,

$$\theta_G = -\frac{g_t - x_t - s_t}{b_t} \tag{2}$$

holds at steady state for a given value of θ_G. By equations (1) and (2), therefore,

$$\theta_G = \Gamma_G\left(\frac{1-\alpha}{\alpha}\right) . \tag{3}$$

at steady state.

The value of $-\frac{g_t - x_t - s_t}{b_t}$ at steady state in equations (1) and (2) indicates the rate of increase of the government's real obligation to pay for its bonds' return at steady state.

3.1.2 Rate of increase of the government's real obligation

Let R_t be the nominal interest rate for government bonds at time t. Harashima (2007a, 2007c, 2008, 2013a, 2013b, 2018c) has shown that approximately

$$R_t = \int_{t-1}^{t} \int_{s}^{s+1} \pi_v dv ds + r \ , \tag{4}$$

where π_t is the inflation rate at time t and r is the real interest rate at steady state in the private sector. The private sector means the part of the economy run by households and non-governmental firms.

Evidently, $R_t - \pi_t$ indicates the rate of increase of the government's real obligation at time t. On the other hand, as shown in Section 3.1.1, the value of $-\frac{g_t - x_t - s_t}{b_t}$ at steady state also indicates the rate of increase of the government's real obligation. Hence, at steady state

$$R_t - \pi_t = -\frac{g_t - x_t - s_t}{b_t} \ . \tag{5}$$

Therefore, by equations (1), (2), and (5),

$$R_t - \pi_t = \varGamma_G \left(\frac{1-\alpha}{\alpha} \right) = \theta_G \tag{6}$$

at steady state such that $\dot{g}_t = 0$, $\dot{x}_t = 0$, $\dot{s}_t = 0$, and $\dot{b}_t = 0$, which is also at MDC of government. Hence, the increases in the government's real obligation

$$(R_t - \pi_t) b_t = \left[\varGamma_G \left(\frac{1-\alpha}{\alpha} \right) + \pi_t \right] b_t \ \ (= \theta_G b_t)$$

is equal to the real budget surplus $-(g_t - x_t - s_t)$ at steady state.

Note that the rate of increase of the government's real obligation $(R_t - \pi_t)$ is not necessarily equal to the real interest rate in the private sector (r), as indicated in equation (4).

3.2 The nature of household MDC

3.2.1 MDC

Suppose for simplicity that all households are identical (i.e., the homogeneous population model shown in Section 2.2 is used) because the focus of this paper is on the law of motion for inflation, not on household heterogeneity, and the law of motion for inflation basically does not change in the case of heterogeneous population. Note that because $\tilde{S}$ indicates the state of the private sector, the capital owned by government is not included in k_t in $\Gamma(\tilde{S})$ and $\Gamma(\tilde{S}_{MDC})$.

Let Γ_P be the household Γ (i.e., the value of $\frac{w_t}{k_t}$ at the MDC of each identical household), and therefore

$$\Gamma_P = \Gamma(\tilde{S}_{MDC}) \ .$$

In addition, let θ_P be the RTP of each identical household under the RTP-based procedure. The numerical value of θ_P is unknown to the household, but it can be estimated by calculating it back from the value of Γ_P under the MDC-based procedure, as will be shown below. Note, nevertheless, that we cannot know that this estimated numerical value of θ_P is identical to its objectively correct, true, and intrinsic value.

The numerical value of θ_P can be estimated based on the value of Γ_P as follows. First, suppose a Ramsey-type growth model such that each identical household maximizes its expected utility

