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Law of Motion for Inflation:
An Analogy to Newtonian Mechanics

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Abstract

This paper proposes that inflation dynamics follow a law of motion analogous to Newtonian mechanics, driven by a "repulsive force" between the government and households. While the government attempts to manipulate the real interest rate toward its preferred level, households resist to maintain their own, resulting in a strategic tug-of-war. The study demonstrates how this force-based inflationary motion mirrors Newtonian laws—specifically inertia, acceleration, and action-reaction. Additionally, the concept of kinetic energy is employed to analyze central bank strategies for achieving price stability.

JEL Classification: E31, E58, E60

Keywords: Central bank; Inflation acceleration; Law of motion for inflation; Maximum degree of comfortability; Newtonian mechanics

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1 INTRODUCTION

A variety of theories on inflation have been proposed. The pure New Keynesian Phillips curve (NKPC) is one possibility, but it has been criticized for its inconsistency with the highly persistent nature of inflation (e.g., Fuhrer and Moore, 1995; Galí and Gertler, 1999). Mankiw (2001) presents a compelling argument that the NKPC has failed to align with established stylized facts concerning the dynamic effects of monetary policy.

Since the seminal work of Galí and Gertler (1999), a modified version of the NKPC—the hybrid NKPC, which includes lagged inflation—has been the subject of extensive research. While the hybrid NKPC effectively captures inflation persistence, it remains perplexing why rational agents would behave in a backward-looking manner, even partially. Galí et al. (2005) argue that a key unresolved issue is the lack of a coherent rationale for the role of lagged inflation. Furthermore, Fuhrer (2006) concluded that inflation in the hybrid NKPC inherits relatively little persistence from the driving process, suggesting that a micro-founded mechanism generating substantial intrinsic persistence is required.

An alternative approach argues that high intrinsic inflation persistence is a spurious result of trend inflation. Research by Cogley and Sbordone (2005, 2006) shows that incorporating trend inflation into the pure NKPC substantially improves its ability to fit actual inflation data. They conclude that trend inflation has been historically volatile and that, once these long-run fluctuations are accounted for, a purely forward-looking model approximates short-run dynamics quite well. Woodford (2007) notes that Cogley and Sbordone (2005) offer a viable alternative to the inclusion of lagged inflation terms (see also Hornstein, 2007).

Indeed, inflation data in most industrialized economies exhibit high volatility and a transition from high to low inflation in the 1980s, strongly implying the existence of trends (e.g., Stock and Watson, 2006; Sbordone, 2007). Ascari (2004) contends that disregarding trend inflation is a questionable assumption and that results from models log-linearized around a zero-inflation steady state may be misleading (see also Bakhshi et al., 2003). These studies suggest that the issue of persistence can be resolved by incorporating trend inflation into the NKPC framework. However, if this research direction is pursued, a significant theoretical challenge emerges: the absence of a micro-foundation for trend inflation. Could trend inflation be explained as a consequence of rational agents' optimization? Furthermore, what factors lead monetary policymakers to permit an upward trend in inflation?

The fiscal theory of the price level (FTPL) posits that a fundamental limitation in conventional inflation theory is the underestimation of how government borrowing

behavior influences inflation dynamics (see Leeper, 1991; Sims, 1994, 1998, 2001; Woodford, 1995, 2001; Cochrane, 1998a, 1998b, 2005). The FTPL suggests that, by effectively modeling government borrowing, significantly divergent inflation paths can be explained without relying on ad hoc frictions or irrationality. However, it should be noted that most FTPL models have not explicitly incorporated detailed government behavior. Consequently, some critics contend that the theory is fundamentally flawed (e.g., Kocherlakota and Phelan, 1999; McCallum, 2001, 2003; Buiter, 2002, 2004; Niepelt, 2004).

Harashima (2004a, 2005, 2006[1], 2007a, 2007b[2], 2007c[3], 2008, 2013b) has proposed an alternative inflation model that explains the persistent nature of inflation while explicitly incorporating government borrowing behavior, thereby avoiding the ad hoc assumption of backward-looking household behavior. This model addresses the primary shortcomings of inflation models based on the New Keynesian Phillips Curve (NKPC) and the FTPL. In this alternative framework, an inflation trend is naturally generated as a result of heterogeneity in the rate of time preference (RTP) between households and the government.

As with most recent economic models, Harashima's alternative inflation model is constructed within the framework of the rational expectations hypothesis. Nevertheless, this hypothesis has been criticized for the substantial cognitive demands it imposes on economic agents. To generate rational expectations, households must undertake tasks comparable to computing complex, large-scale, non-linear, and dynamic macro-econometric models. It is therefore crucial to consider whether such tasks can realistically be performed in daily life. Evans and Honkapohja (2001) argued that this issue could be addressed by introducing a learning mechanism (see also Marcet and Sargent, 1989; Ellison and Pearlman, 2011). However, this solution is not universally regarded as successful, as it necessitates the assumption of arbitrary learning rules.

Harashima (2018a[4]) presented an alternative procedure for households to reach a steady state, substituting the conventional approach in which rational expectations are generated by discounting expected utilities by RTP (hereafter, the RTP-based procedure). Under this alternative procedure, the capital-wage ratio (CWR) at the "maximum degree of comfortability" (MDC) is of central importance (hereafter, the MDC-based procedure). The MDC-based procedure is straightforward: a household simply acts based on its perception of whether its combination of labor income and capital (wealth) is

[1] Harashima (2006) is also available in Japanese as Harashima (2016a).

[2] Harashima (2007b) is also available in Japanese as Harashima (2013a).

[3] Harashima (2007c) is also available in Japanese as Harashima (2018c).

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

"comfortable." Specifically, households target their own CWR at their respective MDC. The steady state reached via the MDC-based procedure can be interpreted as equivalent to that achieved under the RTP-based procedure (i.e., the rationally expected steady state).

Since the MDC-based procedure is far more accessible for households than the RTP-based procedure yet leads to the same steady state, it is significantly more likely that households utilize the former. Harashima (2022a, 2023a, 2023b, 2023c, 2024a, 2025a, 2025b) conducted a series of simulations to examine steady states reached under the MDC-based procedure, exploring various scenarios and conditions.

In Harashima (2022b), the alternative inflation model developed by Harashima (2004a, 2005, 2006, 2007a, 2007b, 2007c, 2008, 2013b) was adapted for an economy where households and the government operate under the MDC-based procedure. This modification demonstrates that the law of motion for inflation remains identical under both the MDC-based and RTP-based procedures.

In this paper, I demonstrate that the law of motion for inflation can be derived from a "so-called repulsive force" generated between the government and households, similar to the derivation under the RTP- and MDC-based procedures. Essentially, the government and households each attempt to align the real interest rate with their respective preferences. This dynamic creates a strategic "tug-of-war" where both entities pull toward their own targets, thereby generating a repulsive force. Consequently, the rate of inflation appears to be driven by this force acting between these conflicting preferences.

Since this law of motion is force-based, it can be interpreted within the framework of Newtonian mechanics. Specifically, inflation dynamics can be understood through the concepts of velocity and acceleration. Furthermore, the laws of inertia, acceleration, and action-reaction are shown to align with Newtonian principles. Finally, the central bank's strategy for price stability can be elucidated using the concept of kinetic energy.

