Fiscal Stimulus and Distortionary Taxation*

Thorsten Drautzburg

Federal Reserve Bank
of Philadelphia

Harald Uhlig[†]

University of Chicago

First draft: January 2nd, 2010

This revision: September 9, 2015

Abstract

We quantify the fiscal multipliers in response to the American Recovery and Reinvestment Act (ARRA) of 2009. We extend the benchmark medium-scale New Keynesian model, allowing for credit-constrained households, the zero lower bound, government capital, and distortionary taxation. The posterior yields modestly positive short-run multipliers around 0.53 and modestly negative long-run multipliers around -0.36. We compare and relate recent literature multiplier calculations to ours. We explain the central empirical findings with the help of a simple three equation New Keynesian model with sticky wages and credit-constrained households.

Keywords: Fiscal Stimulus, New Keynesian model, liquidity trap, zero lower bound, fiscal multiplier

JEL codes: E62, E63, E65, H20, H62

*This research has been supported by the NSF grant SES-0922550.

[†]Address: Thorsten Drautzburg, Federal Reserve Bank of Philadelphia, Email: tdrautzburg@gmail.com. Harald Uhlig, Department of Economics, University of Chicago, 1126 East 59th Street, Chicago, IL 60637, U.S.A, email: huhlig@uchicago.edu. Additional affiliations for H. Uhlig: CentER, NBER and CEPR. We are grateful for the useful feedback from a number of seminar and conference audiences. The views expressed herein are the authors' views only. They do not necessarily reflect the views of the Federal Reserve Bank of Philadelphia, the Federal Reserve System, or its Board of Governors.

1 Introduction

Since the financial crisis, fiscal policy has been at the heart of policy debates. Many European governments struggle with the debt they accumulated because of their fiscal response to the financial crisis. In the US, the debt ceiling, and cuts to transfer programs or direct tax increases to finance the government deficit are key policy issues that point to the costs of increased government spending. At the same time, it is often argued that the effect of government spending on GDP and unemployment is larger in a financial crisis, making discretionary spending more attractive. In this paper, we bring both aspects of “fiscal stimulus” together. We quantify the size, uncertainty, and sensitivity of fiscal multipliers in response to a fiscal stimulus, as in the American Recovery and Reinvestment Act (ARRA) of 2009 in the United States, using an extension of a benchmark New Keynesian model.

Purists might disagree with the focus on the size of fiscal multipliers. Policy should care about welfare, rather than derivative measures such as GDP or unemployment. Policy should solve a Mirrlees-Ramsey problem and use the best combinations of available tools to maximize welfare, subject to constraints imposed by markets and the asymmetry of information. We do not disagree. Indeed, there is considerable literature on these topics. We address welfare issues in section 7, but they are not the main focus of this paper.

Many public debates focus on the effects of fiscal spending on GDP and unemployment. Economists have the tools to answer these questions, and therefore, perhaps they should. Several recent papers have addressed these issues. This paper seeks to contribute to this literature. We quantify the relative importance of the optimistic analysis of fiscal policy in New Keynesian models of the zero lower bound (ZLB) (e.g., Eggertsson (2010) and Christiano et al. (2011)) relative to the pessimistic assessment of fiscal policy in a neoclassical growth model with distortionary taxes as in Uhlig (2010b). We therefore use a model that adds many New Keynesian frictions to the backbone of the neoclassical growth model with distortionary taxes, building on the models in Christiano et al. (2005) and Smets and Wouters (2007). We extend the fiscal

sector in these models by including distortionary labor taxes and productive government capital. We also add rule-of-thumb consumers to give transfers a role. The ARRA is modeled as a gradual build-up of government transfers, government consumption, and government investment. We simulate the ARRA effect with a deterministic ZLB duration, using the model posterior to quantify parameter uncertainty.

In a nutshell, we find: While the benchmark long-run multiplier is modestly negative, rather than substantially negative as in the pure neoclassical model, and while the precise answer is sensitive to some key assumptions and uncertain parameters, much of the pessimistic assessment survives indeed. For a benchmark parameterization, we find modestly positive short-run multipliers with a posterior mean of 0.53 and modestly negative long-run multipliers centered around -0.36. These multipliers are substantially higher than multipliers away from the ZLB, but lower than the short-run multiplier of 1.2 reported in Christiano et al. (2011) and of 1.55 in Coenen et al. (2012).

Using our posterior estimates, we show that four key model ingredients explain the bulk of the difference between our estimates of the short-run multiplier and those in the literature. First, rule-of-thumb consumers matter and increase the short-run multiplier. Rule-of-thumb-consumers increase the multiplier by about 0.31 and thereby explain most the difference between Christiano et al. (2011) and Coenen et al. (2012). Second, the composition of the stimulus matters: Moving from a consumption-only stimulus to the ARRA composition of fiscal stimulus with consumption, investment, and transfer components lowers the multiplier by 0.70. This explains most of the difference between our results and Coenen et al. (2012). The remaining two important components of our model are the introduction of the empirical built-up in government expenditures and the presence of distortionary rather than lump-sum taxes. Both lower the median posterior multiplier further, by about 0.12 each.

Comparing median multipliers abstracts from our uncertainty about model parameters. We therefore use Bayesian estimation techniques as well as sensitivity analysis to quantify the uncertainty in our answers. Given our model, the data turns out to be quite informative about multipliers. While the 90%

prior confidence intervals exceed 1.0 in our baseline scenario, the 90% posterior confidence interval for short-run multipliers is typically in the order of 0.15 or smaller. This implies that the model features described above matter more than the parameter uncertainty within our model, as also pointed out by Leeper et al. (2011). This is desirable: The model assumptions should be crucial.

