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Implementability of the Non-Ricardian Optimal Fiscal Policy

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Dealing with out-of-equilibrium behaviors of economic agents is necessary to fill in the gaps in the controversy surrounding the admissibility of the fiscal theory of the price level (FTPL). Incorporating Nash equilibrium into the theory serves this purpose. It turns out that under certain conditions, strategic interaction between a non-Ricardian benevolent government and households with tit-for-tat moves leads to an equilibrium consistent with the FTPL, where the non-Ricardian optimal fiscal policy is not globally viable. Implementability of the non-Ricardian policy depends on the stochastic properties of government expenditure, especially its variance.

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1. Introduction

Determinants of price level and inflation have long been a central concern for monetary economics and these are still under dispute. The recent development of the fiscal theory of the price level (FTPL) has spurred a debate on this issue.

This theory has two significant implications with regard to inflation. First, price stabilization may not be achieved even though the monetary authority fully commits to it. Second, the theory gives another insight into the welfare implications of inflation; since debt finance is a distortion-free source of funds, it may be better for the fiscal authority to issue nominal bonds and let the price level fluctuate than to raise funds solely by levying distorting taxes.

These new findings offered by the theory have been regarded as critical challenges to the traditional monetarist's view and have caused a great controversy. The major criticism leveled against the theory pertains to the admissibility of the so-called "non-Ricardian" fiscal policy that enables the government to select

arbitrary inflation paths. The difficulty in settling the dispute stems from the fact that opponents make an issue of the out-of-equilibrium behavior of an economy under the non-Ricardian regime, whereas many existing analyses on the FTPL incorporate Walrasian general equilibrium, which is not a suitable concept when it comes to dealing with a consequence of deviation from an equilibrium path.

In order to reach a balanced understanding about the admissibility of the FTPL, this paper treats an economy as a game between a representative household and a benevolent government, and incorporates Nash equilibrium. Their conduct is characterized as complete contingent plan and strategic interactions among them are investigated. It turns out that under certain conditions, a strategic interaction between a non-Ricardian benevolent government and a tit-for-tat household leads to the FTPL. However, the non-Ricardian optimal fiscal policy is not globally viable. Whether or not the non-Ricardian rule is implementable depends on the stochastic characteristics of government expenditure, such as its mean and variance.

2. Overview of the Literature

The main idea of the FTPL comes from the intertemporal budget equation, which links the real value of public debt to the present value of fiscal surpluses in the future.

$$\frac{B_t}{P_t} = E_t \sum_{j=0}^{\infty} \frac{s_{t+j}}{(1+r_t)^j}, \qquad s_t = s_t^f + s_t^m, \tag{1}$$

where B_t, P_t, r_t, s_t, s_t^f, and s_t^m are nominal government debt, price level, real interest rate, consolidated government surplus, primary surplus, and seigniorage at period t, respectively. The FTPL claims that the price level is determined as a consequence of the adjustment of the real value of the outstanding nominal debt in response to a change in the present value of government surplus.

What makes the FTPL unique is its interpretation of the intertemporal budget equation (1). That is, the theory treats the equation as an "equilibrium condition"; the equation holds only at the equilibrium price level. By contrast, the same equation is thought of as a "constraint" in the traditional view; a dynamic path of government surpluses has to be set so that equation (1) holds in all contingencies. Fiscal policy is called "Ricardian" when it is designed in line with the traditional view, whereas it is "non-Ricardian" when consistent with the fiscal theorist's view [14]. Under a Ricardian regime, fiscal policy is a strategy for setting surplus as a function of real debt. Under a non-Ricardian regime, it is a commitment to a particular action.

Among an infinite number of specifications of non-Ricardian policy rules, Christiano and Fitzgerald (2000) take up a micro-founded one. They emphasize that the FTPL offers deeper insights into the key questions of monetary economics.

The first question deals with the manner in which price stability can be achieved and the second, with the extent of the desirability of price stability. They analyze a simple two-period economy to demonstrate that fiscal disturbances make price fluctuation inevitable even when the central bank is fully committed to price stability. They also show that Ramsey equilibrium in the economy is achieved by implementing a non-Ricardian fiscal policy rule: a constant labor tax rate. This means that price fluctuation is more socially desirable than distorting the economy with volatile tax rates.

The fiscal theorist's interpretation of the intertemporal budget equation implies that the government can enforce an arbitrary inflation path as equilibrium by controlling a dynamic path of fiscal surpluses. Proponents of the FTPL such as Woodford (1998) and Cochrane (2000) justify this by comparing a government to a large player in an economy which has the ability to affect prices.

The other side of the same coin is that a non-Ricardian government would violate the equation (1) out of equilibrium. Opponents argue that the fundamental principles of a market economy would not accept such thinking. For instance, Buiter (2002, 2004) argues that any economic agent in a market economy, irrespective of its size, is subject to hard budget constraint based on clearly defined property rights[1].