2 LAW OF MOTION FOR INFLATION

2.1 Two procedures to reach a steady state

As outlined in Section 1, the RTP-based procedure is a well-established concept in economics; therefore, a detailed explanation is omitted here. This section briefly provides an overview of the MDC-based procedure, following Harashima (2018a, 2021a, 2022b).

For simplicity, all households are assumed to be identical. Let k_t and w_t denote a household's capital and wage (labor income) in period t, respectively. Under the MDC-based procedure, a household first subjectively evaluates the ratio $\frac{w_t}{k_t}$. Let Γ be the

subjective valuation of $\frac{w_t}{k_t}$ by a household and Γ_i be the value of $\frac{w_t}{k_t}$ of household i (i = 1, 2, 3, … , M). Each household assesses whether its current Γ (i.e., its combination of income and capital expressed by CWR) is "comfortable". In this context, "comfortable" signifies being "at ease" or "free from anxiety."

Let the "degree of comfortability" (DOC) represent the extent to which a household feels comfortable with its Γ. A higher DOC indicates greater comfort. Each household has an optimal CWR value, as comfort diminishes if the CWR is either excessively high or low. Thus, a maximum DOC exists for each household. Let $\tilde{s}$ denote the state in which a household's DOC is maximized (MDC). MDC, therefore, represents the state where the combination of revenues and assets is perceived as most comfortable. Let $\Gamma(\tilde{s})$ be the household's Γ at state $\tilde{s}$, indicating the value that yields the MDC. Correspondingly, $\Gamma(\tilde{s}_i)$ is the value for household i at its MDC state $\tilde{s}_i$.

Household i is assumed to act according to the following rules:

- **Rule 1:** If household i perceives its current Γ_i to be equal to $\Gamma(\tilde{s}_i)$, it maintains its current level of consumption.
- **Rule 2:** If household i perceives its current Γ_i to be different from $\Gamma(\tilde{s}_i)$, it adjusts its consumption level until Γ_i equals $\Gamma(\tilde{s}_i)$.

As demonstrated in Harashima (2018a), households can reach a steady state by following these rules alone. This steady state is equivalent to the one achieved under the RTP-based procedure.

2.2 Inflation under the RTP-based procedure

In this section, I briefly outline the law of motion for inflation when economic agents operate under the RTP-based procedure, following Harashima (2004a, 2005, 2006, 2007a, 2007b, 2007c, 2008, 2013b).

2.2.1 Law of motion for inflation

As demonstrated by Harashima (2004a, 2005, 2006, 2007a, 2007b, 2007c, 2008, 2013b), when households behave according to the RTP-based procedure, the law of motion for inflation is given by

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

where π_t is the inflation rate in period *t*, θ_G is the RTP of the government, and θ_P is the RTP of the representative household. Note that θ_G and θ_P are not necessarily identical. For given values of θ_G and θ_P, a solution to the integral in Equation (1) is

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

More generally, the inflation path satisfying Equation (1) for $0 \leq t$ can be expressed as

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

where z_t is a time-dependent variable whose trajectory depends on the boundary conditions. However, if π_t satisfies Equation (1) for $0 \leq t$, and $-\infty < \pi_t < \infty$ for $-1 < t \leq 1$, then

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

2.2.2 The central bank

A sufficiently independent central bank can compel the government to adjust the practical value of θ_G until it matches θ_P. By maintaining this equality, the central bank ensures that inflation neither accelerates nor decelerates, as implied by Equation (1). In other words, to stabilize inflation, an independent central bank will penalize the government—effectively forcing an adjustment of its preference θ_G—whenever the intrinsic value of θ_G deviates from θ_P.

2.3 Inflation under the MDC-based procedure

In this section, I briefly explain the law of motion for inflation when economic agents operate under the MDC-based procedure, following Harashima (2022b).

2.3.1 Government MDC

The value of

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

is constant at the steady state such that $\dot{g}_t = 0$, $\dot{x}_t = 0$, $\dot{s}_t = 0$, and $\dot{b}_t = 0$. Here, b_t represents the government's nominal obligation to pay for its accumulated bonds, g_t is

nominal government expenditure, x_t is nominal tax revenue, and s_t is the nominal amount of seigniorage in period *t*. All variables are expressed in per capita terms. At this steady state, the government's MDC must be satisfied, as this is the state the government intends to achieve and has successfully managed to maintain.

Let

$$\Gamma_G = -\frac{g_t - x_t - s_t}{b_t}\left(\frac{\alpha}{1-\alpha}\right) \tag{3}$$

at the government's MDC, where α ($0 < \alpha < 1$) is a constant in the production function $y_t = A^{\alpha}k_t^{1-\alpha}$, y_t is per capita output in period *t*, and *A* represents technology. Since both $-\frac{g_t - x_t - s_t}{b_t}$ at the government's MDC (i.e., at the steady state) and α are constants, Γ_G is also constant. Furthermore, while the MDC indicates the state in which the combination of revenues and assets is perceived as most comfortable, Γ_G represents the specific optimal combination of net revenues $-(g_t - x_t - s_t)$ and debt b_t. Therefore, Γ_G can be interpreted as a parameter reflecting the government's preference regarding its MDC. Harashima (2006) demonstrated that

$$\theta_G = -\frac{g_t - x_t - s_t}{b_t} \tag{4}$$

holds at the steady state for a given value of θ_G. Consequently, from Equations (3) and (4), it follows that

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

at the steady state.

2.3.2 Rate of increase in the government's real obligation

Let R_t be the nominal interest rate on government bonds in period *t*. As Harashima (2004a, 2005, 2006, 2007a, 2007b, 2007c, 2008, 2013b) has shown, the following approximation holds:

$$R_t = \int_{t-1}^{t}\int_{s}^{s+1}\pi_v dv ds + r \ , \tag{5}$$

where r is the steady-state real interest rate in the private sector. Here, the private sector is defined as the segment of the economy managed by households and non-governmental firms.

Evidently, $R_t - \pi_t$ represents the rate of increase in the government's real obligation in period *t*. At the same time, the steady-state value of $-\frac{g_t - x_t - s_t}{b_t}$ also indicates this rate of increase. Therefore, at steady state,

$$R_t - \pi_t = -\frac{g_t - x_t - s_t}{b_t} \ . \tag{6}$$

Consequently, from Equations (3), (4), and (6),

$$R_t - \pi_t = \Gamma_G \left(\frac{1-\alpha}{\alpha}\right) = \theta_G \tag{7}$$

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

$$(R_t - \pi_t) b_t = \Gamma_G \left(\frac{1-\alpha}{\alpha}\right) b_t \ (= \theta_G b_t)$$

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

Finally, it should be noted that the rate of increase in the government's real obligation ($R_t - \pi_t$) is not necessarily equivalent to the real interest rate in the private sector, *r*, as shown in Equation (5).