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

subject to

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

where c_t is the per capita consumption at time t, $u(\cdot)$ is the utility function, and $f(A, k_t)$ is the production function. The production function is assumed to be the same as that assumed in Section 3.1.1 (i.e., $y_t = A^\alpha k_t^{1-\alpha}$). In this Ramsey-type growth model, as a result of the utility maximization behavior of households,

$$\theta_P\left(\frac{\alpha}{1-\alpha}\right) = \frac{w_t}{k_t} \tag{7}$$

at steady state such that $\dot{c}_t = 0$ and $\dot{k}_t = 0$, where w_t is the per capita labor income (wage) that indicates the contribution of labor to output and

$$y_t = w_t + \frac{\partial y_t}{\partial k_t} k_t \ . \tag{8}$$

On the other hand, if household MDC is achieved under the MDC-based procedure (i.e., at $\tilde{S}_{MDC}$),

$$\frac{w_t}{k_t} = \Gamma\left(\tilde{S}_{MDC}\right) = \Gamma_P \tag{9}$$

because $\dot{c}_t = 0$ and $\dot{k}_t = 0$ at $\tilde{S}_{MDC}$. Hence, we can obtain the numerical value of θ_P by calculating it back from the value of Γ_P by substituting equation (9) into equation (7).

3.2.2 The real interest rate

The real interest rate (r) is determined by

$$r = \frac{\partial y_t}{\partial k_t} \tag{10}$$

in the private sector. On the other hand, by the production function ($y_t = A^{\alpha} k_t^{1-\alpha}$),

$$\frac{\partial y_t}{\partial k_t} = (1-\alpha) A^{\alpha} k_t^{-\alpha} = (1-\alpha) \frac{A^{\alpha} k_t^{1-\alpha}}{k_t} = (1-\alpha) \frac{y_t}{k_t} \ , \tag{11}$$

and by equations (8) and (11),

$$\frac{y_t}{k_t} = \alpha^{-1} \frac{w_t}{k_t} \ . \tag{12}$$

Hence, by equations (7), (9), (10), (11), and (12),

$$r = \Gamma_P \left(\frac{1-\alpha}{\alpha}\right) = \theta_P \tag{13}$$

at steady state such that $\dot{c}_t = 0$ and $\dot{k}_t = 0$.

4 LAW OF MOTION FOR INFLATION

It is assumed that Γ_G and Γ_P are heterogeneous. In addition, $\Gamma_P < \Gamma_G$ (i.e., $\theta_P < \theta_G$ by equations [3] and [13]) because this inequality seems to be naturally satisfied and to have held historically in most economies (see Harashima, 2004, 2007a, 2007c, 2008, 2013a, 2013b, 2018c).

4.1 Government

Suppose that the government initially guesses that the rate of increase of its real obligation ($R_t - \pi_t$) is currently lower than $\Gamma_G \left(\frac{1-\alpha}{\alpha}\right)$, that is, $R_t - \pi_t < \Gamma_G \left(\frac{1-\alpha}{\alpha}\right)$. Because equation (6) has to hold at the MDC of government, the current state $R_t - \pi_t < \Gamma_G \left(\frac{1-\alpha}{\alpha}\right)$ does not correspond to the MDC of government. Therefore, the government will take actions to increase $R_t - \pi_t$ up to the point at which equation (6) is satisfied.

To increase $R_t - \pi_t$, the government will absorb additional money (savings) from the private sector, particularly by selling more government bonds and increasing its borrowings (b_t). Because additional government bonds are supplied in the private sector, their price decreases, and thereby their nominal interest rate (R_t) increases. If the inflation rate (π_t) is unchanged, the rate of increase of the government's real obligation ($R_t - \pi_t$) also increases. Nevertheless, equation (1) indicates that current additional increases in b_t require additional increases in x_t (tax revenue) and/or decreases in g_t (expenditures) at steady state (i.e., in the future). Even so, however, the government will increase b_t up to the point at which equation (6) is satisfied to be able to reach its MDC.

This behavior (i.e., current additional increases in b_t despite future additional increases in x_t and/or decreases in g_t) means that the government cares relatively more about the present and less about the future. That is, it has a higher time preference rate (θ_G) than the discount rate that the initial value of $R_t - \pi_t$ indicates. The state where the government's satisfaction with the balance between current borrowing subject to future payment is maximized is its MDC. If a government borrows substantially large amounts of money from the private sector at present despite high future costs, the government's Γ_G (or θ_G) is very high. This value may become particularly high in the case where a regime is in danger, for example, after a defeat in war or a revolution. Even in this type of extreme case, however, a government can still behave with appropriate consideration of its future, and its Γ_G (or θ_G) will still stay within the usual range.

