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The Optimal Composition of Public Spending in a Deep Recession

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Abstract

We study optimal fiscal policy in an economy plunged into a deep recession characterized by a liquidity trap, and in which the government can allocate spending both to consumption and investment goods. Public investment increases the stock of public capital subject to a time-to-build constraint. The zero lower bound on the nominal interest rate binds as a result of a large shock that increases households' desire to save in the risk-free asset, pushing the natural rate of interest below zero. Under nominal rigidities and sub-optimal monetary policy, the shock leads to a large decline in private consumption and investment. We show that the optimal response to such a shock is to temporarily raise public spending above the level that would be dictated by classical principles, and to tilt its composition towards public investment. This compositional shift lasts well after the natural rate has ceased to be negative. Our results suggest that the American Recovery and Reinvestment Act of 2009 was insufficiently oriented towards public investment.

Keywords: Public consumption, Public investment, Optimal fiscal policy, Time to build, Zero lower bound.

JEL classification: E4, E52, E62, H54

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1. Introduction

What is the optimal composition of a fiscal expansion in a depressed economy? Despite the widespread interest in the stimulative effects of fiscal policy generated by the unprecedentedly large stimulus plans enacted in most industrialized economies at the onset of the Great Recession, this question has remained largely overlooked by the literature. Existing studies indeed mostly focus on the size of the spending multiplier when the economy is plunged into a liquidity trap — that is, when nominal interest rates are at their zero lower bound (ZLB) — and on the desirability of public consumption from a welfare standpoint in such circumstances.

By focusing exclusively on government purchases of consumption goods, the normative literature has neglected public investment spending.² This neglect is unlikely to be innocuous when it comes to determining the optimal level of public spending and its welfare consequences. Perhaps more importantly, it precludes the analysis of the optimal composition of a fiscal expansion, an issue that was at the center of policy debates during the Great Recession. The various fiscal plans that have been implemented worldwide in 2008–2009 assigned a significant fraction of the additional spending to public investment in infrastructure,³ but to our knowledge, there has not been any formal attempt to determine whether this allocation scheme was warranted from a welfare standpoint.

The objective of this paper is to study optimal fiscal policy in an economy where monetary policy follows a Taylor-type rule subject to a ZLB constraint on the nominal interest rate, and where the policy maker can pre-commit to future paths of public consumption and investment. We focus on a scenario in which the ZLB binds as a result of a large liquidity-preference shock that raises agents' incentive to save in the risk-free bond, pushing the natural rate

²See, for example, [1], [2], [3], [4], [5], and [6] in the context of a closed economy, and [7] in the context of a small open economy.

³For instance, the American Recovery and Reinvestment Act of 2009 allocated 40 percent of the non-transfer stimulus to public investment (see [8]).

of interest below zero. The main novelty of our model with respect to the literature is the possibility for the government to accumulate public capital, which is an external input in the firms' production technology. As in [9], [10],
30 and [11], we assume that the accumulation of public capital is subject to lengthy time-to-build delays, a distinctive feature of public infrastructure projects.⁴

In response to a positive realization of the liquidity-preference shock, the optimal fiscal plan involves an increase in public spending that is both large and persistent, extending for several quarters after the natural rate of interest
35 has ceased to be negative. This initial fiscal expansion is eventually followed by a protracted consolidation, such that the overall change in public spending is small in present discounted value. Given the nature of the shock, the (efficient) flexible-price allocation remains constant at its steady-state level. The optimal plan therefore drives public spending temporarily above its flexible-price level.
40 For this reason, we refer to the initial fiscal expansion as stimulus spending.⁵

Importantly, the optimal stimulus is characterized by a significant shift in the composition of public spending towards public investment, whose share in total spending rises from roughly 23 to 30 percent at the peak. This compositional
45 shift reflects the fact that public investment is a more effective stabilization tool than public consumption, all the more so when the economy is in a liquidity trap. Public investment boosts current aggregate demand while raising the future marginal productivity of private inputs. When the latter effect occurs once the economy has escaped the liquidity trap, it amplifies the increase in current aggregate demand (see [11]). Nonetheless, the optimal stimulus is not
50 exclusively composed of public investment because the planner needs to strike a balance between two competing objectives: closing the negative output gap

⁴None of the three papers studies optimal policy.

⁵In a previous version of this paper, we also considered the case in which monetary policy is set optimally under full commitment. We found that the contractionary effects of the shock are negligible, which leaves very little scope for fiscal stimulus. This in turn suggests that optimal monetary policy can go a long way towards stabilizing the economy even when the ZLB is binding.

and meeting the efficiency condition that would prevail in the absence of such a gap.

We find our main result — an optimal fiscal stimulus that is skewed towards public investment — to be robust when the set of fiscal instruments available to the planner is expanded to include a subsidy to private investment and transfers. For the latter to play a meaningful role, we allow for household heterogeneity by considering a two-agent version of our benchmark economy. Finally, we use this version of the model to evaluate the optimality of the American Recovery and Reinvestment Act (ARRA) enacted in 2009 to cope with the Great Recession. This exercise suggests that while the transfer component of the ARRA was nearly optimal, the non-transfer part deviated markedly from the optimal plan. The spending-based stimulus was insufficiently front-loaded, overly persistent, and inadequately designed in terms of its allocation between public consumption and public investment.

The rest of this paper is organized as follows. Section 2 presents the model and characterizes the first-best allocation. Section 3 discusses the economy’s response to the liquidity-preference shock under constant fiscal policy. Section 4 studies optimal fiscal policy. Section 5 presents the results of the robustness analysis. Section 6 evaluates the optimality of the ARRA. Section 7 concludes.

2. A New Keynesian Model with Public Capital

We consider a New Keynesian economy composed of infinitely lived households, firms, a government, and a monetary authority. The key feature of the model is that a fraction of government spending can be invested in public capital subject to a time-to-build requirement. The remaining fraction, i.e., government consumption, directly affects households’ utility. The breakdown of public spending into investment and consumption expenditures is chosen optimally by the government. The stock of public capital enters as an external input in the production of intermediate goods, which are used to produce an homogenous final good. The latter is used for consumption and investment purposes. There

is a continuum of monopolistically competitive intermediate-good producers, indexed by $z \in (0, 1)$, who set prices subject to a Rotemberg-type adjustment cost. Final-good producers are perfectly competitive. The nominal interest rate is set by a monetary authority subject to a non-negativity constraint.

85 *2.1. Households*

The economy is populated by a large number of identical households who have the following lifetime utility function:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left[U(C_{t+s}, N_{t+s}) + V(G_{t+s}^c) + \zeta_{t+s} W\left(\frac{\mathcal{B}_{t+s}}{P_{t+s}}\right) \right], \quad (1)$$

where β is the discount factor, C_t is consumption, N_t denotes hours worked, G_t^c is government consumption, \mathcal{B}_t is a stock of one-period riskless nominal bonds that mature in period t , and P_t is the price of the final good. We assume that $U(\cdot)$ is increasing and concave in C_t and decreasing and concave in N_t ; $V(\cdot)$ is increasing and concave in G_t^c ; and $W(\cdot)$ is increasing and concave in $\frac{\mathcal{B}_t}{P_t}$ and is such that $W(0) = 0$ and $W'(0) = 1$. The assumption that the utility function depends positively on the real value of risk-free bonds reflects that households value the liquidity and safety of those assets (see [12]). Accordingly, the term ζ_t is interpreted as a liquidity-preference shock, which is assumed to evolve according to the following process:

$$\log(\zeta_t) = \rho \log(\zeta_{t-1}) + \epsilon_t,$$

where $\rho \in (0, 1)$ and ϵ_t is an i.i.d. disturbance.