One would hardly believe that the budget constraint is so soft as to allow a government to ignore it and choose any arbitrary price level; this argument does seem to have a point. However, this criticism itself does not clarify "how hard" the government budget constraint is. It is indispensable to explicitly address the out-of-equilibrium behavior of economic entities in order to draw a line on how far a government could exercise an influence on its own budget constraint. As Bassetto (2002) points out, a competitive equilibrium, which is employed in both of the papers that advocate and oppose the FTPL, is not a good concept to deal with the consequences of deviations from the equilibrium path. Alternatively, he suggests describing the economy as a game among economic agents and specifies their actions as strategies or complete contingent plans. That is, he treats the economy as a Shapley-Shubik trading-post game among households and the government and reaches a clearer and less controversial conclusion than the previous literature; his main findings are that there exist government strategies that lead to a version of the FTPL but that these strategies are more complex than the simple rules associated with the FTPL and the intertemporal government budget equation cannot merely be viewed as an equilibrium condition.

Christiano and Fitzgerald (2000) also interpret an economy as a game between a government and a Walrasian auctioneer, whose objective is to achieve market clearing. The FTPL is justified as a case where the government makes the first

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[1] Many other authors' criticisms against the FTPL are based on speculative bubble-like findings of a collection of anomalies or counter-intuitive outcomes brought by the theory (Kocherlakota and Phelan 1999, McCallum 2001) or the lack of learnability of the non-Ricardian fiscal policy (McCallum 2003).

move. However, Bassetto (2002) argues that the Walrasian auctioneer is purely a reduced form for a more complex price formation mechanism and hence one cannot evaluate within such a framework as to who makes the first move. A crucial point of his argument is that the analysis in Christiano and Fitzgerald (2000) is based on an assumption that a government has the ability to commit to an action while maintaining labor tax at a constant level before households make a move. Bassetto (2005) calls this standard definition of commitment "Ramsey timing." He stresses that the optimal policy is sometimes not implementable in Ramsey timing because the government's action leads to infeasible outcomes for some of the moves made by the other players.

This argument is closely connected to the problem of time inconsistency[2]. Since the Ramsey implementation does not tell us what will happen if the second mover takes an action inconsistent with the Ramsey outcome, it cannot exclude possible outcomes other than the optimal allocation. A government may break its commitment and respond differently from the promised action after observing households' actions, resulting in a sub-optimal allocation.

Alternatively, Bassetto (2005) advocates modeling commitment as a process of threats and promises that the government is able to bind itself to. In this case, the government commits not to an unconditional action but to a strategy that is a conditional response to households' actions. The government chooses its actual action according to the strategy committed to only after observing households' actions. Bassetto calls this "Schelling timing." He argues that Ramsey implementation is inadequate to justify a preferred allocation as an outcome of strategic interaction among agents; he also argues that Schelling implementation is more appropriate to approach this issue.

The issue of the implementability of the non-Ricardian fiscal policy parallels the argument made by opponents of the FTPL in that the FTPL allows out-of-equilibrium behavior of agents; without the ability to commit to an unconditional action, a government cannot implement a Ramsey outcome unless it preprograms its response to the household's actions out of the preferred equilibrium. Thus, a full description of a strategic environment is necessary for settling the controversy on the admissibility of the FTPL. The present paper sheds light on this issue. It treats an economy as a game between a representative household and a benevolent government that issues nominal debt for the purpose of implementing a non-Ricardian optimal tax rule. It is shown that Ramsey implementation of the optimum faces time inconsistency. Then, it specifies each player's action as a complete contingent plan in order to reveal in what cases the optimal policy rule is implementable and when the equilibrium that is consistent with the FTPL arises among the possible outcomes.

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[2] Indeed, Bassetto (2005) considers an analysis of the optimal capital taxation in Fischer (1980) as an example, which is also introduced as an example of the issue of time inconsistency in Chapter 7 of Cooper (1999) and others.

3. Time Inconsistency of the Non-Ricardian Fiscal Policy

3.1. FTPL in a Two-period Christiano-Fitzgerald Economy

Christiano and Fitzgerald (2000) analyze the following two-period economy to show that Ramsey equilibrium is characterized by a non-Ricardian fiscal policy rule.

Suppose that an economy exists for two periods. There are many representative households and representative firms. A competitive firm employs a representative household to produce consumption goods. Production technology follows one-for-one mapping:

$$y=h$$

where y represents the amount of consumption goods produced and h is the labor force supplied by the representative household. The firm pays a unitary real wage, which equals the marginal product of labor, to the household.

A government levies labor tax at the rate τ on the households and issues nominal bonds to finance its expenditure. There is uncertainty about the government expenditure in the second period; it will be either g_h ("high" state) or g_l ("low" state), each with probability $\frac{1}{2}$.

3.1.1. Representative Household's Problem

The representative household faces the following two-period optimization problem:

$$\underset{c,c_h,c_l,h,h_h,h_l}{Max}\ U=c-\frac{1}{2}h^2+\frac{\beta}{2}\left[\left(c_h-\frac{1}{2}h_h^2\right)+\left(c_l-\frac{1}{2}h_l^2\right)\right],$$

subject to

$$B+(1-\tau)h\geq\frac{B'}{N}+c,$$
$$\frac{B'}{P_h}+(1-\tau_h)h_h\geq c_h,$$
$$\frac{B'}{P_l}+(1-\tau_l)h_l\geq c_l,$$

where c and h are the consumption and labor supply in the first period, respectively; c_i and h_i are the consumption and labor supply in the second period, respectively, when the state is i; β is the subjective discount rate; B is the initial public debt; B' is the bond purchase in the first period; N is the (gross) nominal

interest rate set by the monetary authority; τ is the labor tax rate in the first period; and τ_i is the labor tax rate in the second period, when the state is i. Further, P_i is the price level in the second period when the state is i (the price level in the first period is set at unity).