Multipliers are, however, sensitive to some key model parameters. Both short-run and long-run multipliers increase in the fraction of transfers given to rule-of-thumb consumers and the anticipated length of the zero lower bound, but fall when taxes are adjusted faster. Multipliers are non-linear in the degree of price and wage-stickiness, but fall when nominal rigidities are smaller than estimated. Long-run multipliers in particular are also sensitive to the specification of distortionary taxes the size of the tax base and which type of taxes is adjusted.

We develop a version of the workhorse three equation New Keynesian model that explains the key results of our sensitivity analysis. For example, our finding that adjusting labor taxes faster lowers multipliers and more flexible prices and wages can lower the multiplier at the ZLB is seemingly at odds with the literature: Eggertsson (2011) suggests that raising labor taxes at the ZLB should increase the multiplier in the workhorse New Keynesian model. Farhi and Werning (2012) point out that the government spending multiplier should increase with price flexibility at the ZLB in the same model. Both arguments operate through higher expected inflation channel which lowers real interest rates at the ZLB. We show that introducing distortionary labor taxes and rule of thumb consumers into the three equation New Keynesian model with rigid wages explains the opposing results of our sensitivity analysis. In particular, it shows that adjusting labor taxes at the ZLB can even push the pure government consumption multiplier below one because of a traditional Keynesian demand effect due to the rule-of-thumb consumers. This direct demand effect can dominate the substitution effect through expected inflation.¹

¹Our finding complements the finding in Erceg and Linde (2014) that tax rules can lower the slope of the Phillips Curve and thereby weaken the expected inflation channel. Since

Second, when taxes are adjusted only slowly the response of the monetary policy to higher labor taxes after exit from the ZLB explains why more nominal rigidity raises the multiplier in our model: More flexible wages imply a higher pass-through of labor taxes to wage and ultimately price inflation. According to the Taylor rule, monetary policy reacts aggressively to higher inflation. Lower future consumption leads agents to also lower their demand in the short-run and results in lower multipliers.

Policy should be concerned with welfare, not multipliers. We therefore complement our analysis of multipliers with a positive analysis of the welfare effects of fiscal stimulus.² Since our model features heterogeneous agents, we compute the welfare effects of the policy intervention separately for credit-constrained and unconstrained agents. The effects on unconstrained agents are significantly negative but small because they are close to their unconstrained optimum. As credit-constrained agents have a higher rate of time preference, we consider a range of rates of time preference, up to 30% higher than those of unconstrained agents on an annual basis. If agents are not too impatient, the welfare gains through higher short-run consumption are more than offset by the disutility of hours worked and the lower consumption in the transition back to the balanced growth path. However, starting at rates of time preference about 15% higher than that of unconstrained agents, the welfare effects become significantly positive for constrained agents.

The paper is structured as follows. Section 2 discusses the related literature. Section 3 gives an overview of the model. Section 4 discusses the estimation and calibration procedure. It also provides a decomposition of the shocks driving the 2007–2009 recession. Section 5 presents the main results on the multiplier. Section 6 provides a sensitivity analysis and explains empirical results using an extended version of the three-equation New Keynesian

the expected inflation channel underlies Eggertsson (2011), this Phillips Curve channel can further explain why distortionary tax financing lowers the multiplier even at the ZLB.

²We do not analyze optimal fiscal policy. Indeed, optimal policy need not involve government expenditure at all, as pointed out by Correia et al. (2010). They have shown that when consumption tax rates are a policy instrument, adjusting tax rates can substitute for adjusting interest rates, thereby circumventing the ZLB.

model. Section 7 discusses welfare effects. The analysis is complemented by a detailed Online Appendix which provides all model details as well as code for replicating our results or calculating other fiscal experiments. Section 8 concludes.

2 Related Literature

Starting with Eggertsson (2010) and Christiano et al. (2011), several studies have analyzed government spending multipliers in New Keynesian models of the ZLB. Cogan et al. (2010) analyze the effect of the ARRA government expenditure path on output in the Smets and Wouters (2007) model. We build on their analysis, but model the fiscal sector in more detail to reflect the composition of ARRA: We introduce credit-constrained agents, which allows us to analyze transfers which constitute 59% of the ARRA. We also introduce productive government investment to analyze the investment portion of the ARRA, 17% of the total. These additions are important: Accounting for the ARRA composition and the slow spending build-up accounts for much of the differences between our results and Coenen et al. (2012), who analyze fiscal multipliers at the ZLB in a range of models. Other notable quantitative contributions include Erceg and Linde (2014), as well as Leeper and various co-authors (Davig and Leeper, 2009; Leeper et al., 2010, 2009). In a model that also features distortionary taxes, rule-of-thumb consumers, and financial frictions, Erceg and Linde (2014) point out that the marginal multiplier differs from the average multiplier: If the stimulus is successful, the economy leaves the binding ZLB earlier, and the effect of additional spending is reduced. We address this issue by endogenizing the duration of the ZLB in robustness tests. A key difference to our paper is their focus on the short run when the effects of adjusting distortionary taxes instead of transfers matters less. Leeper et al. (2010) allow future government consumption and transfers to adjust in order to rebalance the government budget, and they find that adjusting spending and transfers in addition to taxes raises the multiplier. Leeper et al. (2009) point out the importance of productive government investment and government cap-

ital. Davig and Leeper (2009) allow for fiscal policy to switch between passive and active regimes in a New Keynesian model. Interestingly, they find the largest difference in multipliers due to switches in the monetary policy regime, which we address by varying the ZLB duration.