4.2 Households and firms

4.2.1 Households

If the government successfully manipulates and increases $R_t - \pi_t$ up to the point at which equation (6) is satisfied, $R_t - \pi_t$ becomes larger than the real interest rate in the private sector (r) because $\Gamma_P < \Gamma_G$. That is, by equations (6) and (13),

$$r = \Gamma_P\left(\frac{1-\alpha}{\alpha}\right) < \Gamma_G\left(\frac{1-\alpha}{\alpha}\right) = R_t - \pi_t \tag{14}$$

for $\Gamma_P < \Gamma_G$. Inequality (14) means that the real capital incomes of households that own government bonds will unexpectedly increase from the levels estimated before the government began to manipulate $R_t - \pi_t$ because the households initially estimated their real capital incomes based on r, not $R_t - \pi_t$ (i.e., $\Gamma_G\left(\frac{1-\alpha}{\alpha}\right)$).

Faced with the unexpectedly larger capital incomes, households will feel richer. Consequently, they may feel that they can buy more higher-priced goods and services than before. At the least, households' psychological resistance to purchasing higher-priced goods and services will be weakened to some extent.

On the other hand, the unexpectedly larger capital incomes mean that the value of Γ also is perceived as higher than previously estimated; that is, the household feels that $\Gamma > \Gamma_P$, not $\Gamma = \Gamma_P$. If a household does not change its consumption, its capital will gradually increase, and thereby the value of Γ will eventually be perceived as lower than Γ_P (i.e., $\Gamma < \Gamma_P$). In any case, the estimated value of Γ will continuously deviate from Γ_P. Hence, faced with an unexpectedly larger capital income, a household will adjust its behaviors so as to return to the state $\Gamma = \Gamma_P$. In particular, it will increase its consumption to lower the value of Γ to the point at which the household again feels that $\Gamma = \Gamma_P$. Increasing consumption means a higher probability that households will purchase higher-priced goods and services, so households' psychological resistance to purchasing higher-priced goods and services will be weakened from this channel as well.

This weakened psychological barrier to higher prices means that households can tolerate a higher general price level than they previously would have in an environment where the government forces $R_t - \pi_t$ to be equal to $\Gamma_G\left(\frac{1-\alpha}{\alpha}\right)$. They do so because, as shown above, they can maintain a perceived $\Gamma = \Gamma_P$ by adjusting their behaviors even if the general price level increases. Maintaining that perception (i.e., that $\Gamma = \Gamma_P$) is equivalent to maintaining a state where $r = \Gamma_P\left(\frac{1-\alpha}{\alpha}\right)$ is satisfied, so households look as if they are keeping $r = \Gamma_P\left(\frac{1-\alpha}{\alpha}\right)$ regardless of what the government does.

Note that if a household surmises that labor income has become permanently higher thanks to technological progress, it will also increase its consumption up to the point where $\Gamma = \Gamma_P$. In this case, however, prices do not change because there is no motivation to force $R_t - \pi_t$ to increase.

4.2.2 Firms

When $R_t - \pi_t$ increases, the real interest cost of firms will also increase through arbitration in financial markets until it becomes equal to the new value of $R_t - \pi_t$. That is, if π_t is unchanged, the real interest cost will become larger than the real interest rate (r), as inequality (14) indicates. Faced with this higher real interest cost, firms will be motivated to raise the prices of their goods and services because otherwise they will suffer losses, and in fact, they will actually raise prices. If the demand for these products changes little in response to the increases in prices, firms will maintain the higher price levels even after that. Furthermore, firms will not stop raising the prices until equation (13) is again satisfied.

4.2.3 Combined forces

When inequality (14) is forced by government actions, households will be willing to allow a higher general price level, as Section 4.2.1 indicates; and at the same time, firms will more likely raise prices, as Section 4.2.2 indicates. Therefore, the general price level will increase as a result of households' and firms' combined responses to the increased $R_t - \pi_t$.

If a firm raises the price of its intermediate product, it can increase revenues and profits, but other firms that purchase this intermediate product will be tempted to raise the prices of their products and will eventually raise them because they will suffer losses if they do not raise their prices. An increase in price from the initial firm will therefore produce a chain-reaction of price increases.