The first-order necessary conditions for the optimality are the following:

$$h=1-\tau, \tag{2}$$
$$h_h=1-\tau_h, \tag{3}$$
$$h_l=1-\tau_l \tag{4}$$
$$N\beta\frac{1}{2}\left(\frac{1}{P_h}+\frac{1}{P_l}\right)=1. \tag{5}$$

3.1.2. Ramsey Equilibrium in the Economy

The government in the economy is assumed to be benevolent; taking account of the household's optimizing behavior characterized by conditions (2) to (5), it chooses a set of policy variables $\prod=(\tau, \tau_h, \tau_l, B')$ such that the household's expected lifetime utility is maximized. The government's action is also subject to the budget constraints:

$$\frac{B'}{N}+\tau h\geq g+B, \tag{6}$$
$$\tau_h h_h\geq g_h+\frac{B'}{P_h}, \tag{7}$$
$$\tau_l h_l\geq g_l+\frac{B'}{P_l}. \tag{8}$$

Together with the budget constraint for the household, we have the following resource constraints:

$$h\geq c+g,$$
$$h_h\geq c_h+g_h,$$
$$h_l\geq c_l+g_l.$$

Combining the above budget and resource constraints with the household's optimality conditions (2) to (5), one can obtain constraints on the government's action:

$$\beta\frac{\tau_h(1-\tau_h)-g_h+\tau_l(1-\tau_l)-g_l}{2}\geq B+g-\tau(1-\tau). \tag{9}$$

This implies that the present value of expected surplus (the left side of the above equation) in the second period has to be greater than the deficit in the first period (the right-hand side). As another constraint, the government cannot run a deficit in

the second period because it is the last period of the economy:

$$\tau_h(1-\tau_h)-g_h \geq 0, \tag{10}$$
$$\tau_l(1-\tau_l)-g_l \geq 0. \tag{11}$$

Ramsey equilibrium in this economy is characterized by the solution to the following problem.

$$\underset{\tau,\tau_h,\tau_l}{Max}U=(1-\tau)-g-\frac{1}{2}(1-\tau)^2 + \frac{\beta}{2}\left\{\left[(1-\tau_h)-g_h-\frac{1}{2}(1-\tau_h)^2\right]+\left[(1-\tau_l)-g_l-\frac{1}{2}(1-\tau_l)^2\right]\right\},$$

subject to the constraints (9), (10), and (11).

The first-order conditions to this problem are the following:

$$\frac{\beta}{2}\left(\frac{2\tau}{1-2\tau}-\frac{2\tau_h}{1-2\tau_h}\right)=0,$$
$$\frac{\beta}{2}\left(\frac{2\tau}{1-2\tau}-\frac{2\tau_l}{1-2\tau_l}\right)=0.$$

These imply

$$\tau=\tau_h=\tau_l.$$

Thus, the optimal policy rule requires constancy of labor tax rate[3]. This is a non-Ricardian policy rule, for fiscal surpluses are not a function of the real value of government debt. The benevolent government should issue nominal bonds in the first period and allow the price level in the second period to fluctuate so that the real value of debt adjusts in accordance with shifts in fiscal surplus, rather than changing the rate of the distorting tax. In Ramsey equilibrium, nominal bonds work as a shock absorber.

3.1.3. Time Inconsistency of the Non-Ricardian Optimal Fiscal Policy

However, determining which rule is socially optimal is one thing and enforcing it quite another. If the government does not have the ability to commit to certain

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[3] Sims (2001) points out that this conclusion results from simplifying the assumptions that agents are not risk averse or that government expenditure does not affect the marginal utility of consumption (analysis here relies on the latter assumption). However, at the same time, he demonstrates that the conclusion is not fundamentally misleading in a more general setup: a government that issues fiat debt and optimally sets taxes in a way that is totally unresponsive to changes in expected primary surpluses, so that all surprises in the intertemporal government budget constraint are absorbed in surprise inflation.

policies, then its action may backfire. Troubles stemming from inability to commit to action are referred to as the problem of time inconsistency.

Time inconsistency arises when the incentive for a government to keep commitment changes over time [7]. This is exactly the case in this Christiano-Fitzgerald economy; incentive for the government to inflate the economy changes over time. That is, it is optimal for the government in the first period to promise to fix the labor tax rate and issue nominal bonds in preparation for uncertainty about fiscal expenditure; however, it would want to cut the labor tax in order to inflate the accumulated debt away when the second period actually arrives. Constant labor tax rate is optimal ex ante but not ex post.

Suppose that in the first period the government decides to set labor tax rate at $\tau=\tau_h=\tau_l=\bar{\tau}$ so that conditions (10) and (11) are satisfied with strict inequality. Then, the household's utility in the second period is $(1-\bar{\tau})-g_h-\frac{1}{2}(1-\bar{\tau})^2$ when the high state arises and $(1-\bar{\tau})-g_l-\frac{1}{2}(1-\bar{\tau})^2$ when the low state does. However, the government would set $\tau_i=0(i=h, l)$ when the second period actually arrives because it yields higher utility $-\frac{1}{2}-g_h$ in the high state and $\frac{1}{2}-g_l$ in the low state — than the redemption of the above commitment would. In this case, conditions (7) and (8) require the price level in the second period to be infinity.