Several recent contributions have analyzed fiscal policy in the workhorse three-equation New Keynesian model in more detail. Farhi and Werning (2012) show that multipliers are strictly increasing in price flexibility and backloading of the stimulus spending while the ZLB lasts. In contrast, Cochrane (2013) argues for a different equilibrium selection that implies the opposite result for price flexibility and negative multipliers. Unlike Cochrane (2013), we choose what he calls the “standard” solution. We still find that more flexibility can lower the multiplier through its interaction with distortionary taxes in a Farhi and Werning (2012)-type setting. In contrast, our finding that a shorter and flat stimulus profile would increase the multiplier compared to the six year ARRA differs from the case Farhi and Werning (2012) consider. Instead, Woodford (2011) shows that backloading stimulus beyond the ZLB duration lowers the multiplier. Braun et al. (2012) and Mertens and Ravn (2013) analyze a non-linear version of the workhorse model. Braun et al. (2012) question whether standard log-linearization is appropriate for analyzing fiscal policy at the ZLB since the economy may be far away from its steady state. Their non-linear analysis implies substantially smaller multipliers. Mertens and Ravn (2013) argue that the cause of the ZLB matters and propose a sunspot shock as the underlying cause. A sunspot ZLB equilibrium implies in their analysis that labor tax cuts are actually more effective than government spending at stimulating the economy.³ While these mechanisms are outside our model, we view their pessimistic analysis of the effectiveness of fiscal stimulus as complementary to our findings. Fernandez-Villaverde et al. (2011) point out that at the ZLB, future labor market reforms are particularly important, as the positive wealth effects stimulate demand during the ZLB. This argument is the flip side of our finding that the negative wealth effect due to distortionary

³Aruoba and Schorfheide (2012) estimate a small-scale sunspot model of the ZLB, but find that sunspot regime switches played only a minor role for the US.

taxes also matters for low short-run multipliers.

Besides the structural literature, a growing body of literature has empirically analyzed multipliers and employment effects of fiscal policy. A contribution closely related to our paper is by Conley and Dupor (2013), who investigate the ARRA employment effects at the state level. They find that only government employment has increased significantly, while private employment effects are not significantly different from zero. Even though they consider a ZLB episode, their findings are in line with the aggregate time series evidence in Barro and Redlick (2011) and Ramey (2011). In their sample, Barro and Redlick (2011) find short-run multipliers significantly below one that do not vary significantly with the business cycle. Ramey (2011) concludes that government spending does not tend to increase private activity – suggesting that the multiplier is not larger than one. While her finding on the overall private-sector activity is in line with our main finding, she does not find significant effect of marginal tax rates on private activity, unlike our model. This may be because tax rates respond only slowly to deficits, as in our model, and may therefore be hard to detect in an estimation exercise. Also, Barro and Redlick (2011) do find significant negative effects of higher marginal tax rates on GDP. Other estimates of multipliers also point to the importance of financing effects, even at the state level, where fiscal policy can be analyzed as if interest rates were held constant. While Shoag (2010) finds multipliers significantly in excess of unity at the state level using pension windfalls, Clemens and Miran (2012) find multipliers smaller than one when using variation in state spending financed by states themselves. Clemens and Miran (2012) explain this difference with the importance of Ricardian elements, in line with the theoretical analysis in Farhi and Werning (2012).

3 The model

The model is an extension of Smets and Wouters (2007), and we refer the reader to that paper and to the Online Appendix for the complete details. Here we provide a brief overview and describe the extensions.

The model in Smets and Wouters (2007) model is a New Keynesian model, set in discrete time. There is a continuum of households. Workers supply homogeneous labor. Unions differentiate the labor supplied by households and set wages for each type of labor in monopolistic competition. Wages are Calvo-sticky. There is a continuum of intermediate good firms. They supply intermediate goods in monopolistic competition. They set prices. Prices are Calvo-sticky. Final goods use intermediate goods. Final goods are produced in perfect competition. Households have preferences for final goods, allowing for habit formation and leisure. Capital is produced by investing in final goods, subject to adjustment costs: Given installed capital and previous-period investment, the marginal product of investment for producing new capital is decreasing. There is variable capital utilization.

We extend the model with several features: We constrain the interest rate set by the central bank to be nonnegative. The government raises revenues with distortionary taxation. We introduce credit-constrained consumers. There is productive government capital. We introduce a wedge between various returns as a stand-in for financial frictions. We adopt the notation convention that variables indexed as t are known in period t .

3.1 The zero lower bound

The monetary authority follows a Taylor-type rule, but interest rates may be held constant for a deterministic period of time. We alternatively also consider interest bounded below by a constant slightly above zero, resulting in an endogenous ZLB duration. It is easier to describe these scenarios in their log-linearized form: For the original version, the reader is referred to the Online Appendix.

In our benchmark scenario, the central bank keeps the interest rate at its historical level of 2008:4 for k quarters. Households fully anticipate this policy. Let $\hat{R}_t^{TR}$ denote the log-deviation of the shadow Taylor Rule return, given by:

$$\hat{R}_t^{TR} = \psi_1(1 - \rho_R)\hat{\pi}_t + \psi_2(1 - \rho_r)(\hat{y}_t - \hat{y}_t^f)$$

$$+\psi_3\Delta(\hat{y}_t - \hat{y}_t^f) + \rho_R \hat{R}_{t-1}^{TR} + ms_t$$

where $\hat{\pi}_t$ is the log-deviation for inflation, $\hat{y}_t$ is the log-deviation for output, $\hat{y}_t^f$ is the log-deviation in the flexible-price version of the economy and ms_t is a shock to the interest rate set by the central bank.

The effective interest rate in our benchmark scenario is then given by:

$$\hat{R}_t^{FFR} = (1 - ZLB_t)\hat{R}_t^{TR} + ZLB_t\hat{R}_0^{FFR},$$

where ZLB_t is an indicator function modeling that takes the value of one while the ZLB binds and is otherwise zero. At the ZLB, the central bank return equals its historical starting value, $\hat{R}_0^{FFR}$.