The representative household enters period t with \mathcal{B}_{t-1} units of bonds and
 90 K_t units of capital. During the period, it receives wage and rental payments in exchange of labor and capital services, as well as dividends from intermediate-good producers. This income is allocated to consumption, investment, I_t , the payment of a lump-sum tax to the government, and the purchase of new bonds. The household's budget constraint is therefore

$$C_t + I_t + T_t + \frac{\mathcal{B}_t}{P_t} \leq w_t N_t + r_t^k K_t + D_t + (1 + R_{t-1}) \frac{\mathcal{B}_{t-1}}{P_t}, \quad (2)$$

95 where w_t is real wage rate, r_t^k is the real rental rate of capital, R_t is the net return on a nominal bond purchased at time t , and D_t and T_t are dividends and lump-sum taxes, expressed in real terms. The accumulation of private capital is subject to investment-adjustment costs as in [13]:

$$K_{t+1} = (1 - \delta)K_t + \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t, \quad (3)$$

where δ is the depreciation rate and the function $S(\cdot)$ satisfies $S'(\cdot) \geq 0$, $S''(\cdot) \geq 0$, $S(1) = 0$, and $S'(1) = 0$.
100

The household maximizes (1) subject to (2), (3), and a no-Ponzi-game condition. The first-order conditions for this problem are given by

$$w_t = -\frac{U_{N,t}}{U_{C,t}}, \quad (4)$$

$$U_{C,t} = \beta(1 + R_t)\mathbb{E}_t\left(\frac{U_{C,t+1}}{1 + \pi_{t+1}}\right) + \zeta_t W'\left(\frac{\mathcal{B}_t}{P_t}\right), \quad (5)$$

$$1 = \left[1 - S(x_t) - S'(x_t)x_t\right]q_t + \beta\mathbb{E}_t\frac{U_{C,t+1}}{U_{C,t}}S'(x_{t+1})(x_{t+1})^2q_{t+1}, \quad (6)$$

$$q_t = \beta\mathbb{E}_t\frac{U_{C,t+1}}{U_{C,t}}[(1 - \delta)q_{t+1} + r_{t+1}^k], \quad (7)$$

where $U_{X,t}$ is the partial derivative of $U(\cdot)$ with respect to its argument X_t , $\pi_t = \frac{P_t}{P_{t-1}} - 1$ is the inflation rate between $t - 1$ and t , $x_t = \frac{I_t}{I_{t-1}}$, and q_t is the shadow value of installed capital in terms of the consumption good, given by
105 the ratio of the Lagrange multiplier associated with the capital accumulation equation to the marginal utility of consumption.

Equation (5) implies that an increase in ζ_t lowers the marginal disutility of saving in the risk-free bond $\left(U_{C,t} - \zeta_t W'\left(\frac{\mathcal{B}_t}{P_t}\right)\right)$, thus increasing the incentive
110 to save, but only through this vehicle rather than via capital accumulation.⁶ In a decentralized economy with sticky prices, a positive realization of the liquidity-premium shock should therefore lead to a simultaneous fall in private consumption and investment.

⁶[14] shows that ζ_t can be viewed as an alternative (structural) interpretation of the risk-premium shock introduced by [15]. Under certain conditions, equation (5) is isomorphic — up to a first-order approximation — to the Euler equation in [15].

2.2. Firms

115 The final good is produced by perfectly competitive firms using the following constant-elasticity-of-substitution (CES) technology:

$$Y_t = \left(\int_0^1 Y_t(z)^{1-1/\theta} dz \right)^{\frac{\theta}{\theta-1}}, \quad (8)$$

where $Y_t(z)$ is the quantity of intermediate good z and $\theta \geq 1$ is the elasticity of substitution between intermediate goods. Denoting by $P_t(z)$ the price of intermediate good z , demand for z is given by

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\theta} Y_t. \quad (9)$$

120 Firms in the intermediate-good sector are monopolistically competitive, each producing a differentiated good using labor and private capital, as well as public capital as an external input

$$Y_t(z) \leq F(N_t(z), K_t(z), K_{G,t}), \quad (10)$$

where $F(\cdot)$ is increasing and concave in its arguments. This specification implies that public capital acts as a positive externality that improves the marginal
 125 productivity of private inputs. This assumption is consistent with the empirical evidence reported by [16], [17], [10], and [11], among many others.⁷ [16] estimates an aggregate production function for the U.S. economy and finds that non-military infrastructure has a strong positive effect on total factor productivity. [17] finds a causal effects of growth in roads (the largest component of
 130 U.S. public infrastructure) on the productivity of U.S. vehicle-intensive industries. [10] find evidence that federal highway spending works like an anticipated productivity shock, raising output several years in the future. Finally, using cointegration techniques and post-War U.S. data, [11] find a positive long-term relationship between the stock of public capital and (a purified measure of) total
 135 factor productivity.

⁷For recent surveys of the empirical literature on the productivity of public capital see [18] and [19].

We assume that firms set prices subject to a Rotemberg-type adjustment cost:

$$\Xi_t(z) = \frac{\psi}{2} \left(\frac{P_t(z)}{P_{t-1}(z)} - 1 \right)^2 Y_t, \quad (11)$$

where $\psi \geq 0$ governs the magnitude of the price-adjustment cost. Dividends paid by firm z are given by

$$D_t(z) = (1 + \tau) \frac{P_t(z)}{P_t} Y_t(z) - w_t N_t(z) - r_t^k K_t(z) - \Xi_t(z), \quad (12)$$

140 where $\tau = 1/(\theta - 1)$ is a subsidy that corrects the steady-state distortion stemming from monopolistic competition in the goods market. Firm z chooses $P_t(z)$, $N_t(z)$, and $K_t(z)$ for all t to maximize its total real market value

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \frac{U_{C,t+s}}{U_{C,t}} D_{t+s}(z), \quad (13)$$

subject to the production technology (10) and the demand function (9).

Since all the firms face an identical problem, the first-order conditions are
145 given by

$$\frac{w_t}{F_{N,t}} = 1 + \frac{\psi}{\theta} \left[(1 + \pi_t) \pi_t - \beta \mathbb{E}_t \frac{U_{C,t+1}}{U_{C,t}} \frac{Y_{t+1}}{Y_t} (1 + \pi_{t+1}) \pi_{t+1} \right], \quad (14)$$

$$\frac{w_t}{F_{N,t}} = \frac{r_t^k}{F_{K,t}}, \quad (15)$$

$$Y_t = F(N_t, K_t, K_{G,t}), \quad (16)$$

where $F_{X,t}$ is the partial derivative of $F(\cdot)$ with respect to its argument X_t . The real marginal cost of production, mc_t , satisfies $mc_t = \frac{w_t}{F_{N,t}} = \frac{r_t^k}{F_{K,t}}$.