In addition, if the general price level increases due to increases in product prices by firms, the real wage (w_t) will decrease and households will be unable to maintain $\Gamma = \Gamma_P$. Faced with the decrease in w_t, workers will be highly motivated to push for higher nominal wages to maintain the previous value of w_t.

As a result, the inflation rate (π_t) will increase, but it will not increase beyond the level that satisfies $R_t - \pi_t = r$. If $R_t - \pi_t = r$ is satisfied, households will feel that $\Gamma = \Gamma_P$ and that MDC is satisfied. In addition, if $\Gamma = \Gamma_P$ is satisfied, $r = \Gamma_P \left(\frac{1-\alpha}{\alpha}\right)$, and the motivation for firms to increase the prices of their products will disappear because households will no longer tolerate higher prices and the firm would suffer losses by attempting to raise prices. Hence, both households and firms will act in such a way as to not allow the inflation rate to increase beyond the level at which $R_t - \pi_t = r$ is satisfied.

4.3 The law of motion for inflation

Section 2.2 indicates that the government behaves so as to force equation (6), and at the same time, households and firms behave as if they persistently maintain equation (13). Therefore, equations (6) and (13) have to be satisfied simultaneously while equation (4) always holds. Hence, by equations (4), (6), and (13),

$$\Gamma_G\left(\frac{1-\alpha}{\alpha}\right)+\pi_t=\int_{t-1}^{t}\int_{s}^{s+1}\pi_v dv ds+\Gamma_P\left(\frac{1-\alpha}{\alpha}\right)\ ;$$

that is,

$$\int_{t-1}^{t}\int_{s}^{s+1}\pi_v dv ds=\pi_t+\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G-\Gamma_P) \tag{15}$$

holds. By equations (3) and (13), equation (15) is equivalent to

$$\int_{t-1}^{t}\int_{s}^{s+1}\pi_v dv ds=\pi_t+\theta_G-\theta_P\ . \tag{16}$$

Equation (16) is exactly the same equation obtained under the RTP-based procedure shown in Harashima (2004, 2007c, 2008, 2013b, 2018c).

What is important in equation (15) is that the contradiction between equations (6) and (13)—that is, the discrepancy between the rate of increase of the government's real obligation and the real interest rate in the private sector generated by heterogeneity in the preference ($\Gamma_P < \Gamma_G$) as indicated in inequality (14)—is resolved through the acceleration of inflation. Conversely, inflation accelerates because the values of Γ_G and Γ_P (or θ_G and θ_P) are different. This is the essential mechanism of inflation acceleration, and equation (15) indicates the law of motion for inflation, particularly for its trend component. Because equation (16) is exactly the same equation as the one obtained under the RTP-based procedure, the law of motion for inflation is identical under both procedures.

A solution of equation (15) for given values of Γ_G and Γ_P is

$$\pi_t=\pi_0+6\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G-\Gamma_P)t^2\ . \tag{17}$$

Equation (17) is equivalent to

$$\pi_t=\pi_0+6(\theta_G-\theta_P)t^2 \tag{18}$$

for given values of θ_G and θ_P. Harashima (2007a, 2007c, 2008, 2013a, 2013b, 2018c) has shown that, generally, the paths of inflation that satisfy equation (17) or (18) for $0 \leq t$ are expressed as

$$\pi_t = \pi_0 + 6\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P)\exp[z_t \ln(t)]$$

or

$$\pi_t = \pi_0 + 6(\theta_G - \theta_P)\exp[z_t \ln(t)] \ ,$$

respectively, where z_t is a time-dependent variable. If π_t satisfies equation (17) or (18) for $0 \leq t$ and $-\infty < \pi_t < \infty$ for $-1 < t \leq 1$, then

$$\lim_{t \to \infty} z_t = 2 \ .$$

4.4 The role of expectations

In conventional NKPC-type inflation models, expectations play an essential role for the development of inflation. Expectations can be both forward-looking and backward-looking, but the former have been viewed as far more likely to be actually generated than the latter because economic agents are viewed as rational. However, in these conventional inflation models, a key property of inflation—persistence—cannot be fully explained only by forward-looking expectations (e.g., Fuhrer and Moore, 1995; Galí and Gertler, 1999; Mankiw, 2001). Backward-looking expectations must be incorporated into these models, at least partially (Galí and Gertler, 1999). In this sense, these conventional inflation models seem to have a serious drawback.