2.3.3 Household 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). If the household MDC is achieved under the MDC-based procedure, then

$$\frac{w_t}{k_t} = \Gamma_P \ , \tag{8}$$

since $\dot{c}_t = 0$ and $\dot{k}_t = 0$ at the MDC, where c_t denotes per capita consumption in period *t*. On the other hand, as demonstrated by Harashima (2018a), the household's behavior under the RTP-based procedure results in

$$\theta_P \left(\frac{\alpha}{1-\alpha}\right) = \frac{w_t}{k_t} \tag{9}$$

at the steady state where $\dot{c}_t = 0$ and $\dot{k}_t = 0$. Therefore, from Equations (8) and (9), we obtain

$$\theta_P = \Gamma_P \left(\frac{1-\alpha}{\alpha}\right) .$$

The real interest rate in period *t* (r_t) is determined in the private sector by

$$r_t = \frac{\partial y_t}{\partial k_t} . \tag{10}$$

Given the production function ($y_t = A^{\alpha} k_t^{1-\alpha}$), it follows that

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

and

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

Hence, by Equations (8), (9), (10), (11), and (12),

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

at the steady state where $\dot{c}_t = 0$ and $\dot{k}_t = 0$.

2.3.4 The behaviors of government, households, and firms

2.3.4.1 Government

Should the government estimate that the rate of increase in its real obligation ($R_t - \pi_t$) is currently lower than $\Gamma_G \left(\frac{1-\alpha}{\alpha}\right)$ —that is, $R_t - \pi_t < \Gamma_G \left(\frac{1-\alpha}{\alpha}\right)$ —it will be deemed dissatisfied, as this state does not correspond to its MDC. Consequently, the government implements measures to raise R_t until it aligns with the MDC. To achieve this increase in R_t, the government absorbs additional liquidity (savings) from the private sector,

primarily by issuing more government bonds and increasing its borrowings.

2.3.4.2 Households

If the government successfully sets $\Gamma_G\left(\frac{1-\alpha}{\alpha}\right) = R_t - \pi_t$ by increasing R_t, and assuming $\Gamma_P < \Gamma_G$, it follows that $\Gamma_P\left(\frac{1-\alpha}{\alpha}\right) < R_t - \pi_t$. This implies that the real capital income of households holding government bonds increases beyond the levels anticipated prior to the government's intervention. Under these conditions, households may perceive an enhanced capacity to purchase high-priced goods and services without depleting their principal capital.

Furthermore, these unexpectedly high capital incomes cause the perceived value of Γ to exceed the initial estimate ($\Gamma > \Gamma_P$). To restore the equilibrium where $\Gamma = \Gamma_P$, households increase their consumption. This shift in behavior manifests as a higher propensity to purchase premium-priced goods and services.

2.3.4.3 Firms

When the government successfully increases R_t, the real interest costs for firms rise, assuming π_t remains unchanged. Faced with elevated borrowing costs, firms are incentivized to raise the prices of their products to avoid losses. If demand remains relatively stable despite rising inflation—supported by the shift in household behavior described in Section 2.3.4.2—firms will tend to maintain these higher price levels.

2.3.5 Law of motion for inflation

The government acts to enforce Equation (7), while households and firms behave as if they persistently maintain Equation (13). Consequently, Equations (7) and (13) must be satisfied simultaneously, ensuring that Equation (5) remains valid. Combining Equations (5), (7), and (13) yields:

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

that is,

$$\int_{t-1}^{t}\int_{s}^{s+1} \pi_v dv ds = \pi_t + \left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P) \tag{14}$$

holds. Equation (14) is equivalent to Equation (1) in an economy where agents operate under the RTP-based procedure.

For given values of Γ_G and Γ_P, a solution to Equation (14) is:

$$\pi_t = \pi_0 + 6\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P)t^2 \,. \tag{15}$$

Equation (15) is equivalent to Equation (2) under the RTP-based procedure. As in that case, the inflation paths satisfying Equation (15) for $t \geq 0$ are generally expressed as:

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

If π_t satisfies Equation (15) for $t \geq 0$ and remains bounded ($-\infty < \pi_t < \infty$) for $-1 < t \leq 1$, then:

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

2.3.6 The central bank

It is the responsibility of the central bank to ensure that the government reduces the practical value of Γ_G, with the aim of halting and eventually lowering the acceleration of π_t. To achieve this, the central bank absorbs liquidity (savings) from the private sector, leading to increases in R_t and $R_t - \pi_t$, as long as the practical value of Γ_G remains insufficiently reduced. Consequently, the following condition persists:

$$R_t - \pi_t > \Gamma_G\left(\frac{1-\alpha}{\alpha}\right)(=\theta_G) \,.$$

This situation is unacceptable for the government as it deviates from its MDC; thus, the government is ultimately compelled to reduce its own absorption of liquidity from the private sector. As a result, a state where Γ_P is not less than Γ_G is established, thereby halting the acceleration of inflation.

The central bank can also cause $R_t - \pi_t$ and $\Gamma_G\left(\frac{1-\alpha}{\alpha}\right)$ to diverge by reducing R_t. In this case, however, the government can easily circumvent such pressure by increasing its absorption of liquidity. Conversely, if the central bank raises R_t to force a divergence between $R_t - \pi_t$ and $\Gamma_G\left(\frac{1-\alpha}{\alpha}\right)$, the government is left with no choice but to reduce the practical value of $\Gamma_G\left(\frac{1-\alpha}{\alpha}\right)$.

2.4 Origin of inflation acceleration

A key principle in the law of motion for inflation is that the government cannot rigidly fix π_t; it can only manage R_t. In the law of motion outlined in Sections 2.2 and 2.3, this principle is reflected by the fact that the government cannot directly control $R_t - \pi_t$ but only the term:

$$R_t - \int_{t-1}^{t} \int_{s}^{s+1} \pi_v dv ds \,.$$

Consequently, the government allows households the opportunity to achieve

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

by adjusting π_t in the subsequent infinitesimal time interval, mediated through the integral term

$$\int_{t-1}^{t} \int_{s}^{s+1} \pi_v dv ds \ .$$

A discrepancy between Γ_G and Γ_P (or equivalently, θ_G and θ_P) triggers a strategic "tug-of-war" over $R_t - \pi_t$ between the government and private agents (households and firms). In this context, the "rope" in this tug-of-war—represented by π_t, which anchors the actions of both parties—is not necessarily rigid. Instead, it can stretch at an accelerated rate, much like a rubber band. The rope (π_t) remains stable if $\Gamma_G = \Gamma_P$ ($\theta_G = \theta_P$), but it stretches whenever $\Gamma_G > \Gamma_P$ ($\theta_G > \theta_P$).

Note that the length of the deposit period is irrelevant to the law of motion for inflation, as the unit of time can be arbitrarily defined. Let $\delta (\geq 0)$ denote the deposit period. For any given δ, there exists a path that satisfies:

$$\lim_{t \to \infty} \frac{1}{\delta} \int_{t-\delta}^{t} \int_{s}^{s+\delta} \pi_v dv ds = X \,,$$

where X is a constant.

3 ANALOGY TO NEWTONIAN MECHANICS

3.1 "Repulsive force" acting on inflation

Essentially, the government's actions are intended to align r_t with θ_G (or equivalently $\Gamma_G\left(\frac{1-\alpha}{\alpha}\right)$), while households and firms aim to align r_t with θ_P (or equivalently $\Gamma_P\left(\frac{1-\alpha}{\alpha}\right)$). For example, assume that in period $t=1$, the government successfully manages R_1 such that $R_1 = \pi_1 + \theta_G$. In response, households and firms behave in a manner that ensures $R_2 = \pi_2 + \theta_P$ in period $t=2$. If $\Gamma_G = \Gamma_P$, it follows that $\pi_1 = \pi_2$, indicating that the inflation rate remains constant over time. However, if $\Gamma_G \neq \Gamma_P$, then it necessarily follows that $\pi_1 \neq \pi_2$.