As long as this government's change of mind is expected, the equation (5), the optimality condition for the household's bond purchase, would never be met and hence, no one would buy the government bond in the first period. If no one buys the government bond, then the government's optimal strategy fails. This result confirms the opposing argument against the FTPL: since out-of-equilibrium behavior of the government would destroy people's property rights by infinite inflation, they would not allow the non-Ricardian fiscal rule to be implemented.

3.2. Non-Ricardian Optimal Fiscal Policy in a Multi-period Economy

In the two-period Christiano-Fitzgerald economy, incentive incompatibility of the non-Ricardian optimal fiscal rule becomes unsatisfied and therefore, the government cannot implement it. However, the non-Ricardian optimal fiscal rule could be credible in a multi-period setting. This subsection extends the Christiano-Fitzgerald economy to a multi-period setting and characterizes the economy as a repeated game between the representative households and the government.

3.2.1. Ramsey Equilibrium in a Multi-period Economy

Consider an economy with infinitely lived identical households. Let the lifetime utility of a representative household be

$$E_0 \sum_{t=0}^{\infty} \beta^t (c_t - Ah_t^2),$$

where c_t and h_t are consumption and labor supply at period t, respectively; β is the subjective discount rate; and A is a parameter for disutility from working. Production technology is the same as that in the two-period model in the previous subsection, and hence, the household receives unitary real wage for one unit of labor supply. A budget constraint for the household is

$$(1-\tau_t)h_t + \frac{N_{t-1}B_{t-1}}{P_t} \geq c_t + \frac{B_t}{P_t},$$

where τ_t, B_t, N_t, and P_t are the labor tax rate, purchase amount of nominal bond, (gross) nominal interest rate, and price level at period t, respectively.

Formally, the dynamic optimization problem for the household can be formulated as below.

$$\underset{c_t, h_t, b_t}{Max} E_0 \sum_{t=0}^{\infty} \beta^t (c_t - Ah_t^2),$$

subject to

$$(1-\tau_t)h_t + \frac{N_{t-1}}{\phi_t} b_{t-1} \geq c_t + b_t,$$

where $\phi_t = \frac{P_t}{P_{t-1}}$ and $b_t = \frac{B_t}{P_t}$. Clearly, the first-order conditions for this problem are

$$h_t = \frac{1-\tau_t}{2A},$$
$$\beta N_t E_t \left(\frac{1}{\phi_{t+1}} \right) = 1.$$

Then the problem for a benevolent government can be formulated as follows.

$$\underset{\tau_t, b_t, \phi_t}{Max} E_0 \sum_{t=0}^{\infty} \beta^t [(1-\tau_t) - g_t - A(1-\tau_t)^2],$$

subject to

$$\mu_t : b_t + \tau_t \frac{1-\tau_t}{2A} \geq \frac{N_{t-1}}{\phi_t} b_{t-1} + g_t,$$

$$\zeta_t : N_t \beta E_t \left(\frac{1}{\phi_{t+1}} \right) = 1,$$

where μ_t and ζ_t are Lagrangian multipliers associated with each condition. The first-order conditions are

$$\mu_t = \frac{(1-2A+2A\tau_t)2A}{1-2\tau_t},$$
$$\beta N_t E_t \left(\frac{\mu_{t+1}}{\phi_{t+1}} \right) = \mu_t,$$
$$\mu_t = \frac{\zeta_{t-1}}{N_t b_t}.$$

The second and third conditions imply

$$\beta \frac{\zeta_t}{b_t} E_t \frac{1}{\phi_{t+1}} = \frac{\zeta_{t-1}}{N_{t-1} b_{t-1}}.$$
$$\Leftrightarrow \quad \frac{\zeta_t}{N_t b_t} = \frac{\zeta_{t-1}}{N_{t-1} b_{t-1}}.$$
$$\Leftrightarrow \quad \mu_{t+1} = \mu_t.$$

Together with the first condition, this implies

$$\tau_{t+1} = \tau_t.$$

Again, Ramsey equilibrium is characterized by a constant labor tax rate.

In the rest of this paper, three assumptions shall be maintained. First, the government decides to commit to implementing the optimal tax rule $\tau_t = \tau \in (0, 1)$, $\forall t = 1, 2, \cdots$. Second, its expenditure g_t follows a two-state discrete Markov chain; it takes either a high or low value and the transition probability matrix is given by

$$\Pi = \begin{bmatrix} \pi & 1-\pi \\ 1-\pi & \pi \end{bmatrix}.$$

Finally, the nominal interest rate is set by the monetary authority at $N_t = N$, $\forall t = 1, 2, \cdots$. Then, a stationary equilibrium in this economy is characterized in terms of $Z = (b^h, b^l, \phi^{hh}, \phi^{lh}, \phi^{hl}, \phi^{ll})$, where b^i denotes the real debt in state i and ϕ^{ij} represents the inflation rate from state i to state j $(i, j = h, l)$. Here, of course, arguments of Z must satisfy the following constraints:

$$b^h + \tau \frac{1-\tau}{2A} \geq \frac{N}{\phi^{hh}} b^h + g^h,$$

$$b^h+\tau\frac{1-\tau}{2A}\geq\frac{N}{\phi^{lh}}b^l+g^h,$$
$$b^l+\tau\frac{1-\tau}{2A}\geq\frac{N}{\phi^{hl}}b^h+g^l,$$
$$b^l+\tau\frac{1-\tau}{2A}\geq\frac{N}{\phi^{ll}}b^l+g^l,$$
$$N\beta\left[\pi\frac{1}{\phi^{hh}}+(1-\pi)\frac{1}{\phi^{hl}}\right]=1,$$
$$N\beta\left[\pi\frac{1}{\phi^{ll}}+(1-\pi)\frac{1}{\phi^{lh}}\right]=1.$$