2.3. Fiscal and monetary authorities

The government runs a balanced budget. It levies lump-sum taxes to finance
150 its expenditures (composed of public consumption and public investment, G_t^i), and the subsidy given to firms in the intermediate-good sector. Its budget constraint is given by

$$G_t^c + G_t^i + \tau Y_t = T_t. \quad (17)$$

Public investment increases the stock of public capital according to the following accumulation equation:

$$K_{G,t+T} = (1 - \delta) K_{G,t+T-1} + \left(1 - S_g \left(\frac{G_t^i}{G_{t-1}^i}\right)\right) G_t^i, \quad (18)$$

155 where $T \geq 1$ and the function $S_g(\cdot)$ satisfies $S_g'(\cdot) \geq 0$, $S_g''(\cdot) \geq 0$, $S_g(1) = 0$, and $S_g'(1) = 0$. Equation (18) allows for the possibility that several periods may be required to build new productive capital, i.e., time to build (see [20]). This feature reflects the implementation delays typically associated with the different stages of public investment projects (planning, bidding, contracting, construction, etc.). The function $S(\cdot)$ captures adjustment costs of public investment, 160 as an additional unit of investment at time t increases the stock of capital at time $t + T$ by less than one unit.

Monetary policy is set according to the following Taylor rule:

$$R_t = \max \left\{ 0, (1 + R) \left(\frac{1 + R_{t-1}}{1 + R}\right)^{\rho_r} \left[\left(\frac{1 + \pi_t}{1 + \pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_y} \right]^{1 - \rho_r} - 1 \right\}, \quad (19)$$

165 where $\phi_\pi > 1$, $\phi_y \geq 0$, $0 \leq \rho_r \leq 1$, and variables without a time subscript refer to steady-state values.

2.4. Market clearing and private-sector equilibrium

Since households are identical and the government does not issue debt, the net supply of bonds must be zero in equilibrium ($B_t = 0$). Substituting the definition of dividends in the representative household's budget constraint, and 170 using (17), one obtains the resource constraint of this economy

$$\Delta_t Y_t = C_t + I_t + G_t^c + G_t^i, \quad (20)$$

where $\Delta_t = \left(1 - \frac{\psi}{2} \pi_t^2\right)$.

A private-sector equilibrium for this economy is a sequence of quantities and prices $\{N_t, C_t, I_t, Y_t, K_{t+1}, q_t, \pi_t, w_t, r_t^k, R_t\}_{t=0}^\infty$ such that, for a given sequence of policy variables $\{G_t^c, G_{t-T}^i\}_{t=0}^\infty$ and the implied sequence of $\{K_{G,t}\}_{t=0}^\infty$ (through 175 equation 18), a given sequence of exogenous variables $\{\zeta_t\}_{t=0}^\infty$, and given initial

stocks of private and public capital, K_0 and $K_{G,-T}$, and the specifications of the utility, production, and adjustment-cost functions, equations (3) to (7), (14) to (16), (19), and (20) hold.

It is worth noting that the liquidity-preference shock, ζ_t , does not affect the equilibrium allocation when prices are fully flexible. Under price flexibility, the model has a block-recursive equilibrium in which quantities are determined independently of equations (5) and (19), which residually determine R_t and π_t given the equilibrium quantities. Since the shock only appears in (5), it leaves the flexible-price allocation unchanged.

2.5. The first best allocation

Before studying optimal fiscal policy, it is useful to have as a benchmark the efficient (or first-best) allocation of resources. Formally, the first best is the sequence of allocations $\{C_t, N_t, I_t, K_{t+1}, G_t^c, G_t^i, K_{G,t+T}\}_{t=0}^\infty$ that maximize households' lifetime utility given the accumulation equations for private and public capital (equations 3 and 18, respectively) and the sequence of the economy's resource constraints (equation 20). The first-order conditions associated with this problem are listed in Section 1 of the Online Appendix.

Combining the first-order conditions with respect to C_t and G_t^c yields the so-called Samuelson condition

$$V'(G_t^c) = U_{C,t}, \quad (21)$$

which equates the marginal utilities of private and public consumption. This condition states that since final output can be transformed into public as well as private consumption goods, the marginal rate of substitution between C_t and G_t^c must be equal to their marginal rate of transformation, which is 1.

Defining $q_{G,t}$ as the shadow value of an extra unit of public capital in consumption units at time t , the first-order condition with respect to $K_{G,t+T}$ implies the following asset-pricing equation:

$$q_{G,t} = \beta^T \mathbb{E}_t \frac{U_{C,t+T}}{U_{C,t}} F_{K_G,t+T} + \beta(1-\delta) \mathbb{E}_t \frac{U_{C,t+1}}{U_{C,t}} q_{G,t+1}. \quad (22)$$

At the optimum, the shadow value of an extra unit of public capital in consumption units at time t is equal to the sum of two components: (i) the contribution of the invested unit of capital to output T periods in the future, valued
 205 in consumption units of time t at $\beta^T \mathbb{E}_t \frac{U_{C,t+T}}{U_{C,t}} F_{K_G,t+T}$, and (ii) the depreciated shadow value of capital in $t+1$, valued in consumption units of time t at $\beta(1-\delta) \mathbb{E}_t \frac{U_{C,t+1}}{U_{C,t}} q_{G,t+1}$.

Clearly, since the liquidity-premium shock does not affect equations (3), (18), and (20), it does not alter the efficient allocation of resources. Following such
 210 a shock, the first-best allocation remains at its steady-state level, and both the marginal rate of substitution between public and private consumption and the shadow value of public capital remain equal to 1.

3. Baseline Scenario

We start by considering an economy in which public consumption and public
 215 investment are kept constant at their steady-state levels. We study a scenario in which a sufficiently large liquidity-premium shock causes the nominal interest to bind, sending the economy into a liquidity trap. This baseline scenario is meant to represent the deep-recession context within which we wish to evaluate the optimal response of fiscal policy. To simulate this scenario, we need to specify
 220 functional forms for the utility, production, and adjustment-cost functions, and to assign values to the model parameters.

3.1. Functional forms and calibration

We assume that preferences take the form

$$U(C_t, N_t) + V(G_t^c) = \frac{[C_t^\gamma (1 - N_t)^{1-\gamma}]^{1-\sigma}}{1-\sigma} + \chi \frac{(G_t^c)^{1-\sigma}}{1-\sigma}, \quad (23)$$

where $\sigma > 0$ and $0 < \gamma \leq 1$, and that the production function is given by

$$F(N_t, K_t, K_{G,t}) = AN_t^a \left[(1-\varrho)^{\frac{1}{\nu}} K_t^{\frac{\nu-1}{\nu}} + \varrho^{\frac{1}{\nu}} K_{G,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{(1-a)\nu}{\nu-1}}, \quad (24)$$

where $0 \leq a, \varrho \leq 1$, $\nu > 0$, and $A = [\varrho^\varrho (1-\varrho)^{1-\varrho}]^{1-a}$. This specification assumes that total capital is a CES aggregate of private and public capital,

which nests the Cobb-Douglas case when the elasticity of substitution between the two types of capital, ν , is equal to 1. We also assume that the investment-adjustment-cost functions are given by

$$S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\varpi}{2} \left(\frac{I_t}{I_{t-1}} - 1\right)^2, \quad S_g\left(\frac{G_t^i}{G_{t-1}^i}\right) = \frac{\varpi_g}{2} \left(\frac{G_t^i}{G_{t-1}^i} - 1\right)^2,$$

225 where $\varpi, \varpi_g \geq 0$.

Our calibration closely follows [11], and is summarized in Table 1. The values of β and σ are based on [21]. We set the labor intensity, a , to 0.6 and the elasticity of substitution between private and public capital, ν , to 1. Under the latter assumption, the elasticity of output with respect to public capital is equal to $\varrho(1 - a)$. Based on a meta-analysis of available empirical studies, [19] 230 report an estimate of 0.08 for this elasticity. Accordingly, we set ϱ to 0.20. The elasticity of substitution between domestic goods, θ , is chosen so as to yield a steady-state markup of 20 percent. We set the depreciation rate, δ , to 0.02, and the investment-adjustment-cost parameters, ϖ and ϖ_g , to 2.5, which is very 235 close to the macro estimate of 2.48 obtained by [22] and to the micro estimate of 1.86 obtained by [23]. Consistent with the evidence discussed in [9], [10], and [11] regarding the delays associated with the completion of public investment projects, we set $T = 16$.