When endogenizing the ZLB duration, the central bank sets the log-deviation of the central bank return to

$$\hat{R}_t^{FFR} = \max\{(1 - \bar{R}^{FFR}) + \bar{\epsilon}, \hat{R}_t^{TR}\},$$

where $\bar{R}^{FFR}$ is the steady state nominal return and $\bar{\epsilon} > 0$ is a constant set slightly above zero, for technical reasons (and set to $\bar{\epsilon} = \frac{0.25}{400}$ in the numerical calculations, implying a lower bound of 25 basis points for the central bank interest rate). To implement this specification, we need to estimate the counterfactual level of the interest rate $\hat{R}_t^{TR}$ when the ZLB is binding. The estimation is discussed in section 4.2.⁴

⁴Note that the deterministic length of the ZLB in our model is likely to produce lower multipliers compared to a stochastic duration with the same mean duration, as pointed out by Carlstrom et al. (2013). However, the deterministic exit also produces smaller linear approximation errors in the model in Carlstrom et al. (2013) and is therefore their recommended method.

3.2 Households, distortionary taxation, and financial frictions

A fraction $1-\phi$ of the household is unconstrained and solves an infinite-horizon maximization problem. The preferences of such a household, j , are

$$U = \mathbb{E} \left[\sum_{t=0}^{\infty} \beta^s \left(\frac{1}{1-\sigma} (c_t(j) - h c_{t-1}^{aggr})^{1-\sigma} \right) \exp \left(\frac{\sigma-1}{1+\nu} n_t(j)^{1+\nu} \right) \right], \quad (3.1)$$

where $c_t(j)$ is consumption of household j , $n_t(j)$ is its labor supply and c_t^{aggr} is aggregate consumption. $h \in [0, 1)$ captures external habit formation, σ denotes the inverse of the intertemporal elasticity of substitution, and ν equals the inverse of the labor supply elasticity. Households discount the future by $\beta \in (0, 1)$.

Following Trabandt and Uhlig (2011), we assume that the government provides transfers and collects linear taxes on labor income, capital income net of depreciation as well as consumption, adapted to the model here. The budget constraint of household j is therefore given by

$$\begin{aligned} (1 + \tau^c) c_t(j) + x_t(j) + \frac{B_t^n(j)}{R_t^{gov} P_t} \\ \leq s_t^{\text{unconstr}} + \frac{B_{t-1}^n(j)}{P_t} + (1 - \tau_t^n) \frac{W_t}{P_t} \left(n_t(j) + \lambda_{w,t} n_t^{(\text{aggr})} \right) + \\ + \left((1 - \tau^k) \left(\frac{R_t^k u_t(j)}{P_t} - a(u_t(j)) \right) + \delta \tau^k \right) ((1 - \omega_{t-1}^k) k_{t-1}^p(j) + \omega_{t-1}^k k_{t-1}^{p,aggr}) + \frac{\Pi_t^p}{P_t}, \end{aligned}$$

and the capital accumulation constraint is given by

$$k_t^p(j) = \frac{(1 - \delta)}{\mu} k_{t-1}^p(j) + q_{t+s}^x \left(1 - \xi \left(\frac{x_t(j)}{x_{t-1}(j)} \right) \right) x_t(j),$$

where $c_t(j)$ is consumption, $x_t(j)$ is investment, $B_{t-1}^n(j)$ are nominal government bond holdings, $n_t(j)$ is labor, $k_{t-1}^p(j)$ is private capital, and $u_t(j)$ is capacity utilization, all of household j and chosen by household j . R_t^{gov} is the nominal return for the one-period government bond from t to $t+1$ set at date

t , $n_t^{(\text{aggr})}$ is aggregate labor, P_t is the aggregate price level, W_t is aggregate wages, $\lambda_{w,t}$ is the aggregate markup from union-determined wages, R_t^k is the undistorted return on capital, and ω_t^k is a friction or wedge on private capital markets. In the budget constraint, note that ω_t^k enters as a variable known at date $t - 1$, so that the distortions to future capital returns affect investment in the current period. Also note that individual losses due to this wedge are redistributed in the aggregate, so that the wedge distorts investment decisions but does not destroy aggregate resources directly. Π_t^p is nominal firm profits, q_{t+s}^x is an investment-specific technology parameter; $\xi(\cdot)$ captures adjustment costs, satisfying $\xi(\mu) = \xi'(\mu) = 0, \xi'' > 0$; τ^c , τ^n , τ^k are taxes; s_t^{unconstr} are real transfers to unconstrained households, all taken as given by household j ; and $a(\cdot)$ represents the strictly increasing and strictly convex cost function of varying capacity utilization. In particular, note that taxing capital net of depreciation implies deducting a depreciation rate that depends on capacity utilization. Furthermore, the household receives labor income both directly from working as well as indirectly from the surplus that unions charge on labor; both sources of labor income are taxed.

The New Keynesian models underlying our analysis have been criticized for their lack of a financial sector, a feature likely to be important for understanding the events of 2008 (see Uhlig, 2010a; Krugman, 2009; Buiter, 2009). We agree with this critique and therefore feature a financial friction per the “short cut” of allowing for time-varying wedges between the central bank interest rate, government bond rates, and the return to private capital, following Hall (2011).⁵ Specifically, we assume that the interest rate R_t^{gov} on government bonds, which unconstrained households can freely trade, equals the federal funds rate R_t^{FFR} up to an exogenous friction or wedge ω_t^{gov} :

$$R_t^{gov} = (1 + \omega_t^{gov})R_t^{FFR}.$$

Our government bond shock takes the place of the discount rate shock to β in Smets and Wouters (2007) and models such as Christiano et al. (2011).

⁵This feature also allows us to endogenize the duration of the ZLB.