In the case where $\Gamma_G \neq \Gamma_P$, a strategic "tug-of-war" ensues between these two entities. As the government pulls r_t towards θ_G and private agents pull it towards θ_P, the rate of inflation—defined as the difference between the nominal and real interest rates—behaves as if driven by a repulsive force between these two target points.

3.2 Law of motion for inflation

3.2.1 Acceleration of inflation

As outlined in Section 3.1, if $\Gamma_G = \Gamma_P$ (or equivalently, $\theta_G = \theta_P$), no repulsive force is generated. In this case, the inflation rate moves inertially and remains particularly constant. Conversely, when a force is applied to inflation, it undergoes acceleration. As previously discussed, a repulsive force arises when Γ_G and Γ_P diverge. The greater the deviation between Γ_G and Γ_P, the more strongly the government and households pull r_t toward θ_G and θ_P, respectively, resulting in a stronger repulsive force. Therefore, it is reasonable to assume that the repulsive force is proportional to the difference in preferences, $\Gamma_G - \Gamma_P$.

Drawing an analogy with Newtonian mechanics, where force is represented by acceleration, the "acceleration" of inflation can be modeled in its simplest form as:

$$\begin{aligned}\frac{d^2\pi_t}{dt^2} &= \chi\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P) \\ &= \chi(\theta_G - \theta_P)\,, \end{aligned} \tag{16}$$

where χ is a constant. Consequently, the repulsive force (F) is defined as:

$$F = m_e\frac{d^2\pi_t}{dt^2} = m_e\chi\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P)$$

$$= m_e \chi(\theta_G - \theta_P) \,, \tag{17}$$

where m_e is a parameter representing the mass (scale) of the economy.

3.2.2 Velocity of inflation

By integrating Equation (16) with respect to *t*, the "velocity" of inflation is given by:

$$\begin{aligned} \frac{d\pi_t}{dt} &= \chi\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P)t \\ &= \chi(\theta_G - \theta_P)t \,, \end{aligned} \tag{18}$$

assuming the initial condition $\frac{d\pi_0}{dt} = 0$.

3.2.3 Inflation rate

The inflation rate is obtained by integrating Equation (18) with respect to *t*:

$$\begin{aligned} \pi_t &= \pi_0 + \frac{\chi}{2}\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P)t^2 \\ &= \pi_0 + \frac{\chi}{2}(\theta_G - \theta_P)t^2 \,. \end{aligned} \tag{19}$$

Equation (19) is equivalent to Equations (2) and (15) when $\chi = 12$. This demonstrates that the law of motion for inflation derived from the concept of repulsive force is consistent with the household behavior modeled under the MDC- and RTP-based procedures outlined in Section 2.

3.2.4 Analogy with Newtonian Mechanics

The law of motion for inflation, grounded in the concept of repulsive force, is analogous to Newtonian mechanics. This analogy is defined by the following principles:

- **The first law (inertia)**: The inflation rate (π_t) remains constant—effectively in a state of uniform motion— unless acted upon by an external force (i.e., as long as $\Gamma_G = \Gamma_P$).

- **The second law (acceleration)**: At any given moment, the force acting on inflation is equal to the product of the economy's mass (scale), m_e, and the acceleration—defined as $\chi\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P)[= \chi(\theta_G - \theta_P)]$.

- **The third law (action and reaction)**: If two segments of an economy exert inflationary forces on each other, these forces are equal in magnitude and opposite in direction.

The first law holds because, even when $\Gamma_G = \Gamma_P$, the government continues to set the nominal interest rate (R_t) equal to the sum of θ_G and π_t. This is achieved, as before, by absorbing private sector liquidity (savings) to ensure that the real interest rate (r_t) remains anchored at θ_G. Regarding the third law, suppose an economy is composed of two segments (*A* and *B*). When $\frac{d\pi_t}{dt}$ is constant,

$$m_{e,A}\frac{d^2\pi_{A,t}}{dt^2} + m_{e,B}\frac{d^2\pi_{B,t}}{dt^2} = 0\ ,$$

where $\pi_{A,t}$ and $\pi_{B,t}$ are the inflation rates in segments *A* and *B*, and $m_{e,A}$ and $m_{e,B}$ are their respective masses (scales). This implies that the acceleration of inflation caused by the repulsive force is independent of relative price fluctuations between these segments.

In this framework, the inflation rate (π_t) corresponds to a physical body, while the economic scale (m_e) corresponds to inertial mass in Newtonian mechanics. Crucially, π_t represents the body itself rather than its velocity. In the limit where the deposit period δ approaches zero, this law becomes equivalent to Newtonian mechanics (see Section 5). This analogy further suggests that the law of motion for inflation can be interpreted through action principles, allowing for reformulation using Lagrangian and Hamiltonian formalisms.

3.3 The central bank

3.3.1 Counterforce

According to the law of motion for inflation, a sufficiently robust external force must be applied to arrest inflationary acceleration. This force requires an equivalent or greater counterforce, provided by an entity independent of the government, households, and firms. Therefore, controlling inflation necessitates an organization that possesses both institutional independence and the capacity to exert a decisive counterforce against such pressures. The central bank is designed to fulfill this role.

An independent central bank can exert this counterforce by managing the nominal interest rate (R_t) independently of the government. It has the authority to always increase R_t beyond the levels desired by the government. In a scenario where $\Gamma_G > \Gamma_P$, the central bank must increase R_t and maintain it above $\theta_G + \pi_t$ as long as the government acts on its intrinsic value of Γ_G. This action forces $r_t > \theta_G$, thereby driving π_t down toward the inflation target.

Under such pressure from the central bank, the government's only way to achieve $r_t = \theta_G$ is to reduce its upward pressure on R_t. This is equivalent to lowering the government's practical value of Γ_G below its intrinsic value. The central bank maintains a high R_t until the government sufficiently moderates its stance, ensuring the practical value of Γ_G does not exceed Γ_P. Consequently, π_t decreases and stabilizes at the target.

Crucially, when inflation exceeds the target, merely matching the magnitude of the repulsive force (F) with an equal counterforce ($-F_C$) is insufficient to restore price stability. If $F - F_C = 0$, the condition $\Gamma_G = \Gamma_P$ is practically met and acceleration ceases; however, π_t would remain above the target, maintaining its upward momentum through inflationary inertia, consistent with the first law of motion. To bring π_t back to the target, the central bank must ensure $F - F_C < 0$, maintaining the government's practical Γ_G below Γ_P until inflation sufficiently subsides.

Even if the central bank compels the government to lower its practical Γ_G via the counterforce ($-F_C$), the government's intrinsic Γ_G may remain elevated, meaning the underlying repulsive force (F) persists. Thus, the central bank must remain vigilant. It is obligated to monitor government actions even after π_t reaches the target, prepared to take immediate and decisive action to raise R_t at any sign of renewed inflationary pressure.