We calibrate γ and χ such that, given the values of the remaining parameters, 240 the optimal fraction of time devoted to work in steady state, N , is equal to $1/3$, and the optimal steady-state ratio of total government spending to output, $g \equiv \frac{G^c + G^i}{Y}$, is equal to 0.2.⁸ Given our calibration, the implied (optimal) share of public investment in total public spending, $\alpha \equiv \frac{G^i}{G^c + G^i}$, is equal to 0.2286, which is very close to the historical average of 0.23 that we observe in U.S. 245 data.⁹ By ensuring that the decentralized economy shares the same steady-

⁸See Section 1 of the Online Appendix for a detailed description of the steady state.

⁹The share of public investment in total public spending is computed by dividing the series A782RC1Q027SBEA (Gross Government Investment) by the series GCE (Government Consumption Expenditures and Gross Investment) and taking the average. Both series are taken from the FRED database.

state allocation as the efficient economy described in Section 2.5, we can focus on the stabilizing role of fiscal policy.¹⁰

Table 1: Parameter values.

Discount factor	$\beta = 0.99$
Preference parameter	$\sigma = 2$
Preference parameter	$\gamma = 0.29$
Preference parameter	$\chi = 0.054$
Labor intensity	$a = 0.6$
Weight of public capital in CES aggregator	$\varrho = 0.20$
Elasticity of substitution b/w private and public capital	$\nu = 1$
Elasticity of substitution b/w intermediate goods	$\theta = 6$
Time-to-build delay	$T = 16$
Price-adjustment-cost parameter	$\psi = 200$
Depreciation rate of private and public capital	$\delta = 0.02$
Investment-adjustment-cost parameters	$\varpi = \varpi_g = 2.5$
Steady-state inflation	$\pi = 0$
Inflation coefficient in Taylor rule	$\phi_\pi = 1.5$
Output coefficient in Taylor rule	$\phi_y = 0.05$
Interest-rate smoothing parameter	$\rho_r = 0$
Autocorrelation of the liquidity-premium shock	$\rho = 0.8$

The remaining parameters are calibrated as follows. The parameter governing price-adjustment costs, ψ , is set such that, conditional on the chosen value of θ , it implies a slope of the (linearized) Phillips curve equal to 0.03.¹¹ Steady-state inflation is assumed to be zero and the Taylor-rule parameters are set to $\phi_\pi = 1.5$, $\phi_y = 0.05$, and $\rho_r = 0$.¹² Finally, we set the autocorrelation coefficient

¹⁰Note that, outside the steady state, the only distortion stems from price rigidity, which implies that the flexible-price allocation is efficient in this economy.

¹¹Under Calvo-type rigidity, this slope would imply an average price spell of 5.9 quarters.

¹²We set ϕ_y to a slightly lower value than the standard one of 0.125 to ensure that we obtain

of the liquidity-premium shock, ρ_r , to 0.8.

3.2. *The economy's response under constant fiscal policy*

255 Assume that the economy is initially at the steady state when a liquidity-
premium shock hits. The shock is assumed to be persistent, with an autocorre-
lation coefficient of 0.8. We select the size of the shock such that the resulting
decline in output in the absence of any fiscal-policy response matches the ob-
served decline in U.S. per capita GDP from peak to trough during the Great
260 Recession, which amounted to 5.65%. Using the equilibrium conditions for the
private-sector equilibrium, we compute the economy's response to the shock. In
solving the system of (non-linear) first-order conditions, we assume that agents
have perfect foresight over the simulation horizon.¹³ The results are depicted
in Figure 1.

265 The liquidity-premium shock increases households' incentive to save in the
riskless bond. Given that prices are sticky, this drives down both consumption
and investment. As output and employment fall below their socially optimal
levels, real marginal cost falls, creating a wedge between the marginal productiv-
ity of private inputs and their prices. As a result, inflation also falls, prompting
270 the monetary authority to lower the nominal interest rate. Given the size of
the shock, the ZLB binds for 7 quarters. Because expected inflation is negative
— given that the shock is persistent — the real interest rate rises, exacerbating
the fall in aggregate output.

4. Optimal Fiscal Policy

275 Consider now the case in which public consumption, G_t^c , and public invest-
ment, G_t^i , are chosen optimally by a 'fiscal Ramsey planner'. Assuming that the
planner can fully commit to future paths of these variables, the Ramsey problem
consists in maximizing household's lifetime utility subject to the private-sector

convergence for all the simulations carried out in the paper.

¹³This approach has also been followed by [21], [2], and [7], among others.

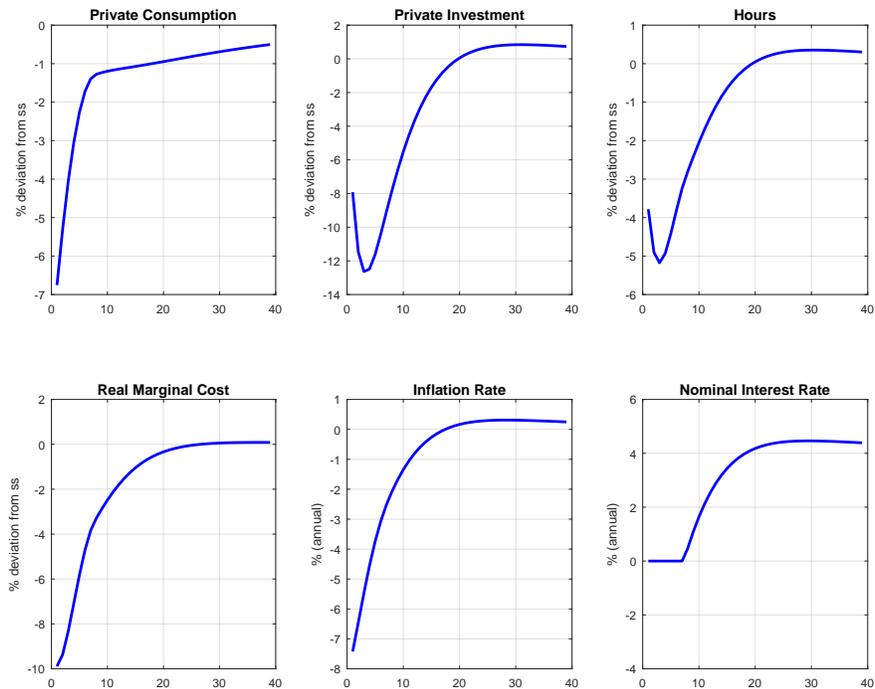


Figure 1: The economy's response to a liquidity-premium shock under constant fiscal policy.

equilibrium defined in Section 2.4. The Lagrangian for this problem and the
 280 associated first-order conditions are listed in Section 2 of the Online Appendix.

4.1. The optimal plan

Figure 2 shows the economy's response to the liquidity-preference shock un-
 der the optimal plan. The shock is calibrated as in Section 3.2. The Figure also
 shows the baseline scenario, reported in Figure 1, and the economy's response
 285 under fully flexible prices, i.e., the first-best allocation. Consumption, invest-
 ment, hours worked, real marginal cost, and the inflation rate decline but less
 than in the baseline scenario. Public consumption rises for 7 quarters before
 falling below its steady-state level for a prolonged period of time. At the peak,
 the increase in public consumption reaches roughly 1.1 percent of steady-state
 290 output. Public investment rises by 0.8 percent of steady-state output on impact

and by 2.3 percent at the peak, and remains above its steady-state level for 10 quarters. Importantly, the optimal fiscal plan endogenously lifts the economy out of the liquidity trap, shortening the ZLB spell to a single period.