The law of motion for inflation under the MDC-based procedure shown in Section 4.3, however, does not require households to generate any expectations. The persistent property of inflation (i.e., the trend component) is naturally generated, as equation (17) indicates, with no need for expectations. This is a remarkable advantage of this inflation model over conventional inflation models. This advantage suggests that what drives inflation, particularly its trend component, is not expectations but the heterogeneous feelings of MDC between the government and households. In this case, expectations are essentially irrelevant to development of inflation, at least to that of trend inflation.

However, this does not mean that households behave in backward-looking manners under the MDC-based procedure. On the contrary, their sole objective is to achieve MDC in the future, regardless of their past behaviors. In some cases, as a result of reconsiderations, they may completely change their courses abruptly, or in others, the behaviors may be similar. In this sense, households and the government are behaving fully in forward-looking manners under the MDC-based procedure.

The RTP-based procedure (i.e., rational expectations) and the MDC-based procedure are therefore common in that households behave in forward-looking manners, but there is an important difference between them. The RTP-based procedure requires households to know the objectively correct and true model and parameter values *ex ante* and to make no systematic errors in their expectations on average. That is, the objectively correct path to the destination exists and can be known, and households must follow this objectively correct path. Nevertheless, the location of destination ($\tilde{S}_{RTP}$) is not initially known to households, but instead the value of RTP is initially given to them. Hence, they first must detect the unknown location of the destination correctly with the given value of RTP while simultaneously uncovering the objectively correct and true path to the destination.

On the other hand, the MDC-based procedure requires households only to move toward destinations that are known to them from the beginning, considering other economic agents' behaviors, whatever those paths may be. Metaphorically speaking, households behave as if they are playing chess. The destination (objective) is always clear (i.e., win the game), although how they will do so is unknown before the game starts. Winning moves can be different in each game; that is, there are various routes to the destination in each case. Therefore, no objectively correct route to a destination exists, or at least, it cannot be known in advance. Even though the routes vary and are unknown *ex ante*, the location of the destination ($\Gamma(\tilde{s})$) itself is clearly known to households from the beginning, and therefore they need not detect it first by themselves. What they should do is only to move toward the *ab initio* known destination regardless of route.

5 MONETARY POLICIES

5.1 Necessity of an independent central bank

If $\Gamma_P < \Gamma_G$, inflation accelerates according to the law of motion for inflation shown in Section 4. To stop inflation acceleration, Γ_G has to be sufficiently lowered so that $\Gamma_P > \Gamma_G$, but how can this be done?

Γ_P and Γ_G should be considered as a kind of preference because it is not acquired after some amount of study or by calculating some "optimal" values. Rather, it is endowed intrinsically, and no household knows the reason why its own unique Γ_P is set at a given point. Because Γ_P and Γ_G are a kind of preference, it is very difficult for a household or a government to control its Γ_P or Γ_G by itself. Both households and governments will want to behave based absolutely on their own intrinsic preferences, even if those preferences result in unfavorable consequences. Therefore, even though a government is fully rational and is not weak, foolish, or untruthful, it will still be unable to self-regulate its own preferences, including its Γ_G.

Hence, the help of an independent neutral organization is needed to control or change a government's Γ_G. A common way to obtain this help is to delegate this authority to an independent central bank, which can set and maintain a target rate of inflation and manipulate interest rates as a way to control Γ_G. The independent central bank can faithfully control Γ_G because these actions are not related to the bank's preferences, but rather they are simply its delegated duty.

5.2 *Monetary policies to lower inflation*

In this discussion, suppose that the central bank is fully independent and the government has no power to influence its behavior. In other words, the bank is completely independent.