It is a reduced form to capture preference for liquidity among investors. It also captures lower borrowing costs for the government when ω_t^{gov} is low. In contrast to the liquidity preference shock ω_t^{gov} , ω_t^k is a financial friction which captures shocks in the intermediation between households and firms.⁶ By including two different financial friction shocks, our model is flexible enough to allow the data to determine the relative importance of the two shocks.

We assume that a fraction $\phi \in (0, 0.5)$ of the households is credit-constrained. In their version of the budget constraint, $B_{t-1}^n(j) = 0$, $x_t(j) = 0$ and $k_{t-1}^p(j) = 0$, i.e., these households do not save or borrow. They receive profit income from intermediate producers (which equals zero in the steady state). Put differently, the budget constraint of a credit-constrained household j is

$$\begin{aligned} & (1 + \tau^c)c_t(j) \\ & \leq s_t^{\text{constr}} + (1 - \tau_t^n)\frac{W_t}{P_t} \left(n_t(j) + \lambda_{w,t} n_t^{\text{(aggr)}} \right) + \frac{\Pi_t^p}{P_t} \end{aligned}$$

where s_t^{constr} is the transfers to credit-constrained agents. As a justification, one may suppose that credit-constrained households discount the future substantially more steeply and are thus uninterested in accumulating government bonds or private capital, unless their returns are extraordinarily high. Conversely, these households find it easy to default on loans and are therefore not able to borrow. We hold the identity of credit-constrained households and thereby their fraction of the total population constant. Note that we allow the transfers s_t^{constr} to constrained households to differ from the transfers s_t^{unconstr} to the unconstrained households.

Wages are set by unions on behalf of the households, recognizing that each differentiated wage is Calvo-sticky. Since the majority of workers in the unions are unconstrained households, wages are set according to their preferences. Firms hire workers randomly from both types of households, so that labor supplied by both types of households is the same in equilibrium.

⁶Ilut and Schneider (2011) propose increased ambiguity as an alternative interpretation which also increases wedges between safe and risky assets.

3.3 Government capital and policy feedback rules

As the ARRA contains government investment, we wish to feature government capital as productive input. In order to maintain the assumption of perfect competition at the firm level, we also wish to keep the final goods production function to have constant returns to scale. We therefore assume that government capital K_{t-1}^g enters private production as an externality for individual intermediate-goods firm, similar to Barro and Sala-i Martin (1992). To obtain an aggregate constant-returns-to-scale production function before fixed costs, we assume that the externality of K_{t-1}^g at the firm level is relative to aggregate output, before fixed costs.

Specifically, the technology of intermediate firm i is given by

$$Y_t(i) = \tilde{\epsilon}_t^a \left(\frac{K_{t-1}^g}{\int_0^1 Y_t(\iota) d\iota + \Phi \mu^t} \right)^{\frac{\zeta}{1-\zeta}} (K_t^{\text{eff.}}(i))^\alpha (\mu^t n_t(i))^{1-\alpha} - \mu^t \Phi,$$

where Φ are fixed costs, $K_t^{\text{eff.}}$ is effective capital used by firm i , created from aggregate private capital,

$$K_t^{\text{eff.}} = u_t k_{t-1}^p (1 - \phi)$$

(assuming symmetric choices for the unconstrained households), where ϵ_t^a is an exogenous, stochastic component of TFP, and where the services of government capital K_{t-1}^g are subject to congestion: What matters is the ratio of government capital to average gross output (i.e., inclusive of the fixed costs). Without price dispersion, the resulting aggregate production function is:

$$Y_t = \epsilon_t^a K_{t-1}^{g\zeta} K_t^{s\alpha(1-\zeta)} (\mu^t n_t)^{(1-\alpha)(1-\zeta)} - \mu^t \Phi, \quad \epsilon_t^a \equiv (\tilde{\epsilon}_t^a)^{1-\zeta},$$

where TFP in terms of the private factors of production is

$$TFP = \epsilon_t^a K_{t-1}^{g\zeta} \mu^{(1-\alpha)(1-\zeta)t}.$$

We assume that the accumulation of government capital is symmetric to the

accumulation of private capital (i.e., is subject to a similar technology),

$$k_t^g = \frac{(1 - \delta)}{\mu} k_{t-1}^g + q_t^g \left(1 - S_g \left(\frac{x_t^g + \epsilon_t^{x,g}}{x_{t-1}^g + \epsilon_{t-1}^{x,g}} \right) \right) (x_t^g + \epsilon_t^{x,g})$$

where $S_g(\mu) = S'_g(\mu) = 0, S''_g(\cdot) > 0$ represent adjustment costs, $q_t^{x,g}$ is a shock to the government-investment-specific technology parameter, and $\epsilon_t^{x,g}$ is additional, exogenous government investment. We assume that the capacity utilization of government capital, and therefore its depreciation, is constant. To pin down the otherwise free parameter ζ and to determine the dynamics of government investment, we assume optimizing behavior: The government chooses investment to maximize the present discounted value of output net of investment costs, except for a discretionary fiscal stimulus, denoted by $\epsilon_t^{x,g}$ and set to zero at the steady state. In other words, the first-order condition of the government determines optimal government investment, while actual government investment may be higher by some amount chosen along the stimulus path. To enforce the expansion of government investment, we stipulate that the government cannot undo the stimulus investment for the first 12 periods but has to provide at least a replacement for the depreciated ARRA investment – otherwise, the optimality condition would imply complete crowding out.