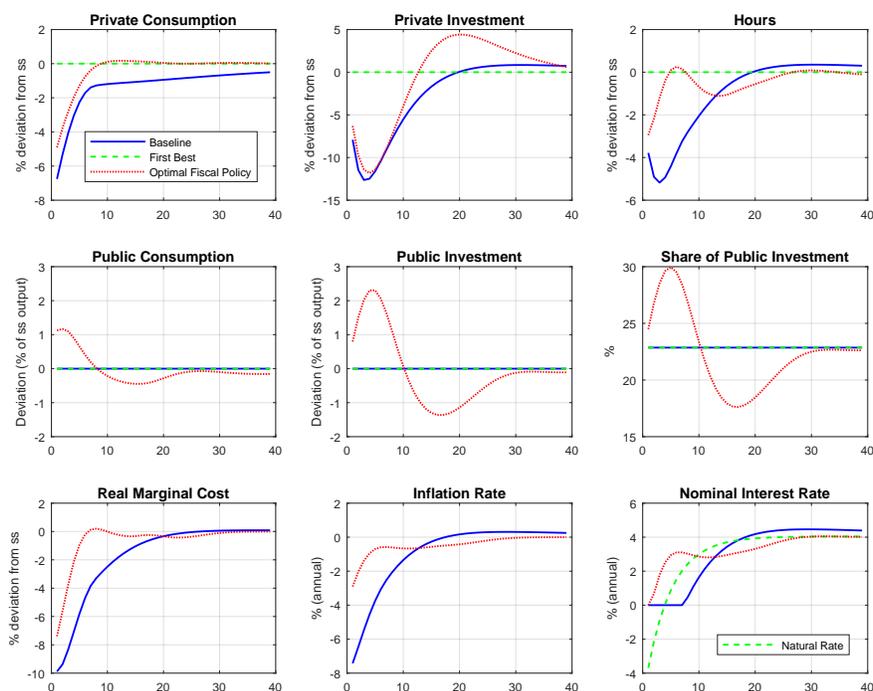


Figure 2: The economy’s response to a liquidity-premium shock under optimal fiscal policy.

Three important observations can be drawn from Figure 2. First, the initial fiscal expansion is both large and persistent, extending for several quarters after the natural rate has ceased to be negative. In what follows, we will refer to this fiscal expansion as stimulus spending, and compute it as the present discounted value of the total increase in public spending before the latter falls below its steady-state level. Stimulus spending amounts to 5.3 and 13.8 percent of steady-state output for public consumption and public investment, respectively. Second, the fiscal stimulus is skewed towards public investment, whose share in total public spending rises from 22.8 to 24.5 percent at the time of the

shock, and reaches a peak of roughly 30 percent 5 quarters later. This compositional shift towards investment lasts for two and a half years after the shock. 305 Third, the cumulated present discounted value of the change in public spending is relatively small and negative (−1.9 percent of steady-state output).

We now provide some intuition for these results. In order to understand why public consumption rises initially, differentiate the households' lifetime utility with respect to G_t^c and evaluate it at the maximum. This yields

$$U_{C,t} \frac{dC_t}{dG_t^c} + U_{N,t} \frac{dN_t}{dG_t^c} + V'(G_t^c) + \mathbb{E}_t \sum_{s=t+1}^{\infty} \beta^{s-t} \left(\frac{dU(C_s, N_s)}{dG_t^c} + \frac{dV(G_s^c)}{dG_t^c} \right) = 0.$$

For simplicity, let us abstract from (private and public) capital. In this case, equation (20) implies $\frac{dC_t}{dG_t^c} = \Delta_t \left(\frac{dY_t}{dG_t^c} + \frac{Y_t}{\Delta_t} \frac{d\Delta_t}{dG_t^c} \right) - 1$, while equation (10) yields $\frac{dN_t}{dG_t^c} = \frac{dY_t}{dG_t^c} F_{N,t}^{-1}$. Neglecting the effects of G_t^c on future variables, the condition 310 above can be rewritten as

$$\begin{aligned} \frac{V'(G_t^c)}{U_{C,t}} &= 1 - \left(\Delta_t + \frac{U_{N,t}}{U_{C,t} F_{N,t}} \right) \frac{dY_t}{dG_t^c} - Y_t \frac{d\Delta_t}{dG_t^c} \\ &= 1 - (1 - mc_t) \frac{dY_t}{dG_t^c} + \frac{\psi}{2} \pi_t^2 \frac{dY_t}{dG_t^c} - Y_t \frac{d\Delta_t}{dG_t^c}. \end{aligned} \quad (25)$$

Under flexible prices, $\Delta_t = 1$, $d\Delta_t = 0$ and $mc_t = 1$, so that the Samuelson condition holds: $V'(G_t^c) = U_{C,t}$. When monetary policy is sub-optimal and/or is constrained by the ZLB — so that full stabilization is unattainable — the optimal choice of G_t^c deviates from the Samuelson condition. In particular, when 315 the economy is hit by a shock that makes the ZLB bind, real marginal cost falls, which implies that the term $(1 - mc_t) \frac{dY_t}{dG_t^c}$ is positive.¹⁴ Equation (25) therefore implies that the marginal rate of substitution between public and private consumption, $\frac{V'(G_t^c)}{U_{C,t}}$, must be smaller than 1 (see Figure 3).¹⁵ Intuitively, this condition reflects the trade-off that the Ramsey planner faces in the presence 320 of a negative output gap: the Samuelson condition calls for lowering G_t^c but a

¹⁴Following the shock, mc_t falls below its steady-state of 1. Thus, $1 - mc_t$ is positive. In addition, a well established result is that the output multiplier associated with public consumption, $\frac{dY_t}{dG_t^c}$, is positive and even exceeds 1 when the ZLB binds (see [24], [21], and [1]).

¹⁵The last two terms in the right-hand side of this equation are of second order.

lower G_t^c further widens the output gap. In this case, the response of G_t^c will be larger than under flexible prices, which happens to be zero in the context of our economy. It is important to emphasize that the planner's desire to increase public consumption has nothing to do with the fact that the spending multiplier is larger than 1 when the ZLB binds. The planner would still find it optimal to do so as long as there is a negative output gap even if the adverse shock is not large enough to make the ZLB bind.¹⁶ The optimal fiscal stimulus will tend to be large when the ZLB binds because the associated output loss is large.

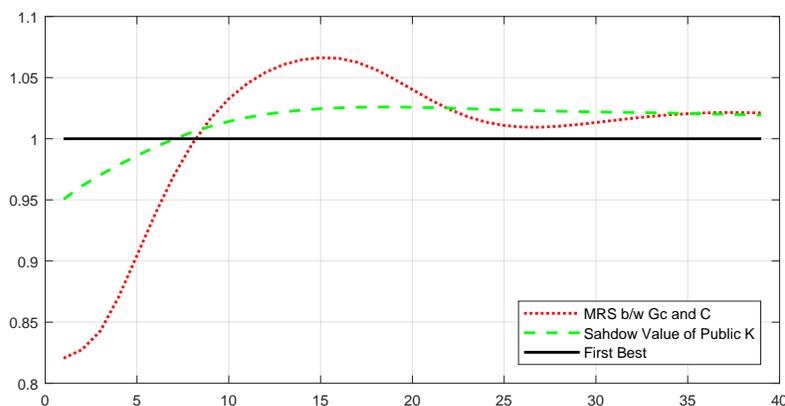


Figure 3: The marginal rate of substitution between public and private consumption and the shadow value of public capital under the optimal plan.