5.2.1 Central bank actions

To lower inflation, the central bank must force the government to lower its Γ_G, but how? One way is for the central bank to absorb money (savings) from the private sector, for example, by selling government bonds in financial markets. As a result of this action, the amount of money (savings) in the private sector decreases until it becomes smaller than the amount needed for equation (1) to be satisfied at steady state. Because of the shortage of money (savings) in financial markets, R_t increases, and if π_t is unchanged, $R_t - \pi_t$ also increases. That is, the increased rate of the government's real obligation becomes higher than the level required for equation (1) to be satisfied at steady state such that

$$R_t - \pi_t = \Gamma_G\left(\frac{1-\alpha}{\alpha}\right) + \psi > \Gamma_G\left(\frac{1-\alpha}{\alpha}\right) \quad (= \theta_G)\,, \tag{19}$$

where ψ (> 0) is a variable controlled by the central bank and can be interpreted as the extra rate of increase of the government's real obligation that the central bank imposed on the government. Clearly, in the situation where inequality (19) holds, the government cannot feel its MDC.

Because the central bank forces $R_t - \pi_t = \Gamma_G\left(\frac{1-\alpha}{\alpha}\right) + \psi$ while households and firms still behave as if they are maintaining $r = \Gamma_P\left(\frac{1-\alpha}{\alpha}\right)$,

$$\Gamma_G\left(\frac{1-\alpha}{\alpha}\right) + \psi + \pi_t = \int_{t-1}^{t}\int_{s}^{s+1} \pi_v dvds + \Gamma_P\left(\frac{1-\alpha}{\alpha}\right)$$

by equations (4), (6), and (13), which means

$$\int_{t-1}^{t}\int_{s}^{s+1} \pi_v dvds = \pi_t + \left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P) + \psi\,. \tag{20}$$

By equations (3) and (13), equation (20) is equivalent to

$$\int_{t-1}^{t}\int_{s}^{s+1}\pi_v dvds = \pi_t + \theta_G - \theta_P \ + \psi \ .$$

By equation (20), inflation will continue to accelerate after the imposition of ψ if the government does not react to the central bank's actions.

5.2.2 Tug of war

The forced situation $R_t - \pi_t = \Gamma_G\left(\frac{1-\alpha}{\alpha}\right) + \psi$ is intolerable for the government because it is not at MDC, and the situation is not sustainable. If the government were to follow the path indicated by inequality (19), it would have to increase taxes and/or decrease expenditures more than it could tolerate in the future, which could threaten the government's existence. Knowing this consequence, the government will be strongly motivated to change the situation imposed on it by the central bank.

One way for the government to do so is to reduce its absorption of money (savings) from the private sector, which can be interpreted as lowering the government's preference from Γ_G to $\check{\Gamma}_G$ ($\check{\Gamma}_G < \Gamma_G$). Because of this reduction, R_t and $R_t - \pi_t$ will also decrease. If the government reduces its absorption of money (savings) by a sufficient amount and the central bank ascertains that $\check{\Gamma}_G$ has become sufficiently low such that

$$R_t - \pi_t = \check{\Gamma}_G\left(\frac{1-\alpha}{\alpha}\right) < \Gamma_P\left(\frac{1-\alpha}{\alpha}\right) < \Gamma_G\left(\frac{1-\alpha}{\alpha}\right) \ , \tag{21}$$

then the central bank will stop imposing ψ, that is, stop absorbing money (savings) from the private sector.

After the central bank eliminates ψ, the government may resume its attempt to raise $R_t - \pi_t$ because, as inequality (21) indicates, $\check{\Gamma}_G$ does not correspond to the intrinsic Γ_G. However, the central bank continuously monitors the government, and if it perceives such an attempt, it will immediately re-impose ψ. This "tug of war" between the central bank and the government may be repeated for an extended period, but eventually the government will realize the determination of the central bank to keep this lower $R_t - \pi_t$ and will no longer resist it (see Section 5.2.3). As a result, inflation will eventually begin to decelerate steadily according to equation (15) as the central bank planned.

Hence, if a fully independent central bank manipulates ψ as shown above, the acceleration of inflation will eventually stop and deceleration will start. However, a "tug of war" period between the two may be unavoidable, and it will usually take some period of time for inflation to completely stabilize at the desired level. As the "disinflation" observed in the 1980s indicates, the process toward lower inflation can proceed quite slowly.