Again, the optimal rule faces time inconsistency. Once households purchase the fiat debt, the government has an incentive to inflate it away. Assume that b_t is below bounded. Since there is no welfare cost in inflation in the flexible price economy, the government would cause an infinite rate of inflation and completely wipe away its debt; ex post utility in period t is maximized at $\frac{1}{4A}-g_t$ by setting $\tau_t=0$ and $b_t=g_t$. Unless the government has the ability to unconditionally commit to the optimal tax rule, it is not implementable.

3.2.2. Strategic Interaction in a Multi-period Economy

In this subsection, each economic agent's action is specified as a complete contingent plan and Nash equilibrium in the economy is investigated. It turns out that the Ramsey equilibrium could emerge as a Nash equilibrium; however, this is not necessarily the case.

To begin with, note that the non-Ricardian optimal fiscal policy can be expressed as

$$(b_t|i,\ \tau_t)=(b^i,\ \tau),\qquad \forall t=1,\ 2,\ \cdots,\ \infty,\qquad i=h,\ l,\qquad \tau\in(0,\ 1).$$

That is, the government chooses the real value of public debt conditional on the realization of fiscal expenditure while it keeps the tax rate constant unconditionally.

Thus, unlike in the previous subsection, the government commits not to a particular action but to a strategy. On the other hand, the representative household is assumed to exercise a threat by adopting a "trigger strategy." This is because he or she knows that the government has an incentive to deviate from the optimal rule. More specifically, the representative household demands public bonds as long as the government clings to the constant labor tax rate. Once the government inflates its nominal debts away, he or she gives up buying nominal bonds once and for all. Clearly, such a strategy is formulated as follows.

$$\text{Play}\quad b_t=b_t^g\quad \textit{if}\quad (b_s|i,\ \tau_s)=(b^i,\ \tau),\quad \forall s=1,\ 2,\ \cdots,\ t-1 \qquad \text{(H-1)}$$

$$\text{Play} \quad b_s=0, \quad \forall s=t, t+1, \cdots, \infty \quad \textit{if} \quad (b_{t-1}, \tau_{t-1})=(b^g_{t-1}, 0), \tag{H-2}$$

where b^g_t denotes the supply of government bonds in real value terms.

Note that the household's strategy just stated is consistent with the criticism made by opponents of the FTPL: he or she will not let the government infringe his or her property right by refusing to purchase the government bond. Further, note that the representative household's labor supply and consumption satisfy the first-order necessary conditions: $h_t=\dfrac{1-\tau_t}{2A}$ and $c_t=h_t+\dfrac{N_{t-1}b_{t-1}}{\phi_t}-b_t$.

Now suppose that the government in period zero decides to commit to the following conditional action plan:

$$\text{Play} \quad (b^g_t|i, \tau_t)=(b^i, \tau) \quad \text{if} \quad (b_s|i, \tau_s)=(b^i, \tau), \quad \forall s=1, 2, \cdots, t-1. \tag{G-1}$$

$$\text{Play} \quad (b^g_t|i, \tau_t)=(0, \tau^i) \quad \text{if} \quad b_{t-1}|i=0 \quad \text{and} \quad \tau^i=\frac{1-\sqrt{1-8Ag^i}}{2}. \tag{G-2}$$

That is, the government promises to maintain the constant labor tax rate as long as the household purchases public debt and to run a balanced budget if he or she refuses to buy public debt. In addition, the actual action of the government is assumed to be chosen after the household's action is observed.

Under this setting, there are two possible outcomes. One is that the government implements the optimal rule: the household and the government play (H-1) and (G-1), respectively. The other is that the government deviates from the optimal rule: the government plays $(b^g_t|i, \tau_t)=(g^i, 0)$ in period t and from then on, the household and the government play (H-2) and (G-2), respectively. Hereafter, the former is called "non-Ricardian Equilibrium" and the latter is called "Balanced Budget Equilibrium".

The non-Ricardian equilibrium would arise if social welfare gain from implementing the optimal fiscal rule exceeds the gain otherwise. First, letting V^O_i be the social welfare achieved by implementing the non-Ricardian optimal fiscal rule in state $i\,(i=h, l)$, we get

$$V^O_h=\frac{1-\tau^2}{4A}-g^h+\beta\,[\pi V^O_h+(1-\pi)V^O_l] \quad \textit{when} \quad g_t=g^h,$$
$$V^O_l=\frac{1-\tau^2}{4A}-g^l+\beta\,[\pi V^O_l+(1-\pi)V^O_h] \quad \textit{when} \quad g_t=g^l.$$