We assume the following feedback rule for labor tax rates, following Uhlig (2010b) (for the full detail, see the Online Appendix): Break the period-by-period government budget constraint into two parts. On the “right side,” there is a “deficit” d_t , prior to new debt and labor taxes

$$\begin{aligned} d_t = & \text{gov.spend.} + \text{subs.}_t + \text{old debt repaym.}_t \\ & - \text{cons.tax rev.}_t - \text{cap.tax rev.}_t - \bar{\tau}^l \text{lab.income}_t, \end{aligned}$$

which is financed on the “left side” with labor tax revenues and new debt,

$$\tau_t^l \text{lab.income}_t + \text{new debt}_t = d_t.$$

Along the balanced growth path, there is a path for the debt level as well as the deficit $\bar{d}_t$. The labor tax rate is then assumed to solve

$$(\tau_t^l - \bar{\tau}^l) \text{lab.income}_t = \psi_\tau(d_t - \bar{d}_t) + \epsilon_{\tau,l}$$

where $\epsilon_{\tau,l}$ is a labor tax shock. While Leeper et al. (2010) have shown that different feedback rules matter for policy analysis, we focus on this simple rule to analyze in detail the effect of distortionary tax financing.

3.4 Shocks

We assume that there are 10 stochastic processes driving the economy. Unless stated otherwise, the processes follow independent AR(1)'s in logs: (1) Technology $\tilde{\epsilon}_t^a$, (2) Gov.bond wedge ω_t^{gov} : financial friction wedge between financial funds rate (FFR) and gov't bonds, (3) Priv. bond wedge ω_t^k : financial friction wedge between gov't bond returns and a component of the returns to private capital, (4) Gov. spending plus net export. Co-varies with technology, (5) Investment specific technology q_t^x (rel. price), (6) Gov. investment specific technology q_t^g (rel. price), (7) Monetary policy ms_t , (8) Labor tax rates $\epsilon_{\tau,l}$, (9) markup for prices: ARMA(1,1), and (10) markup: wages: ARMA(1,1).

For the stimulus plan, we proceed differently: Shortly, we add an exogenous multi-year and perfectly foreseen component to government consumption, transfers, and government investment. Formally, these series are given by, for example, $g_t = g_t^{ARRA} + g_t^{stoch}$, with g_t^{ARRA} predetermined at $t = 0$ and as in Figure 1. g_t^{stoch} is our usual AR(1) process. To incorporate transfer and to decompose government spending into consumption and investment we classify the various spending categories according to the ARRA. We use the estimates by the CBO (CBO, 2009) for the effects of the ARRA by budget title as the source. We take the annual time path for these expenditures directly from the CBO, whereas the distribution within each year is proportional to the Cogan et al. (2010, CCTW) path within each year. Appendix 9.1 contains the details on the components. Figure 1 presents a graphical overview. Essentially, we decompose the CCTW government spending path into a separate

consumption and investment path, and add transfers. Importantly, many of the transfers are “front-loaded,” so that they occur earlier than government spending, while the “stimulus” government investment occurs later.⁷

[Figure 1 about here.]

Furthermore, we consider as our benchmark that the central bank will leave the federal funds rate unchanged at near zero for eight quarters, and that this is fully anticipated as of the 2009:1. A duration of eight quarters already lies above the implied median ZLB duration of six quarters with an endogenous ZLB according to equation (3.1), as shown in Figure D.7 in the Online Appendix. Such a duration is also consistent with Gust et al. (2013). They find in their non-linear model of the ZLB that less than 3% of ZLB spells last 12 quarters or more and 78% of spells last 4 quarters or less. However, if more negative shocks hit the economy, a longer duration would be generated. We therefore consider other deterministic durations as well. For the numerical calculations, the relaxation algorithm proposed by Juillard (1996) and implemented in Dynare is particularly convenient for the type of forward-simulation (rather than estimation) performed here. By solving a time-varying system of equations backward from terminal conditions, it allows us to incorporate anticipated shocks even when they multiply coefficients, for example, to “switch off” the interest rate rule temporarily.

4 Estimation and Analysis

4.1 Data and Estimation

We solve the model using a log-linear approximation and Dynare. The first-order conditions and their log-linearized versions are in a Online Appendix, available upon request. We estimate the model, using the following 10 time

⁷We classify transfers to state and local governments as consumption. To the extent that these transfers are spent only partially by local governments with the remainder being an intergovernmental transfer, the effective stimulus program would weigh transfers and investment more, lowering the overall multiplier from the right panel in Figure 7.

series: (1) Output: Chained 2005 real GDP, growth rates, (2) Consumption: Private consumption expenditure, growth rates, (3) Investment: private fixed investment, growth rates, (4) Government investment, growth rates, (5) Hours worked: Civilian employment index $\times$ average nonfarm business weekly hours worked index, demeaned log, (6) Inflation: GDP deflator, quarterly growth rates, (7) Wages: Nonfarm Business, hourly compensation index, growth rates, (8) FFR: Converted to quarterly rates, (9) Corporate-Treasury bond yield spread: Moody’s Baa index – 10 year Treasury bond at quarterly rates, demeaned, (10) Dallas Fed gross federal debt series at par value, demeaned log.

Sources and details for the data are described in Appendix 9.1. We use an updated version of the Smets-Wouters dataset, for the range 1947:2-2009:4, using quarterly data. In difference to the original dataset, we classify consumer durables as investment expenditure. The estimation of the model uses data from 1948:2 up to 2008:4, with the additional four quarters for comparison of the model prediction to the actual evolution and the first four quarters used to presample. Our earlier starting date is motivated by Barro and Redlick (2011), who find that the multiplier is significantly below one only after including the World Wars in their sample. While we cannot go this far back, we choose the longer sample, as it includes the Korean war as well as the Vietnam war buildup. Figure 2 shows the additional evidence from the larger fluctuation in fiscal expenditures available in this larger sample.

[Figure 2 about here.]