Public investment stimulates aggregate demand, just as public consumption does. But in addition, it increases aggregate supply with a delay that depends on the length of time needed to build the stock of public capital. When the ZLB binds, this delay implies that the disinflationary effect associated with the outward shift in aggregate supply comes into play after the ZLB constraint has ceased to bind. At the same time, the expected increase in the marginal productivity of private inputs resulting from the increase in the stock of public

¹⁶A similar motive for increasing public spending is shown by [25] in the context of a matching model with inefficient unemployment.

capital raises current private spending. The combination of these two effects implies that public investment can be very effective as a stabilization tool during deep recessions (see [11]). In turn, this explains why the optimal stimulus assigns a larger weight to public investment than to public consumption.

340 But why does the planner not rely exclusively on public investment? There are two reasons for this. First, changing public investment entails adjustment costs. Second, the planner faces a trade-off similar to the one underlying the optimal choice of public consumption. On the one hand, increasing public investment above its steady-state level helps close the output gap. On the other
345 hand, this causes the shadow value of public capital (in consumption units) to temporarily fall below its efficient level of 1 (see equation 22 and the discussion below), as shown in Figure 3. The optimal level of public investment must strike a balance between the stabilization motive and the required deviation from efficiency.

350 Eventually, the optimal fiscal plan involves a fiscal consolidation. By committing to reducing public spending at some point in the future, the planner lowers expected future inflation, which leads to a lower real interest rate outside the ZLB. The resulting fall in the long-term real interest rate helps mitigate the fall in current consumption and investment.

355 In sum, when a large negative output gap emerges, this calls for a significant and persistent increase in public expenditures during the quarters following the shock. The fact that the composition of public spending is optimally shifted towards public investment during this period reflects its effectiveness in soaking up idle resources in the economy. In this regard, our findings sharply contrast
360 with the conclusion reached by [26], who find no stabilization motive for public investment even when monetary policy is restricted both by the ZLB and by the monetary authority's inability to optimally commit to future actions. The main reason for this discrepancy lies in the non-standard functional form of the production technology assumed by [26], in which production factors (including
365 public capital) enter in an additively separable manner, thereby implying that public investment completely crowds out private investment. By relaxing the as-

sumption of additive separability, our analysis shows that there is an important scope for using public investment as a stabilization tool.

4.2. *Welfare implications*

370 The fact that the planner finds it optimal to temporarily increase public spending in response to the adverse shock necessarily implies that there are welfare gains to this policy relative to the scenario in which public spending is kept constant. How large are these welfare gains? As is typically done in the literature, we answer this question by computing the compensating variation in
375 private consumption; that is, the perpetual percentage increase in consumption that would make households as well off under constant public spending as under optimal fiscal policy. We describe how we compute this object in Section 3 of the Online Appendix.

We find that the welfare gain associated with optimal public spending amounts
380 to 0.16 percent. This number is 25 percent larger than that obtained in a model in which only public consumption is set optimally (while public investment is held constant), thereby highlighting the importance of public investment in attenuating the welfare loss associated with liquidity traps, and rationalizing the compositional shift in public expenditures entailed in the optimal fiscal plan in
385 such circumstances.

4.3. *Sensitivity Analysis*

In this section, we study the sensitivity of our results with respect to the following parameters: the elasticity of substitution between private and public capital (ν), the length of time to build (T), the adjustment-cost parameter for
390 public investment (ϖ_g), and the interest-rate smoothing parameter (ρ_r). The results are reported in Table 2. For each configuration, the top row shows the amount of stimulus spending, while the bottom row shows the total change in public spending, both measured in present discounted value.

First, we relax the Cobb-Douglas specification and study the cases where the
395 degree of substitutability between private and public capital is lower ($\nu = 0.84$)

and higher ($\nu = 1.16$) than in the benchmark economy. As private and public capital become more substitutable, the optimal stimulus increases in size and becomes more shifted towards public investment. Intuitively, higher substitutability translates into a larger crowding-out of private investment, which
400 implies that a larger amount of public investment is needed to attain a given level of private investment. This in turn calls both for a larger increase in public spending and a larger share of public investment in total spending.

Table 2: Sensitivity analysis.

	Public Consumption	Public Investment	Total
Benchmark	5.35 -2.13	13.77 0.24	19.12 -1.89
$\nu = 0.84$	5.32 -2.08	13.54 -0.10	18.86 -1.98
$\nu = 1.16$	5.38 -2.17	13.94 0.38	19.32 -1.82
$T = 1$	5.09 -2.02	15.98 0.47	21.07 -1.55
$T = 20$	5.51 -2.15	13.43 0.10	18.94 -2.05
$\varpi_g = 2$	4.90 -2.16	15.15 0.80	20.05 -1.36
$\varpi_g = 3$	5.72 -2.09	12.60 -0.24	18.32 -2.33
$\rho_r = 0.7$	4.35 -2.09	12.71 0.49	17.06 -1.60

Note: In each cell, the top entry refers to stimulus spending (i.e., the total initial increase in public spending) while the bottom entry refers to the total change in public spending, both measured in present discounted value and expressed as a percentage of steady-state output.

Second, we consider two alternative scenarios about the length of time to

build: the standard one-quarter delay ($T = 1$) commonly assumed in the literature, and a long delay of 20 quarters ($T = 20$). As T increases, stimulus investment spending and its share in total stimulus decline. As discussed in Section 4.1, when the ZLB binds, public investment becomes an effective stabilization tool to the extent that its aggregate-supply effect is delayed in the future. The longer the time-to-build delay, the less investment is needed to stimulate the economy.

Third, we assume lower and higher adjustment costs of public investment (relative to the benchmark economy) by setting ϖ_g to 2 and 3, respectively. As public investment becomes more costly to adjust, the optimal stimulus becomes smaller and less heavily skewed towards this spending category, a result that should be expected in light of the discussion in Section 4.1.

Finally, we allow for interest rate smoothing in the Taylor rule by assuming $\rho_r = 0.7$. In this case, the optimal stimulus involves a smaller increase in both public consumption and public investment, compared with the benchmark economy. Intuitively, a Taylor rule featuring interest-rate inertia allows the monetary authority to better track the natural rate of interest, reducing the scope for using public spending to stabilize the economy.

In all of these cases, the difference in results with respect to our benchmark calibration is inconsequential for our main message about the optimal design of the fiscal plan.

5. Extensions

In the model economy studied so far, the optimal fiscal response during a liquidity trap entails temporarily raising public spending and shifting its composition towards public investment. In this section, we seek to determine whether and to what extent these results are preserved when we extend the set of fiscal instruments available to the planner. We first allow for an investment subsidy, and then for transfers.