From these

$$V^O_h=\frac{1}{1+2\beta^2\pi-\beta^2-2\beta\pi}\left[(1-\beta\pi)\left(\frac{1-\tau^2}{4A}-g^h\right)+\beta\,(1-\pi)\left(\frac{1-\tau^2}{4A}-g^l\right)\right],$$
$$V^O_l=\frac{1}{1+2\beta^2\pi-\beta^2-2\beta\pi}\left[(1-\beta\pi)\left(\frac{1-\tau^2}{4A}-g^l\right)+\beta\,(1-\pi)\left(\frac{1-\tau^2}{4A}-g^h\right)\right].$$

On the other hand, letting V_i^B be the social welfare achieved by running a balanced budget in state $i\,(i=h,\ l)$, we get

$$V_h^B=\frac{1-\tau^{h^2}}{4A}-g^h+\beta\,[\pi V_h^B+(1-\pi)V_l^B]\quad when\quad g_t=g^h,$$
$$V_l^B=\frac{1-\tau^{l^2}}{4A}-g^l+\beta\,[\pi V_l^B+(1-\pi)V_h^B]\quad when\quad g_t=g^l,$$

where

$$\tau^i=\frac{1-\sqrt{1-8Ag^i}}{2}\quad for\quad i=h,\ l.$$

From these

$$V_h^B=\frac{1}{1+2\beta^2\pi-\beta^2-2\beta\pi}\left[(1-\beta\pi)\left(\frac{1-\tau^{h^2}}{4A}-g^h\right)+\beta\,(1-\pi)\left(\frac{1-\tau^{l^2}}{4A}-g^l\right)\right],$$
$$V_l^B=\frac{1}{1+2\beta^2\pi-\beta^2-2\beta\pi}\left[(1-\beta\pi)\left(\frac{1-\tau^{l^2}}{4A}-g^l\right)+\beta\,(1-\pi)\left(\frac{1-\tau^{h^2}}{4A}-g^h\right)\right].$$

Now, consider the government that has been implementing the non-Ricardian optimal fiscal rule until the beginning of a certain period t. If it deviates from the rule and inflates away its nominal debt, higher utility $\frac{1}{4A}-g^i$ is achieved in period t; however, the economy ends up with attaining period-by-period utility $\frac{1-\tau^i}{4A}-g^i$ from then on because the households play (H-2) against the government's action. Thus, the social welfare achieved by deviating from the optimal rule, which is denoted as V_i^D, becomes

$$V_h^D=\frac{1}{4A}-g^h+\beta\,[\pi V_h^B+(1-\pi)V_l^B]\quad when\quad g_t=g^h,$$
$$V_l^D=\frac{1}{4A}-g^l+\beta\,[\pi V_l^B+(1-\pi)V_h^B]\quad when\quad g_t=g^l.$$

Clearly, the fiscal authority maintains its commitment to the optimal rule as far as the following condition is satisfied:

$$V_h^O\geq V_h^D\ and\ V_l^O\geq V_l^D.$$

This condition gives the upper bound of labor tax rate τ^*, which makes the optimal fiscal rule credible.

$$\tau^{*}=\sqrt{1-\frac{4A\,[(1-\beta\pi)g^{l}+\beta\,(1-\pi)g^{h}-(1+2\beta^{2}\pi-\beta^{2}-2\beta\pi)V_{l}^{D}]}{1+\beta-2\pi\beta}} \tag{12}$$

In other words, Nash equilibrium in this economy is defined as follows.

1) Non-Ricardian Equilibrium
   The representative household plays (H−1) and the government plays (G−1) in $\forall t$ when $\tau\leq\tau^{*}$.
2) Balanced Budget Equilibrium
   The government plays $(b_{t}^{g}|i,\ \tau_{t})=(g^{i},\ 0)$ in period t and later plays (G−2) when the representative household plays (H−2) in period $t+1,\ \cdots,\ \infty$ when $\tau>\tau^{*}$.

The result obtained above can be interpreted intuitively; disutility from working comes from both level of labor supply and variation in it. While the optimal fiscal rule clears the latter effects away, the higher the optimal tax rate that the government sets, the greater is the disutility stemming from the level of labor supply. Therefore, there must be a cut-off point where the level effect caused by the optimal rule exceeds the variation effect caused by deviation from it. In a case where an optimal tax rate exceeds such a cut-off point, commitment to the optimal rule is not credible because people know that the economy would be better off simply deviating from it and expect that the government would indeed do so. The non-Ricardian equilibrium corresponds to a case in which the government is prompted to build a reputation for implementing the optimal fiscal policy rule so that the policy rule wins credibility [1].

The result shown above gives an important caveat against an application of the FTPL. Non-Ricardian fiscal policy is sometimes thought of as an escape from a liquidity trap. It is claimed that non-Ricardian fiscal policy could work as an active policy against deflation even when monetary policy has to be passive because of zero-lower-bound on nominal interest rate. However, the analysis here tells us that the fiscal authority is not given a free hand in selecting an arbitrary price vector; therefore, non-Ricardian policy is not globally implementable[4].