5.2.3 "Tamed" government

As some point, the government will be "tamed" by a truly independent central bank in the manner shown in Section 5.2.2. This tamed behavior means that the government's intrinsic preference Γ_G is forcibly changed by the central bank to $\breve{\Gamma}_G$ so as to satisfy

$$-\frac{g_t - x_t - s_t}{b_t}\left(\frac{\alpha}{1-\alpha}\right) = \breve{\Gamma}_G \leq \Gamma_P < \Gamma_G \tag{22}$$

at steady state. Inequality (22) indicates that the government cannot borrow money (absorb savings) from the private sector as much as it intrinsically desires because the value of $-\frac{g_t - x_t - s_t}{b_t}$ at steady state is forced to be lower than the value at which it intrinsically feels most comfortable.

5.3 *Monetary policies to reverse deflation*

Deflation means that the condition $\Gamma_P > \Gamma_G$ has occurred at least temporarily. This situation is the opposite of the usual case (i.e., $\Gamma_P \leq \Gamma_G$) and has only rarely been observed historically. Deflation can occur, however, so suppose that $\Gamma_P > \Gamma_G$, and Γ_P is exogenously given and does not change. Suppose also that the central bank is fully independent as discussed in Section 5.2.

5.3.1 Measures and consequences

In the case of deflation, a fully independent central bank has to force the government to raise its Γ_G such that $\Gamma_P < \Gamma_G$ to reverse the situation from deflation to inflation. One way to so is for the central bank to inject money into the private sector, for example, by purchasing government bonds in financial markets. This action will reduce the amount of savings in the private sector so it will become less than the amount that corresponds to equation (1) at steady state. As a result, R_t decreases, and if π_t is unchanged, $R_t - \pi_t$ also decreases. That is, the rate of increase of the government's real obligation decreases such that

$$R_t - \pi_t = \Gamma_G\left(\frac{1-\alpha}{\alpha}\right) - \psi < \Gamma_G\left(\frac{1-\alpha}{\alpha}\right) \ \ (= \theta_G)\ . \tag{23}$$

In this situation, the government cannot feel its MDC. Note that, unlike in inequality (19), the sign of ψ (> 0) is negative in inequality (23).

The government can escape from this situation by increasing its absorption of money (savings) from the private sector. Because of the increase in absorption of money (savings), R_t and $R_t - \pi_t$ will increase. However, as with the case of lowering inflation, a tug of war between the central bank and the government will begin, but eventually the government will succumb to the fully independent central bank. This means that the government's preference Γ_G is forced to increase from Γ_G to $\hat{\Gamma}_G$ ($\Gamma_G < \hat{\Gamma}_G$) by the central bank. As a result, $\Gamma_G < \Gamma_P \leq \hat{\Gamma}_G$ will be realized, and the deflation will be eventually reversed to inflation according to equation (15) as the central bank planed.

5.3.2 Lower bound and deflationary steady state

The nominal interest rate, however, has a zero lower bound (i.e., $R_t \geq 0$ must always hold). Hence, ψ (> 0) is subject to

$$R_t = \Gamma_G \left(\frac{1-\alpha}{\alpha} \right) - \psi + \pi_t \geq 0$$

and thereby

$$\Gamma_G \left(\frac{1-\alpha}{\alpha} \right) + \pi_t \geq \psi > 0 \ .$$

Therefore, if π_t is largely negative such that

$$\pi_t < -\Gamma_G \left(\frac{1-\alpha}{\alpha} \right) ,$$

the central bank cannot set ψ appropriately to reverse deflation because it cannot realize inequality $R_t < 0$, even though this inequality needs to hold to reverse deflation. In this case, the central bank cannot reverse deflation and can only keep $R_t = 0$.