3.3.2 "Kinetic energy"

Once inflation (π_t) exceeds the central bank's target, what level of counterforce ($-F_C$) is most effective for returning π_t to its target? As outlined in Section 3.3.1, the condition $F - F_C < 0$ must be satisfied for π_t to revert to the target level. Therefore, from Equation (17):

$$F - F_c = m_e\chi\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P) - m_e\chi\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P + \Gamma_c)$$

$$= -m_e\chi\left(\frac{1-\alpha}{\alpha}\right)\Gamma_c < 0\,, \tag{20}$$

where $\Gamma_c(>0)$ is a parameter, and $-\chi\left(\frac{1-\alpha}{\alpha}\right)\Gamma_c$ represents the negative acceleration

introduced by the central bank to reduce π_t. Equation (20) implies that a counterforce must be exerted to bring π_t back to its target. The magnitude of this force corresponds to the repulsive force combined with the deceleration term $\chi\left(\frac{1-\alpha}{\alpha}\right)\Gamma_c$.

By analogy with Newtonian mechanics, the "kinetic energy" generated when the central bank initiates the condition $F - F_C < 0$ must be completely offset by the time π_t returns to the inflation target. This relationship can be expressed as:

$$\frac{1}{2}m_e\left[\chi\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P)(t_1 - 0)\right]^2 = \frac{1}{2}m_e\left[\chi\left(\frac{1-\alpha}{\alpha}\right)\Gamma_c(t_2 - t_1)\right]^2 , \quad (21)$$

where inflation begins to accelerate at $t = 0$, the central bank intervenes to ensure $F - F_C < 0$ at $t = t_1$, and π_t returns to the target at $t = t_2$. From Equation (21), we obtain:

$$\Gamma_c = (\Gamma_G - \Gamma_P)\frac{t_1}{t_2 - t_1} . \quad (22)$$

Equation (22) demonstrates that since both $\Gamma_G - \Gamma_P$ and $\frac{t_1}{t_2 - t_1}$ are positive, Γ_c is also positive. It further indicates that an increase in t_1 leads to an increase in Γ_c, whereas an increase in t_2 results in a decrease in Γ_c. In other words, if the initial acceleration persists for a longer duration, a larger Γ_c is required. Conversely, if a longer stabilization period for π_t is permitted, the necessary value of Γ_c decreases.

Combining Equations (20) and (22) yields:

$$F_c = F + m_e\chi\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P)\frac{t_1}{t_2 - t_1} . \quad (23)$$

From Equations (17) and (23), we derive:

$$F_c = F\left(\frac{t_2}{t_2 - t_1}\right) . \quad (24)$$

Since $\frac{t_2}{t_2 - t_1} > 1$, it follows from Equation (24) that $F_c > F$. Furthermore, because

$$\lim_{t_2 \to t_1}\frac{t_2}{t_2 - t_1} = \infty \text{ and } \lim_{t_2 \to \infty}\frac{t_2}{t_2 - t_1} = 1 ,$$

Equation (24) suggests that a shorter recovery time t_2 necessitates a stronger counterforce F_c.

However, it is important to note that, in practice, Γ_c and the resulting counterforce $-F_c$ are unlikely to remain constant. The central bank typically adjusts these parameters while monitoring the trajectory of π_t. It is probable that at the onset of the intervention, Γ_c is set high and $-F_c$ is strong. As π_t gradually declines, both Γ_c and $-F_c$ are likely adjusted to lower, weaker levels.

3.3.3 Side-effects of counterforce

It is important to note that the increase in R_t resulting from the central bank's counterforce not only forces the government into a state where $r_t > \theta_G$ but also constrains households such that $r_t > \theta_P$. This occurs because $r_t > \theta_G > \theta_P$. Consequently, until π_t is sufficiently reduced, households remain unable to satisfy their MDC (or, equivalently, to maximize their expected utility).

The total amount of such "dissatisfaction due to non-MDC before π_t reaches the inflation target" (DS) may be proportional to kinetic energy, particularly that generated by Γ_c, such that:

$$DS = \psi \frac{1}{2} m_e \left[\chi \left(\frac{1-\alpha}{\alpha} \right) \Gamma_c (t_2 - t_1) \right]^2 , \tag{25}$$

where ψ is a positive constant. If m_e is proportional to the population of the economy, then the per capita DS is proportionate to

$$[\Gamma_c (t_2 - t_1)]^2 .$$

From Equation (22), we obtain:

$$[\Gamma_c (t_2 - t_1)]^2 = [(\Gamma_G - \Gamma_P) t_1]^2 . \tag{26}$$

Equation (26) indicates that, provided Γ_c and $-F_c$ remain constant, an increase in the gap between Γ_G and Γ_P leads to a higher DS for households. Furthermore, DS increases quadratically as this acceleration persists over time.

It should be noted that while DS increases quadratically over time as shown in Equation (25), the repulsive force (F) itself remains constant as long as the government's intrinsic Γ_G is unchanged. Therefore, the required strength of the counterforce ($-F_C$) does not increase over time; it remains constant unless F changes.

Once the central bank successfully forces the practical value of Γ_G to equal Γ_P, DS stops increasing, though the accumulated DS remains. Consequently, if a central bank lacks sufficient independence, it may fail to ensure $F - F_C < 0$ (the condition necessary to reduce π_t to the target) because maintaining this condition further exacerbates DS. However, if the central bank ceases to enforce $F - F_C < 0$ once the practical value of Γ_G equals Γ_P, the previously elevated π_t will persist—even if it no longer accelerates—due to the first law of motion (the law of inertia).

4 OTHER CONSIDERATIONS

4.1 Two types of inflation

Even in the absence of a repulsive force, the rate of inflation can change. This suggests two distinct types of inflation: persistent inflation driven by the repulsive force and temporary inflation caused by an external shock.

4.1.1 Persistent inflation driven by the repulsive force

It is generally accepted that demand and supply curves remain static unless an external shock occurs. However, as outlined in Section 3, the repulsive force is a constant presence, leading to perpetual shifts in general prices. Consequently, demand and supply curves can shift continuously and persistently without the need for external shocks. In most cases, these curves are expected to shift upward. Notably, the equilibrium quantity of goods and services remains stable even as inflation increases, because both demand and supply curves shift upward at the same rate. Thus, persistent inflation driven by the repulsive force has minimal impact on the real economy, affecting only the inflation rate itself.

4.1.2 Temporary inflation caused by an external shock

Under temporary inflation caused by an external shock, the acceleration of inflation is a one-time event, generated by an external force that is temporary in nature. Unlike the persistent acceleration $\chi\left(\frac{1-\alpha}{\alpha}\right)(\Gamma_G - \Gamma_P)$, the acceleration resulting from this temporary force eventually dissipates. However, if the central bank maintains a condition where the practical value of Γ_G equals Γ_P, the increased inflation rate π_t persists even after the acceleration ceases. This phenomenon can be attributed to the first law of motion (the law of inertia). In this scenario, π_t clearly exceeds the central bank's inflation target.

Therefore, even if an external force is temporary, the central bank must counter it by raising R_t to bring π_t back to the target. This action reduces the practical value of Γ_G, forcing a condition where $\Gamma_G < \Gamma_P$ for a period. Consequently, households

experience a certain amount of DS, in exchange for stabilizing temporary inflation.