We fixed (“calibrated”) several parameters a priori. For tax rates and the debt-GDP ratio, we relied on Trabandt and Uhlig (2011). Time averages of government spending components were obtained from the NIPA, Table 3.1 (quarterly), lines 35 (investment), 16 (consumption), and transfers (17). Government consumption includes net exports (line 2 minus line 14 in Table 4.1). To obtain ratios relative to GDP, GDP data from line 1, Table 1.1.5 was used. Following Smets and Wouters (2007), the Kimball curvature parameter is taken from Eichenbaum and Fisher (2007), who set it to roughly match it to their data on the empirical frequency of price adjustment. Following

Cooley and Prescott (1995), the depreciation rate is derived from the law of motion for capital and their observation of $\frac{\bar{x}}{k} = 0.0076$ at quarterly frequency. The complete list of calibrated parameters, and their comparison to the corresponding parameters in Smets and Wouters (2007), if available, is in Table I. We calibrate the share of credit-constrained agents in the population to 0.25, a share typical for DSGE models used in the IMF comparison project (Coenen et al., 2012). All agents receive the same per-capita transfers.

[Table I about here.]

We estimate our model using Dynare and a fairly standard Bayesian prior. Details on the estimation can be found in Appendix 9.2. The estimates largely agree with those found by Smets and Wouters (2007), leaning somewhat more to more endogenous persistence: The habit parameter is slightly higher, as are estimates of price and wage stickiness, for example. Like these authors' estimates, our estimates also yield a rather small capital share: Our posterior mean is 0.24, while they found 0.19. This is at odds with calibrated values in the literature, see, e.g., Cooley and Prescott (1995), and may play a substantial role in calculating the long-horizon impact of distortionary taxation. We investigate this issue in our sensitivity analysis. The calibrated government investment-to-GDP ratio as well as the estimated growth trend $\mu \approx 1.005$ imply a government share in production of $\zeta \approx 2.30$ percent. The implied Frisch elasticity of labor supply is small at 0.30.⁸ The posterior mean for σ implies that there is a mild complementarity between hours and consumption of unconstrained agents, meaning that unconstrained agents want to work less when their consumption falls, as in Christiano et al. (2011).

4.2 Decomposing the 2007–2009 recession

The model allows the decomposition of movements in our 10 macroeconomic time series into ten shocks that caused them. Beyond helping to understand what caused the recent recession, this analysis is crucial for simulating stimulus

⁸The Frisch elasticity is given by $(\nu + (1 - \sigma^{-1})\bar{n}^{\nu+1})^{-1} = (\nu + (1 - \sigma^{-1})\frac{1-\alpha}{(1-h)C^{RA}/Y})^{-1}$.

effects when the ZLB has an endogenous duration: The interest rate prescribed by the Taylor rule depends on the levels of inflation, the output gap, the change in interest rates, and monetary policy shocks. By estimating the historical state of the economy, we can estimate and simulate the level of the desired interest rate and thereby compute the implied duration of the ZLB.

Financial frictions are important determinants of nominal interest rates. They drive a wedge between returns on government bonds, private capital, and the FFR. In our model, we can decompose the gap between the federal funds rate R_t^{FFR} and the return on private capital R_t^{kp} , up to first order, into ω_t^b and ω_t^k , after rescaling appropriately:⁹

$$1 = \frac{1}{(1 + \omega_t^{gov})} \frac{\pi_{t+1}}{R_t^{FFR}} (1 - \omega_t^k) R_t^{kp}.$$

Here, ω_t^b represents the wedge between the government bond yield and the federal funds rate, whereas the latter is the wedge between private and government bonds. Since the spread between private and government bonds is observable, we estimate only ω_t^b . Our estimation results are consistent with the intuition that financial frictions were indeed central to the 2007–2009 recession. As Figure 3 and Table II document, shocks to these wedges indeed played a large role in understanding the recent recession, accounting alone for over 100% of the decline in output, in stark contrast to their small contribution to the full-sample variance of output as well as other included time series. While both financial friction shocks are important in our estimation, the government bond shock contributes more than twice as much as the private bond shock. In our interpretation, this means that liquidity considerations were

⁹To see this, note that the first-order conditions of the households imply:

$$\begin{aligned} 1 &= \beta E_t \left[\frac{u_{c,t+1}}{u_{c,t}} \frac{R_t^{gov}}{\pi_{t+1}} \right] = \beta E_t \left[\frac{u_{c,t+1}}{u_{c,t}} (1 + \omega_t^{gov}) \frac{R_t^{FFR}}{\pi_{t+1}} \right] \\ &= \beta E_t \left[\frac{u_{c,t+1}}{u_{c,t}} \left((1 - \omega_t^k) ((1 - \tau^k)(r_{t+1}^k u_{t+1} - a(u_{t+1})) + \delta \tau^k) + (1 - \delta) \frac{Q_{t+1}}{Q_t} \right) \right] \end{aligned}$$

where Q_t is the price of capital. Simplify this expression by assuming a constant Q_t , constant utilization, and ignoring uncertainty. The first line can then be substituted into the second. Defining $R_t^{kp} \equiv (r_{t+1}^k - \tau^k(r_{t+1}^k - \delta)) + (1 - \delta)$ yields the above equation.

more important than shocks to intermediation. In the model, the government bond shock depresses output, consumption, and private as well as government investment, whereas the shock to the spread between private bonds and government bonds leads to a decline in consumption only with some delay, and actually increases government investments. Both shocks furthermore result in a modest decline in the federal funds rate. Figure D.4 in the Online Appendix shows these impulse responses for a one-standard deviation shock to the two wedges.

[Figure 3 about here.]

[Table II about here.]