5.1. Investment subsidy

Assume that the government subsidizes investment at rate s_t , where the subsidy is financed through lump sum taxes. The household's budget constraint
 435 therefore becomes

$$C_t + (1 - s_t)I_t + T_t + \frac{\mathcal{B}_t}{P_t} \leq w_t N_t + r_t^k K_t + D_t + (1 + R_{t-1}) \frac{\mathcal{B}_{t-1}}{P_t}, \quad (26)$$

whereas the government budget constraint becomes

$$G_t^c + G_t^i + s_t I_t + \tau Y_t = T_t. \quad (27)$$

Note that because nominal rigidities are the only (uncorrected) distortion in this economy, the optimal subsidy is equal to zero in steady state. Therefore, the steady state will be identical to that of the benchmark economy. In the
 440 decentralized economy, however, the planner can optimally choose s_t to stimulate private investment and close the output gap. The question is whether this additional instrument diminishes the relative importance of public investment or even renders public spending superfluous altogether when the economy is at the ZLB.

Figure 4 shows the results when the set of fiscal instruments is expanded to
 445 allow for an investment subsidy. The optimal policy involves subsidizing private investment during the first 9 quarters after the shock. The optimal subsidy reaches roughly 12.5 percent on impact and decays gradually over time. During this period, private investment exceeds its steady-state level, as the subsidy
 450 lowers the marginal cost of an additional unit of private capital in consumption units. Eventually, as consumption rises above its steady-state level, the optimal policy entails taxing investment at roughly 1 percent for a prolonged period of time during which investment remains below its steady-state level.

Importantly, while the investment subsidy helps mitigate the output loss
 455 resulting from the adverse shock, the planner still finds it optimal to temporarily increase public spending and to shift its composition towards public investment, though the size of the fiscal stimulus and the increase in the share of public investment are significantly smaller than in the case without an investment

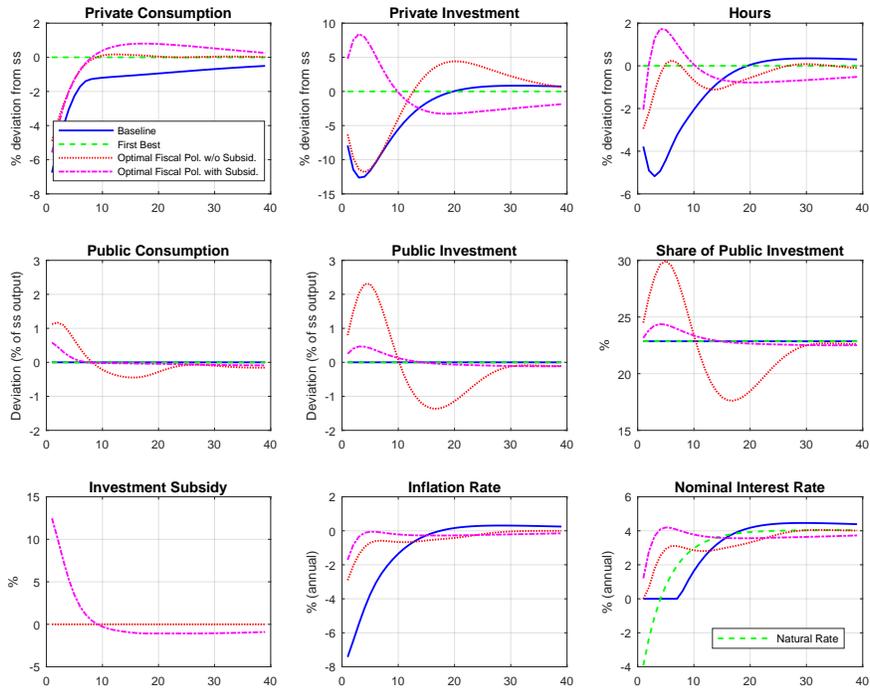


Figure 4: The economy's response to a liquidity-premium shock with an optimal investment subsidy.

subsidy. That being said, we argue that it may be unrealistic to imagine that
 460 a fiscal authority would engineer a stabilization plan whereby the investment
 subsidy exhibits the specific path depicted in Figure 4.¹⁷

5.2. Transfers

Next, we consider the case in which the planner's instrument set includes transfers. For the latter to play a meaningful role, however, we need to depart from the representative agent framework that we have assumed so far. To do so, we consider a Two-Agent New Keynesian (TANK) economy in which a fraction

¹⁷In practice, temporary tax incentives and subsidies are increased to a certain level for a given period of time before they are reset to their initial levels.

φ of households are financially constrained and are therefore obliged to consume their current income in any given period.¹⁸ We refer to these agents as Hand-to-Mouth consumers. Their budget constraint is given by

$$C_t^H = w_t N_t^H + T_t^H,$$

where T_t^H denotes the transfer received from the government. The remaining households can save and invest and will be referred to as Ricardian consumers. Their budget constraint is isomorphic to equation (2) with a superscript R added to the variables C , N , and T . For simplicity, we assume that government spending is entirely financed by (lump-sum) taxes levied on Ricardian households.¹⁹ We also assume that the weights assigned by the Ramsey planner to Hand-to-Mouth and Ricardian consumers is exactly equal to their respective shares in the population. Based on [31], we set the fraction of Hand-to-mouth consumers, φ , to 0.3.

The results for this economy are shown in Figure 5. In the baseline scenario, the liquidity-preference shock leads to a larger drop in the consumption of Hand-to-Mouth households than that of Ricardian households. While labor income declines for both types, the former group of households are unable to smooth their consumption by relying on higher future income. Without transfers, the optimal plan consists in raising public consumption for 7 quarters and public investment for 10 quarters. The increase in public consumption is maximal at the time of the shock and amounts to 1.4 percent of steady-state output, whereas public investment increases in a hump-shaped manner, reaching its peak of roughly 1.6 percent of steady-state output 4 quarters after the shock. As in the benchmark case, the composition of public spending changes in a way that assigns a larger weight to public investment during the first 10 quarters after the shock.

¹⁸Other studies that use a similar a framework include those by [27], [28], [8], [29], and [30]. None of these papers studies optimal transfers, however.

¹⁹The steady-state transfer, T^H , is chosen such that the steady-state allocation in the decentralised economy coincides with the efficient one.

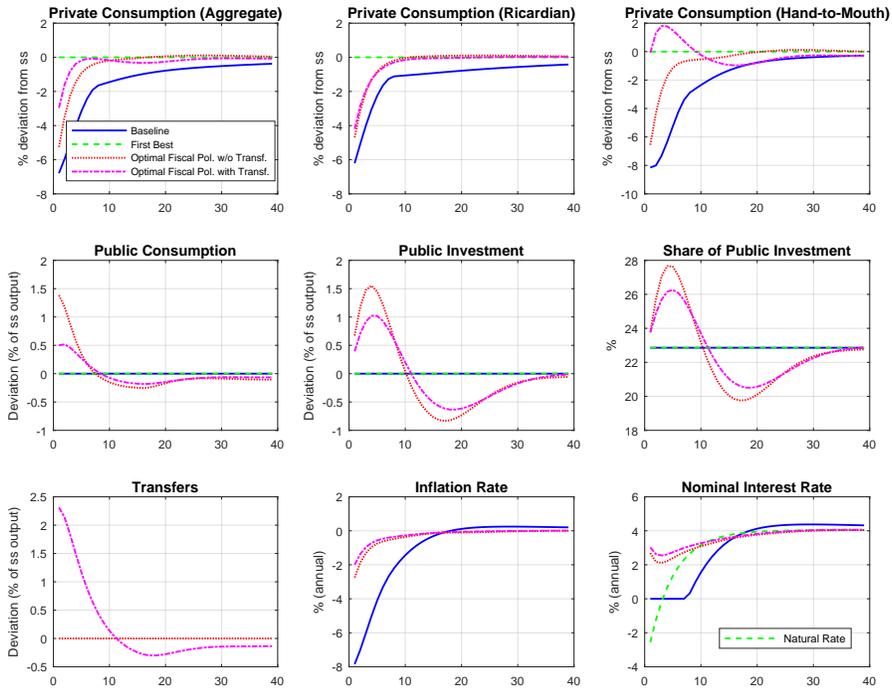


Figure 5: The economy’s response to a liquidity-premium shock in the TANK model with transfers.