4. Implementability of the Non-Ricardian Fiscal Policy

Notice that equation (12) implies that implementability of the non-Ricardian fiscal policy depends on properties of fiscal expenditure in addition to parameters on the representative household's preferences. To see this, let g and σ be the mean and standard deviation of government purchases, respectively. Then, $g^{h}=g+\sigma$,

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[4] In addition, what the fiscal authority could handle is the volatility of inflation and it cannot exercise any influence on average inflation; unanticipated inflation occurs in response to a fiscal shock; however, expected inflation is ruled by monetary policy, as the constraint below indicates.

$$\beta N_{t}E_{t}\left(\frac{1}{\phi_{t+1}}\right)=1.$$

$g^l = g - \sigma$, and

$$\tau^* = \sqrt{1 - \frac{4A\,[(1-\beta\pi)(g-\sigma) + \beta\,(1-\pi)(g+\sigma) - (1+2\beta^2\pi - \beta^2 - 2\beta\pi)V_l^D]}{1+\beta-2\pi\beta}} \quad (13)$$

Thus, the upper bound on the optimal tax rate is affected by the mean (g), standard deviation (σ), and persistency (π) of government expenditure.

Tables 1, 2, and 3 provide some numeric examples. Table 1 compares equilibria with different values for average government expenditure. It is natural that a larger size of government expenditure corresponds to a higher level of tax rate as long as the state of the economy is to the left of a Laffer curve. Thus, we have a higher upper bound of the optimal tax rate for a larger value of g.

Table 2 reports how the economy behaves according to different values of standard deviations of government expenditure. For a larger standard deviation, the upper bound of the optimal tax rate is higher. This is because running a balanced budget is accompanied by larger intertemporal variation in the labor tax rate as the government expenditure becomes more volatile. Since the government finds deviation from it to be less attractive, the optimal fiscal rule even with a higher tax rate can be given credence. At the same time, a mean-preserving spread of government expenditure enlarges the size of fiscal surpluses and deficits, and hence, stationary level of government debt becomes larger as σ increases. With a higher stationary level of debts, even a small adjustment of the price level suffices for absorbing a shock in government expenditure. Consequently, inflation becomes milder in an economy with heavier debts.

Figure 1 displays the upper bound of the optimal tax rates for different values of g and σ. It can be seen that the effect of g on the upper bound is linearly

Table 1 Mean of Government Expenditure and Stationary Equilibria

		g (σ=0. 025, π=0. 5)			
		0. 05	0. 10	0. 15	0. 20
Upper Bound of τ		0. 051	0. 099	0. 156	0. 226
Real Debt					
	High	0. 577	0. 333	0. 263	0. 281
	Low	0. 577	0. 333	0. 263	0. 281
Inflation (%)					
	High to High	8. 5	12. 2	14. 6	13. 9
	Low to High	8. 5	12. 2	14. 6	13. 9
	Low to Low	− 0. 4	− 3. 3	− 5. 1	− 4. 6
	High to Low	− 0. 4	− 3. 3	− 5. 1	− 4. 6
	Average	4. 0	4. 4	4. 8	4. 7
	S. D.	4. 5	7. 8	9. 9	9. 2

Table 2 Standard Deviation of Government Expenditure and Stationary Equilibria

		$\sigma\,(g=0.10,\ \pi=0.5)$			
		0.015	0.025	0.050	0.075
Upper Bound of τ		0.096	0.099	0.112	0.131
Real Debt					
	High	0.094	0.333	1.374	2.890
	Low	0.094	0.333	1.374	2.890
Inflation (%)					
	High to High	23.4	12.2	7.7	6.6
	Low to High	23.4	12.2	7.7	6.6
	Low to Low	−10.4	−3.3	0.2	1.3
	High to Low	−10.4	−3.3	0.2	1.3
	Average	6.5	4.4	4.0	3.9
	S. D.	16.9	7.8	3.7	2.7