Unlike the persistent inflation driven by the repulsive force, a temporary force can affect demand and supply curves asymmetrically, leading to changes in both the price and quantity of goods and services. The extent of these changes in quantity depends on the specific nature of the force. Therefore, the central bank must meticulously monitor both price and quantity when applying counter-forces to address various temporary external shocks.

4.2 Forward-looking behavior that appears backward-looking

As outlined in Sections 2 and 3, inflation expectations do not play a role in decision-making. However, it is important to note that households, firms, and the government all behave in a forward-looking manner in the sense that their sole objective is to achieve optimality in the future (i.e., $r_t = \theta_P$ and $r_t = \theta_G$). Nevertheless, their behavior may appear backward-looking. This is because they consistently adhere to the same forward-looking approach as they have in the past. Consequently, their current activities seem to reflect their recent past actions, making past behavior a reliable predictor of future actions.

Furthermore, inflation naturally exhibits backward-looking dynamics due to the first law of motion—the law of inertia. Because of this inertia, inflation tends to persist in a consistent manner.

4.3 Economic depression caused by an upward shift of Γ_P

As Harashima (2004b, 2009[5], 2016b, 2016c[6], 2018b, 2019b, 2020[7]) demonstrates, during an economic depression caused by an upward shift of Γ_P (equivalent to that of θ_P), households do not behave in a way that aligns r_t with θ_P. As a result, the households' power to pull r_t towards θ_P becomes ineffective, leaving only the government's power to pull it toward θ_G. Therefore, Equation (13) is no longer applicable, while Equation (7) remains in force. This sudden, unilateral loss of pulling power leads to the immediate dissipation of the repulsive force.

Since Equation (7) consists of one equation and two variables, the solution is indeterminate. Consequently, R_t and π_t drift without an anchor. In contrast, it is possible that π_t decelerates as a result of the temporary force generated by the upward shift of Γ_P (or θ_P), which leads to deflation.

As outlined in Harashima (2024b), following a significant upward shift of Γ_P,

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[5] Harashima (2009) is also available in Japanese as Harashima (2018d).

[6] Harashima (2016c) is also available in Japanese as Harashima (2021b).

[7] Harashima (2020) is also available in Japanese as Harashima (2023d).

the demand curve becomes nearly vertical in the low-price zone. Therefore, the central bank lacks the capacity to reverse deflation into inflation, as the nominal interest rate cannot be reduced below zero.

5 DISCUSSION

By analogy with the law of motion for inflation—specifically Equations (14) and (16)—the velocity $\dot{\boldsymbol{r}}(t)$, acceleration $\ddot{\boldsymbol{r}}(t)$, and jerk $\dddot{\boldsymbol{r}}(t)$ can be derived from the following relationship:

$$\int_{t-\delta}^{t}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds=\boldsymbol{r}(t)+\frac{\ddot{\boldsymbol{r}}(t)}{\chi}\,, \tag{27}$$

where $\boldsymbol{r}(t)$ denotes the position of a physical body at time *t*. Suppose that for each applied force:

$$\lim_{t\to\infty}\frac{\chi}{\delta}\left[\int_{t-\delta}^{t}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds-\boldsymbol{r}(t)\right]=Z\,, \tag{28}$$

where Z is a constant unique to each force. Under this condition, the following equations are derived from Equation (27):

$$\dot{\boldsymbol{r}}(t)=\dot{\boldsymbol{r}}(0)+\lim_{\delta\to0}\frac{\chi}{\delta}\left[\int_{t-\delta}^{t}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds-\boldsymbol{r}(t)\right]t=\dot{\boldsymbol{r}}(0)+\chi Zt\,, \tag{29}$$

$$\ddot{\boldsymbol{r}}(t)=\lim_{\delta\to0}\frac{\chi}{\delta}\left[\int_{t-\delta}^{t}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds-\boldsymbol{r}(t)\right]=\chi Z\ , \tag{30}$$

and

$$\dddot{\boldsymbol{r}}(t)=\lim_{\delta\to0}\frac{\chi}{\delta}\left[\int_{t-\delta}^{t}\int_{s}^{s+\delta}\dot{\boldsymbol{r}}(v)dvds-\dot{\boldsymbol{r}}(t)\right]=0\,, \tag{31}$$

since for any $t(>0)$ and $\bar{t}(>0)$:

$$\lim_{\delta\to 0}\left[\int_{t+\bar{t}-\delta}^{t+\bar{t}}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds-\int_{t-\delta}^{t}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds\right]=\boldsymbol{r}(t+\bar{t})-\boldsymbol{r}(t)\ ,$$

and thus, from Equation (28):

$$\lim_{\delta\to 0}\frac{\chi}{\delta}\left[\int_{t-\delta}^{t}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds-\boldsymbol{r}(t)\right]=\lim_{t\to\infty}\lim_{\delta\to 0}\frac{\chi}{\delta}\left[\int_{t-\delta}^{t}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds-\boldsymbol{r}(t)\right]=Z\ .$$

Evidently, Equations (29), (30), and (31) correspond to the velocity, acceleration, and jerk of a rigid body in Newtonian mechanics, respectively.

In the context of the law of motion for inflation, a rigid body can be seen as representing π_t when a government issues cash instead of bonds. However, this is not entirely accurate, as the yield on a government bond does not vanish even as its maturity (δ) approaches zero. The real interest rate serves as the point of application for the repulsive force, as both the government and households seek to align it with their respective preferences. As with cash, a body with $\delta=0$ is unaffected by external forces because it lacks a point of application.

Furthermore, if δ is a positive constant, the motion of a "uniform soft body" can be approximately described by Equation (27), such that:

$$\dot{\boldsymbol{r}}(t)=\dot{\boldsymbol{r}}(0)+\frac{\chi}{\delta}\left[\int_{t-\delta}^{t}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds-\boldsymbol{r}(t)\right]t\ , \tag{32}$$

$$\ddot{\boldsymbol{r}}(t)=\frac{\chi}{\delta}\left[\int_{t-\delta}^{t}\int_{s}^{s+\delta}\boldsymbol{r}(v)dvds-\boldsymbol{r}(t)\right]\ , \tag{33}$$

and

$$\dddot{\boldsymbol{r}}(t)=\frac{\chi}{\delta}\left[\int_{t-\delta}^{t}\int_{s}^{s+\delta}\dot{\boldsymbol{r}}(v)dvds-\dot{\boldsymbol{r}}(t)\right]\ , \tag{34}$$

where $\boldsymbol{r}(t)$ represents the center of gravity of the soft body. Here, the value of δ represents the degree of "softness" or elasticity. Since a body with $\delta=0$ remains unaffected by force, any body subject to force must possess some degree of softness. This implies that the body deforms under influence, suggesting an underlying internal structure. Applying this to inflation dynamics, short-term government bonds exhibit low "softness," while long-term bonds exhibit high "softness."

Equations (32) through (34) suggest that the center of gravity of a soft body follows a complex trajectory when a force is applied. This leads to incremental changes in acceleration before the velocity eventually stabilizes at a value determined by Z. It is likely that the shape of a uniform soft body distorts temporarily upon the application of force but ultimately recovers. While this deformation process creates a complex locus for the center of gravity, the empirical validity and practical utility of these relationships, as well as the approximation, remain questions for future empirical investigation.