485 When transfers are available as a policy tool, the planner finds it optimal to raise the transfer given to Hand-to-Mouth consumers (relative to its steady-state level) for 11 quarters and to decrease it afterwards. The transfer is front-loaded and reaches a total of 2.3 percent of steady-state output at the time of the shock. The optimal transfer helps stabilize the consumption of Hand-to-Mouth
 490 consumers in the short run. Interestingly, it also stabilizes the consumption of Ricardian consumers — though to a much lesser extent — through its effect on inflation. The optimal plan, however, still involves a temporary increase in public spending, with a larger fraction assigned to public investment. At the peak, the increase in public investment reaches 1 percent of steady-state output,
 495 and its share in total public spending reaches 26.3 percent.

In sum, the two extensions discussed above confirm the main conclusion drawn from the benchmark model. In the face of shocks that drive the nominal interest rate down to its lower bound of zero, it is optimal to raise public spending (beyond its flexible-price level) and to shift its composition towards public investment.

6. Discussion: How Optimal was the 2009 ARRA?

To cope with the Great Recession, the U.S. Congress enacted in February 2009 the largest fiscal stimulus package in U.S. history — The American Recovery and Reinvestment Act (ARRA). The ARRA consisted of a series of temporary tax incentives, entitlement programs, and direct government purchases for consumption and investment purposes. In this section, we assess, through the lens of our model, the optimality of the ARRA both in terms of composition and timing of disbursement. To that end, we use [8]’s breakdown of the ARRA into public consumption, public investment, and transfers.²⁰ Since our benchmark economy abstracts from transfers, we contrast the ARRA with the optimal fiscal plan derived in the context of the TANK model described in Section 5.2.

The results are depicted in Figure 6. The largest share of the ARRA was allocated to transfers, but this part of the stimulus was also the briefest, expiring by the end of 2011. Despite the fact that the transfer component of the ARRA was less monotonic than that predicted by the model, it was nearly optimal both in terms of present discounted value (12.3 percent of steady-state output in the data versus 11 percent in the model) and duration.

We reach a different conclusion, however, regarding the non-transfer part of the ARRA. The latter seems to have overstated the size and duration of stimulus consumption, which peaked with a delay of four quarters and persisted

²⁰We refer the reader to the Online Appendix to [8] for details about the classification of the different components of the ARRA into consumption, investment, and transfers, as well as their breakdown by quarter.

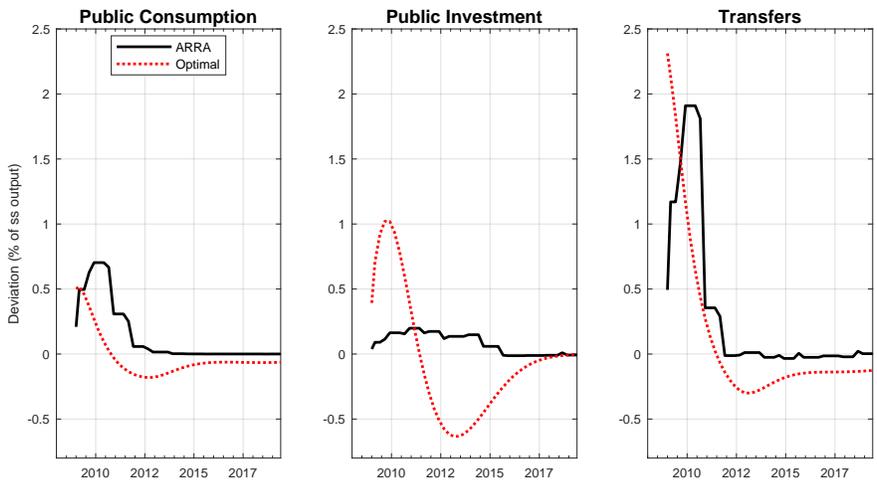


Figure 6: The ARRA versus the Optimal Fiscal Plan.

until the end of 2013, whereas the optimal plan suggests that it should have been more front-loaded and much less persistent. The present discounted value of public consumption spending amounted to 5.7 percent of steady-state output, whereas the corresponding number in the model was 2.3 percent. An even more salient departure from the optimal plan is observed for public investment. While roughly 40 percent of the spending component of the ARRA was allocated to public investment, this stimulus was spread over a long period of time that extended until the end of 2016, such that it never exceeded 0.2 percent of steady-state output at any point in time. This pattern sharply contrasts with the significantly larger and more front-loaded path implied by the optimal plan. While the model implies an investment stimulus that amounts to 6.8 percent of steady-state output in present discounted value, the corresponding figure in the ARRA was barely 3 percent.

A corollary of these results is that the ARRA underweighted the share of public investment in total public spending, as can be seen in Figure 7. While the investment share rose temporarily from 2011 to mid-2015, our analysis suggests that this compositional shift was clearly insufficient and, perhaps even more

importantly, belated.

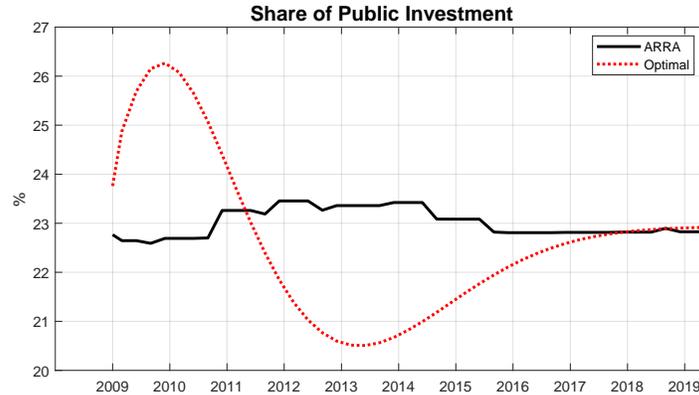


Figure 7: Investment Share in Total Public Spending: The ARRA versus the Optimal Fiscal Plan.

540 7. Conclusion

This paper has shown that fiscal policy can play a potent role in stabilizing an economy plunged into a liquidity trap. We have assumed that the ZLB binds as a result of a large shock that increases households' desire to save in the riskless asset. Due to price rigidity, the shock causes output and employment
545 to fall below their socially optimal levels, thus lowering real marginal cost and creating a wedge between the marginal productivity of private inputs and their prices. Given that monetary policy is unable to fully eliminate the distortions associated with nominal rigidities, an increase in public spending can stimulate employment and help close the gap relative to the efficient allocation. The main
550 question we have attempted to address is: how should this fiscal expansion be divided between public consumption and public investment?

We have shown that the optimal fiscal plan entails a shift in the composition of public spending in a manner that assigns a significantly larger weight to public investment for a prolonged period of time that extends beyond the episode
555 during which the natural interest rate is negative. While this result is preserved

when the set of fiscal instruments is expanded to include investment subsidies and transfers, it has been established under the assumption that public spending is financed entirely through taxes. A natural extension of this work would therefore be to study optimal fiscal policy in a non-Ricardian framework with public debt. The existence of a fiscal limit, i.e., a maximum level of debt that can be financed through taxes, would lead to interesting trade-offs in determining the optimal level and composition of a fiscal stimulus. We leave this extension for future research.

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