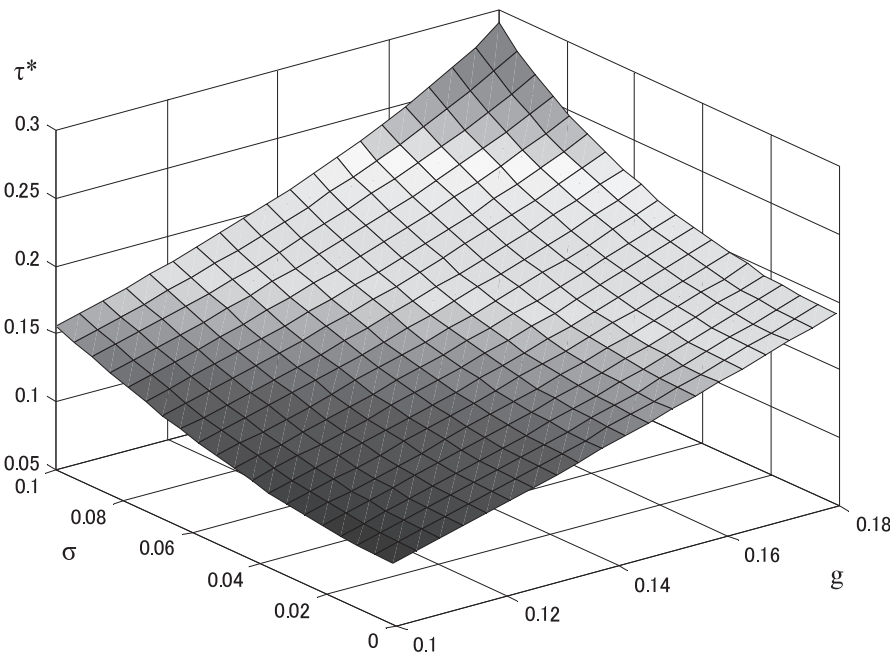

Figure 1 Implementability Frontier: Mean versus Variation

Table 3 Persistency of Government Expenditure and Stationary Equilibria

		π (g=0. 10, σ=0. 025)			
		0. 25	0. 50	0. 75	0. 90
Upper Bound of τ		0. 099	0. 099	0. 099	0. 098
Real Debt					
	High	0. 349	0. 333	0. 285	0. 148
	Low	0. 333	0. 333	0. 334	0. 337
Inflation (%)					
	High to High	11. 8	12. 2	13. 6	23. 7
	Low to High	6. 5	12. 2	33. 1	182. 6
	Low to Low	− 3. 4	− 3. 3	− 3. 2	− 3. 0
	High to Low	1. 4	− 3. 3	− 17. 4	− 57. 5
	Average	4. 0	4. 4	5. 8	15. 6
	S. D.	4. 4	7. 8	14. 6	

Other parameters are set at β=0. 989, A=0. 431, N_t=1. 05, $\forall t$.

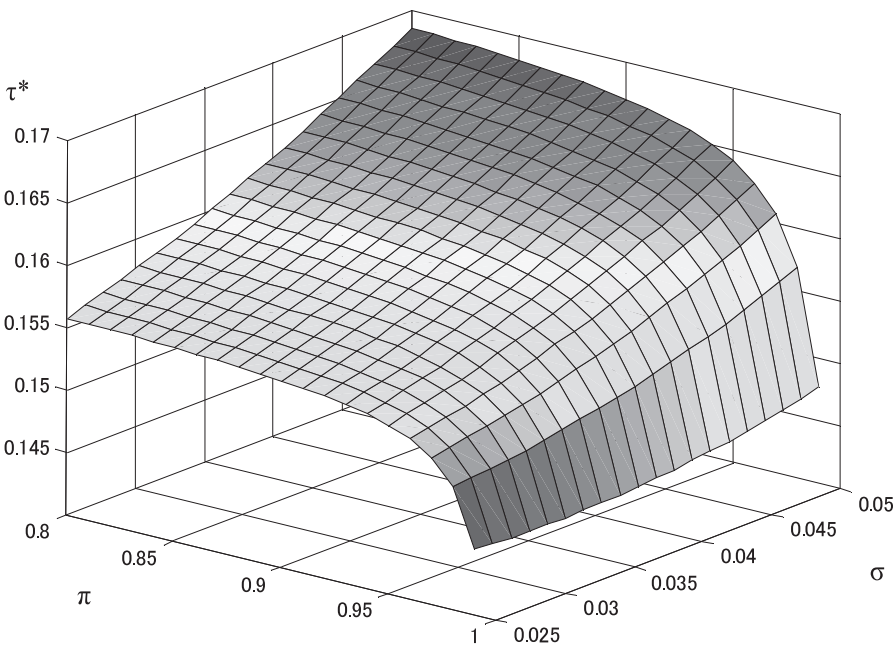

Figure 2 Implementability Frontier: Variation versus Persistency

increasing, whereas the effect of σ escalates as it becomes larger.

Table 3 shows the effect of persistency in government expenditure. When π is very close to 1, states are unlikely to change. In such a case, the welfare costs of running a balanced budget are relatively small, and hence, the government tends to be tempted to break its commitment to the optimal rule. Accordingly, one would expect that only commitments with lower tax rates become credible as π approaches 1. However, this effect on the tax rate is quantitatively negligible except for a case in which π is very close to 1, as can be seen from Figure 2, which plots the upper bound of the optimal tax rates for different values of σ and π.

5. Conclusion

The recent arrival of the FTPL has offered deeper insights into inflation dynamics; however, it has stirred continuing debate on the admissibility of the theory. The reason is that while proponents of the FTPL base the theory on competitive equilibrium, opponents point out the need for a theory that considers the out-of-equilibrium behavior of economic agents. In order to fill the gap in the controversy, it is necessary to explicitly examine people's conducts in a competitive equilibrium.

The game theory is a proper instrument to deal with this issue. The present paper describes an economy as an infinitely repeated game between a representative household and a benevolent government committed to a non-Ricardian optimal fiscal policy rule. The representative household's complete contingent action plan is specified as a trigger strategy; he or she demands government bonds as long as the government keeps its commitment to the optimal policy and otherwise refuses to buy them once and for all.

The analysis in the paper revealed that the non-Ricardian fiscal policy is credible and thus implementable, given that the committed tax rate is not too high. The level of committed tax rate that is credible depends on the stochastic properties of government expenditure; above all, standard deviation in government expenditure is quantitatively important. The fact that the non-Ricardian policy is not globally implementable has an important implication on the applicability of the FTPL. In an economy with large initial outstanding government debt, the tax rate required to sustain it might be too high for the government's commitment to the optimal policy to be credible. The optimal policy in such an economy would backfire.

In this paper, because of the simple settings of the model such as linear-quadratic utility, flexible price, and no uncertainty other than fiscal expenditure, both the optimal policy rule and the government's strategy are fairly naive. In this sense, the analysis may be crude. Nevertheless, the approach that explicitly models the out-of-equilibrium behavior of agents and incorporates Nash equilibrium offers a key clue for settling the lively debate on the FTPL.

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