5 CONCLUDING REMARKS

Various theories on inflation have been proposed, including the New Keynesian Phillips Curve (NKPC), the hybrid NKPC, the NKPC incorporating trend inflation, and the Fiscal Theory of the Price Level (FTPL). However, these models have not always proven sufficiently successful in explaining the key features of inflation. Harashima (2004a, 2005, 2006, 2007a, 2007b, 2007c, 2008, 2013b) presented an alternative model that accounts for inflation's persistence without assuming backward-looking behavior by households. This model explicitly incorporates the government's borrowing behavior. Furthermore, Harashima (2022b) adapted this model to an economy where both households and the government operate under the MDC-based procedure.

In this paper, I demonstrate that the law of motion for inflation can be derived from a "repulsive force" generated between the government and households, analogous to the derivations under RTP- and MDC-based procedures. Essentially, both the government and households seek to align the real interest rate with their respective preferences. This dynamic creates a strategic tug-of-war: as each entity pursues its own preference, a repulsive force is generated that drives the inflation rate.

Given that this law of motion is based on the concept of force, it can be interpreted within the framework of Newtonian mechanics. Specifically, the motion of inflation can be understood through velocity and acceleration, aligning with the laws of inertia, acceleration, and action-reaction. Moreover, the central bank's strategy for maintaining price stability can be elucidated through the lens of kinetic energy.

References

Ascari, Guido (2004) "Staggered Prices and Trend Inflation: Some Nuisances," *Review of Economic Dynamics*, Vol. 7, No. 3, pp. 642-667.

Bakhshi, Hasan, Pablo Burriel-Llombart, Hashmat Khan and Barbara Rudolf (2003) "Endogenous Price Stickiness, Trend Inflation, and the New Keynesian Phillips Curve," *Bank of England Working Paper* No. 191.

Buiter, Willem H. (2002) "The Fiscal Theory of the Price Level: A Critique," *Economic Journal*, Vol. 122, pp. 459–480.

Buiter, Willem H. (2004) "A Small Corner of Intertemporal Public Finance–New Developments in Monetary Economics: Two Ghosts, Two Eccentricities, A Fallacy, A Mirage and A Mythos," *NBER Working Paper* No. 10524.

Cochrane, John H. (1998a) "A Frictionless View of US Inflation," *NBER Macroeconomics Annual*, Cambridge MA, MIT Press, pp. 323–384.

Cochrane, John H. (1998b) "Long-term Debt and Optimal Policy in the Fiscal Theory of the Price Level," *NBER Working Paper* No. 6771.

Cochrane, John H. (2005) "Money as Stock: Price Level Determination with No Money Demand," *Journal of Monetary Economics*, Vol. 52, No. 3, pp. 501–528.

Cogley, Timothy and Argia M. Sbordone (2005) "A Search for a Structural Phillips Curve," *Federal Reserve Bank of New York, Staff Reports*, No. 203.

Cogley, Timothy and Argia M. Sbordone (2006) "Trend Inflation and Inflation Persistence in the New Keynesian Phillips Curve," *Federal Reserve Bank of New York, Staff Reports*, No. 270.

Ellison, Martin and Joseph Pearlman (2011) "Saddlepath Learning," *Journal of Economic Theory*, Vol. 146, No. 4, pp. 1500-1519.

Evans, George W. and Honkapohja, Seppo (2001) *Learning and Expectations in Macroeconomics*, Princeton and Oxford, Princeton University Press.

Fuhrer, Jeff (2006) "Intrinsic and Inherited Inflation Persistence," *International Journal of Central Banking*, Vol. 2, No. 3, pp. 49-86.

Fuhrer, Jeff and George Moore (1995) "Inflation Persistence," *Quarterly Journal of Economics*, Vol. 110, No. 1, pp. 127-159.

Galí, Jordi and Mark Gertler (1999) "Inflation Dynamics: A Structural Econometric Analysis," *Journal of Monetary Economics*, Vo. 44, No. 2, pp. 195–222.

Galí, Jordi, Mark Gertler, and David López-Salido (2005) "Robustness of the Estimates of the Hybrid New Keynesian Phillips Curve," *Journal of Monetary Economics*, Vol. 52, No. 6, pp. 1107-1118.

Harashima, Taiji (2004a) "The Ultimate Source of Inflation: A Microfoundation of the

Fiscal Theory of the Price Level," *EconWPA Working Papers*, ewp-mac/ 0409018.
Harashima, Taiji (2004b) "A More Realistic Endogenous Time Preference Model and the Slump in Japan," *EconWPA Working Papers*, ewp-mac0402015.
Harashima, Taiji (2005) "The Cause of the Great Inflation: Interactions between Government and Monetary Policymakers," *EconWPA Working Papers,* ewp-mac/0510026.
Harashima, Taiji (2006) "The Sustainability of Budget Deficits in an Inflationary Economy," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 1088.
Harashima, Taiji (2007a) "Why should central banks be independent?" *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 1838.
Harashima, Taiji (2007b) "The Optimal Quantity of Money Consistent with Positive Nominal Interest Rates," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 1839.
Harashima, Taiji (2007c) "Hyperinflation, Disinflation, Deflation, etc.: A Unified and Micro-founded Explanation for Inflation," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 3836.
Harashima, Taiji (2008) "A Microfounded Mechanism of Observed Substantial Inflation Persistence," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 10668.
Harashima, Taiji (2009) "Depression as a Nash Equilibrium Consisting of Strategies of Choosing a Pareto Inefficient Transition Path," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 18987.
Harashima, Taiji (2013a) "The Optimal Quantity of Money Consistent with Positive Nominal Interest Rates," in Japanese, *Journal of Kanazawa Seiryo University*, Vol. 46, No. 2, pp. 27-36.（原嶋　耐治「正の名目金利と整合的な最適貨幣量」、『金沢星稜大学論集』第46巻第2号27-36頁）.
Harashima, Taiji (2013b) "The Phillips Curve and a Micro-foundation of Trend Inflation," *Theoretical and Practical Research in Economic Fields*, Vol. 4, No. 2, pp. 153-182.
Harashima, Taiji (2016a) "The Sustainability of Budget Deficits in an Inflationary Economy," in Japanese, *Journal of Kanazawa Seiryo University*, Vol. 49, No. 2, pp. 107-115（原嶋　耐治「「インフレ環境下における財政の持続可能性」、『金沢星稜大学論集』第49巻第2号107-115頁）.
Harashima, Taiji (2016b) "A Theory of Deflation: Can Expectations Be Influenced by a Central Bank?" *Theoretical and Practical Research in Economic Fields*, Vol. 7, No. 2, pp. 98-144.
Harashima, Taiji (2016c) "The Cause of the Great Recession: What Caused the Downward Shift of the GDP Trend in the United States?" *MPRA* (*The Munich*

Personal RePEc Archive) *Paper* No. 69215.

Harashima, Taiji (2018a) "Do Households Actually Generate Rational Expectations? "Invisible Hand" for Steady State," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 88822.

Harashima, Taiji (2018b) "Why Are Inflation and Real Interest Rates So Low? A Mechanism of Low and Floating Real Interest and Inflation Rates," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 84311.