If π_t continues to be largely negative such that $R_t - \pi_t > r$ for $R_t = 0$, the economy will collapse because equation (13) cannot be satisfied and thereby no steady state in the private sector exists except for corner solutions. Because they are well aware of this very negative consequence, households and firms will not persistently allow a largely negative π_t. Therefore, it is likely that generally

$$R_t - \pi_t \leq r$$

is kept for $R_t = 0$. Particularly, for $R_t = 0$, the state that satisfies

$$\pi_t = -r = -\Gamma_P\left(\frac{1-\alpha}{\alpha}\right) \ (= -\theta_P) \tag{24}$$

is a steady state with deflation (i.e., a deflationary steady state). If equation (24) is satisfied, a deflationary steady state can persist indefinitely.

5.3.3 Difficulties

It is highly likely that intrinsically $\Gamma_P \leq \Gamma_G$, as discussed in Section 4, and the case where $\Gamma_P > \Gamma_G$ occurs will be a very special case that will exist only temporarily, if at all. However, the experience of the Japanese economy since the 1990s suggests that it is possible that it is still difficult for a central bank to reverse deflation even after $\Gamma_P \leq \Gamma_G$ has returned. Harashima (2018b) has discussed a Pareto inefficient path as the best choice of households after a shock on RTP under the RTP-based procedure. In this case, the link between r and θ_P is severed (i.e., equation [13] cannot hold); therefore, inflation/deflation will float because equation (16) also does not hold anymore. Under the MDC-based procedure, it seems likely that the same phenomenon (i.e., the link between r and Γ_P is severed) also occurs.

On the other hand, Harashima (2016b) has discussed the possibility after deflation that a "tamed" government (i.e., one that has experienced an inflationary/deflationary period) may fear the punishment that would be imposed on it by the central bank if inflation were to begin to re-accelerate. In an environment where $\Gamma_P < \Gamma_G$ has returned after deflation, the central bank will resume forcing the government toward $\Gamma_P \geq \Gamma_G$. If the government knows this, it may keep $\Gamma_P = \Gamma_G$ during a period of deflation (i.e., maintain the deflationary steady state) to prevent the unwanted actions of the central bank due to the acceleration of inflation. Because of this "inhibitory effect," a deflation may not be reversed, and the economy will stay at a deflationary steady state even after $\Gamma_P < \Gamma_G$ has returned.

6 CONCLUDING REMARKS

The inflation models based on NKPC and FTPL do not seem sufficiently compelling because both possess important problems. Harashima (2004, 2005, 2006, 2007a, 2007b, 2007c, 2008, 2013a, 2013b, 2016a, 2018c) has presented an alternative inflation model in which a trend in inflation is naturally generated as a result of heterogeneity in preferences of households and the government, which all behave in forward-looking manners.

This alternative inflation model is constructed in the framework of the rational expectations hypothesis, but this hypothesis has been criticized for imposing substantial demands on economic agents. Harashima (2018a, 2019) has presented the MDC-based procedure by which households reach a steady state as a substitute for the RTP-based procedure. With the MDC-based procedure, a household simply has to act on its feelings about whether the combination of its labor income and capital (wealth) is comfortable or not. The MDC-based procedure is thus far easier for households to use but leads to the same steady state.

In this paper, I modified Harashima's (2004, 2018b) alternative inflation model to enable it to be used in an economy in which households and the government behave under the MDC-based procedure and showed that, if Γ_P and Γ_G are heterogeneous, inflation accelerates (or decelerates). The essential driving mechanism of inflation acceleration (deceleration) is that a government behaves to match the rate of increase of its real obligation with its Γ_G, but households and firms behave to match the real interest rate with Γ_P. The contradiction between the rate of increase of the government's real obligation and the real interest rate (i.e., the discrepancy between Γ_G and Γ_G) must be resolved by the acceleration (or deceleration) of inflation. The law of motion for inflation is identical under the MDC-based and RTP-based procedures, but the element of expectations need not be directly included in the law of motion for inflation under the MDC-based procedure, even though households and the government still behave fully in forward-looking manners under the MDC-based procedure.

To control inflation, a truly independent neutral central bank is needed because Γ_P and Γ_G is a kind of preference, and both people and the government cannot easily control their own preferences. The central bank can, however, control Γ_G by forcing the government to increase its real obligations and thereby control inflation.

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