Harashima, Taiji (2018c) "Hyperinflation, Disinflation, Deflation, etc.: A Unified and Micro-founded Explanation for Inflation," in Japanese, *Journal of Kanazawa Seiryo University*, Vol. 52, No. 1, pp. 41-68.（原嶋　耐治「ミクロ的基礎に立つインフレーションの統一的説明―超インフレーション、ディスインフレーション、デフレーション等―」、『金沢星稜大学論集』第52巻第1号41～68頁）.

Harashima, Taiji (2018d) "Depression as a Nash Equilibrium Consisting of Strategies of Choosing a Pareto Inefficient Transition Path," in Japanese, *Journal of Kanazawa Seiryo University*, Vol. 51, No. 2, pp. 71 - 101.（原嶋　耐治「パレート非効率な移行経路を選択する戦略からなるナッシュ均衡としての恐慌」『金沢星稜大学論集』第 51 巻第 2 号 71～101 頁）.

Harashima, Taiji (2019a) "Do Households Actually Generate Rational Expectations? "Invisible Hand" for Steady State," in Japanese, *Journal of Kanazawa Seiryo University*, Vol. 52, No. 2, pp. 49 - 70.（原嶋　耐治「家計は実際に合理的期待を形成して行動しているのか―定常状態への「見えざる手」―」、『金沢星稜大学論集』第52巻第2号　49～70頁）.

Harashima, Taiji (2019b) "A Pareto Inefficient Path to Steady State in Recession," *Journal of Applied Economic Sciences,* Vol. 14, No. 3. pp. 842-850.

Harashima, Taiji (2020) "A Mechanism of Recession that Accompanies Persistent Pareto Inefficiency," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 98468.

Harashima, Taiji (2021a) "Consequence of Heterogeneous Economic Rents under the MDC-based Procedure," *Journal of Applied Economic Sciences,* Vol. 16, No. 2. pp. 185-190.

Harashima, Taiji (2021b) "The Cause of the Great Recession: What Caused the Downward Shift of the GDP Trend in the United States?" in Japanese, *Journal of Kanazawa Seiryo University*, Vol. 54, No. 2, pp. 55 - 67.（原嶋　耐治「世界同時不況の原因―米国の GDP 傾向変動の下方移動は何故生じたのか―」『金沢星稜大学論集』第 54 巻第 2 号 55～67 頁）.

Harashima, Taiji (2022a) "Numerical Simulations of Reaching a Steady State: No Need to Generate Any Rational Expectations," *Journal of Applied Economic Sciences*, Vol.

17, No. 4, pp. 321 – 339.
Harashima, Taiji (2022b) "A Theory of Inflation: The Law of Motion for Inflation under the MDC-based Procedure," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 113161.
Harashima, Taiji (2023a) "Numerical Simulation of Reaching a Steady State: Effects of Economic Rents on Development of Economic Inequality," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 117137.
Harashima, Taiji (2023b) "Numerical Simulations of How Economic Inequality Increases in Democratic Countries," *Journal of Applied Economic Sciences*, Vol. 18, No. 3, pp. 221 – 246.
Harashima, Taiji (2023c) "Numerical Simulation of an Endogenously Growing Economy and Its Balanced Growth Path," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 119391.
Harashima, Taiji (2023d) "A Mechanism of Recession that Accompanies Persistent Pareto Inefficiency," in Japanese, *Journal of Kanazawa Seiryo University*, Vol. 57, No. 1, pp. 79 - 93.（原嶋　耐治「パレート非効率を伴う不況の機序」『金沢星稜大学論集』第 57 巻第 1 号 79～93 頁）.
Harashima, Taiji (2024a) "Numerical Simulation of Economic Depression," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 120508.
Harashima, Taiji (2024b) "Macroeconomics Is Still Useful and Necessary: A Mechanism to Explain the Condition when Strict Convexity is Unsatisfied," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 121168.
Harashima, Taiji (2025a) "Numerical Simulation of Economic Inequality Widened by the Persistent Effects of Temporary Rent Income," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 123557.
Harashima, Taiji (2025b) "Numerical Simulation of Reaching a Steady State: Effects of Using Progressive Income Tax and Public Assistance," *MPRA* (*The Munich Personal RePEc Archive*) *Paper* No. 126188.
Hornstein, Andreas (2007) "Evolving Inflation Dynamics and the New Keynesian Phillips Curve," *Economic Quarterly, Federal Reserve Bank of Richmond*, Fall 2007, pp. 317-339.
Kocherlakota, Narayana and Christopher Phelan (1999) "Explaining the Fiscal Theory of the Price Level," *Federal Reserve Bank of Minneapolis Quarterly Review*, Vol. 23, No. 4, pp. 14–23.
Leeper, Eric (1991) "Equilibria under Active and Passive Monetary and Fiscal Policies," *Journal of Monetary Economics*, Vol. 27, pp. 129–147.
Marcet, Albert and Thomas J. Sargent (1989) "Convergence of Least Squares Learning Mechanisms in Self-referential Linear Stochastic Models," *Journal of Economic*

Theory, Vol. 48, No. 2, pp. 337-368.

Mankiw, Gregory (2001) "The Inexorable and Mysterious Tradeoff between Inflation and Unemployment," *The Economic Journal*, Vol. 111, No. 471, pp. C45-C61

McCallum, Bennett T. (2001) "Indeterminacy, Bubbles, and the Fiscal Theory of Price Level Determination," *Journal of Monetary Economics*, Vol. 47, pp. 19−30.

McCallum, Bennett T. (2003) "Is The Fiscal Theory of the Price Level Learnable?" *Scottish Journal of Political Economy*, Vol. 50, pp. 634-49.

Niepelt, Dirk (2004) "The Fiscal Myth of the Price Level," *The Quarterly Journal of Economics*, Vol. 119, pp. 276-99.

Sbordone, Argia M.(2007) "Inflation Persistence: Alternative Interpretations and Policy Implications," *Journal of Monetary Economics*, Vol. 54, pp. 1311–1339.

Sims, Christopher A. (1994) "A Simple Model for Study of the Determination of the Price Level and the Interaction of Monetary and Fiscal Policy," *Economic Theory*, Vol.4, pp. 381–399.

Sims, Christopher A. (1998) "Econometric Implications of the Government Budget Constraint," *Journal of Econometric*s, Vol. 83, pp. 9–19.

Sims, Christopher A. (2001) "Fiscal Consequence for Mexico Adopting the Dollar," *Journal of Money, Credit and Banking*, Vol. 23, pp. 597–625.

Stock, James H. and Mark W. Watson (2006) "Why Has U.S. Inflation Become Harder to Forecast?" *NBER Working Paper* No. 12324

Woodford, Michael (1995) "Price Level Determinacy without Control of a Monetary Aggregate," *Carnegie-Rochester Conference Series on Public Policy*, Vol. 43, pp. 1–46.

Woodford, Michael (2001) "Fiscal Requirements for Price Stability," *Journal of Money, Credit and Banking*, Vol. 33, pp. 669-728.

Woodford, Michael (2007) "Interpreting Inflation Persistence: Comments on the Conference on "Quantitative Evidence on Price Determination," *Journal of Money, Credit and Banking*, Vol. 39, No. s1, pp. 203-210.