Besides being important for extracting the historical starting conditions of the economy in 2009, allowing for a bond premium shock may also change the posterior over structural parameters. Del Negro et al. (2013) also estimate a much higher degree of nominal rigidities in their model than in Smets and Wouters (2007), once they introduce a bond premium shock in their model. As discussed in detail in Del Negro et al. (2013), the higher degree of stickiness is key to explaining the lack of deflation in the recent recession. The high stickiness also implies that our model does not produce a large response of inflation to the fiscal stimulus, which would go against empirical evidence in Dupor and Li (2013). We discuss in detail in Section 6.5 how stickiness affects our analysis.

4.3 Computing multipliers

Our main focus is on the fiscal multiplier (i.e., the ratio of output changes to the total stimulus-planned change in spending and transfers). Note that due to the eventual balancing of the government budget, there will also be an induced movement in tax rates as a “secondary” effect. As is customary, we shall not include these secondary movements in the denominator (i.e., in quantifying the stimulus-planned changes). As this is a dynamic model, the horizon plays a role. Following Uhlig (2010b), we use the net present value

fiscal multiplier φ_t , dividing the net present value of output changes up to some horizon t by the change in government spending and transfers until the same time. I.e., we shall use

$$\varphi_t = \sum_{s=1}^t \left(\mu^s \prod_{j=1}^s R_{j,ARRA}^{-1} \right) \hat{y}_s / \sum_{s=1}^t \left(\mu^s \prod_{j=1}^s R_{j,ARRA}^{-1} \right) \hat{g}_s \quad (4.1)$$

where φ_t : horizon- t multiplier, $R_{j,ARRA}$ is the government bond return, from $j - 1$ to j , $\hat{y}_s$ is the output change at date s due to ARRA in percent of the balanced-growth GDP path and $\hat{g}_s$: ARRA spending at date s in percent of the balanced-growth GDP path. In what follows, we refer to the multiplier at the one year horizon, φ_4 , as the short-run multiplier. Long-run multipliers are the limit for $t \rightarrow \infty$.

When analyzing our results, we report the posterior median, as well as confidence bands covering 90 percent and 67 percent of the posterior probability.

5 Main Results

5.1 Description of benchmark results

Figure 4 contains our benchmark results for output, hours worked, the federal funds rate, inflation, government debt, and consumption.¹⁰ These graphs are perhaps reminiscent of the information shown in the official White House piece by Bernstein and Romer (2009). However, we include an important piece of information, which is missing there. The short-run debt dynamics shown here induce long-run debt-and-tax dynamics, shown in Figure 5. The increase in labor tax rates long after the fiscal stimulus phase has finished induces the decline of output for many years to come.

[Figure 4 about here.]

[Figure 5 about here.]

¹⁰ Results for the consumption of both types of agents, real wages, tax rates, and investment are shown in Figure D.5. Appendix C relates hours worked to unemployment.

The resulting fiscal multiplier therefore declines with the horizon. The fiscal multipliers for the shorter horizon, shown in the left panel of Figure 6, can therefore be quite misleading in terms of assessing the long-term costs of fiscal stimulus. Indeed, the long-run multipliers are considerably smaller or negative, as compared with the short-run multipliers, shown in the right panel of Figure 6. These results are qualitatively in line with Uhlig (2010b), though the results are quantitatively rather different: The long-run fiscal multipliers are negative there and here, but considerably more negative there. One may be tempted to read the difference as “relief,” compared with the pessimistic scenario in Uhlig (2010b). Note, however, that the model here is heavily tilted toward a model in which fiscal stimulus is often thought to work well. We therefore believe that the negative long-run effects of fiscal stimulus should give pause to arguments in its favor. Even at the short horizon, the benchmark multiplier is just around 0.5.

[Figure 6 about here.]

We departed from the original Smets-Wouters model in order to model the fiscal stimulus in more detail by being able to distinguish between money spent on government transfers, consumption, and investment. Our results imply that each component indeed affects the economy differently: Transfers to credit-constrained agents are similar to government consumption, whereas transfers to unconstrained households mainly increase the need to raise distortionary taxes. Discretionary government investment increases private sector productivity but may also crowd out optimal government investment, effectively lowering the size of the long-term debt burden faced by households. The right panel in Figure 7 shows that in our benchmark model, the government investment component contributes to a positive multiplier, whereas the government consumption and transfer components lower the overall multiplier below zero.

[Figure 7 about here.]

As part of our ARRA specification, we also require the government to at least replace depreciating government investment during the first twelve quarters of ARRA. Figure 8 illustrates in its left panel that without this constraint, the government would disinvest when only the government consumption of ARRA is implemented.¹¹ (The corresponding figure for transfers is similar.) Intuitively, there is a negative wealth effect on investment as exogenous spending increases and reduces the resources available in the economy. We therefore also need to specify exogenous government investment as part of ARRA to generate the investment response that is part of ARRA.

[Figure 8 about here.]

5.2 Robustness of the fiscal multiplier

The qualitative findings of a short-run multiplier below one and a long-run multiplier around zero, or even negative, are robust to a wide range of different modeling assumptions. Table III and Table IV provide an overview. We first provide several “partial derivatives”, holding the timing and composition of the ARRA constant. We change (1) the duration of the binding ZLB, (2) the type of distortionary taxes, (3) the fraction of RoT agents, (4) targeted transfers, (5) the degree of nominal rigidities, (6) the capital share, and (7) the speed of budget balancing, alternatively by varying ψ_τ or by gradual adjustment to the target tax rate as in Erceg and Linde (2014). Except with perfectly targeted transfers, the median short-run multiplier is below one in all of these experiments, implying that government spending partially crowds out private activity rather than increasing it. The long-run multiplier is sensitive to the type of taxation, but unless the ZLB is expected to last for more than three years, the median long-run multiplier is negative with labor taxes.

Multipliers are sensitive to the the timing and composition of the stimulus package: The bottom panels of Tables III and IV provide results for the three separate stimulus components with their ARRA timing and consumption-only

¹¹Government investment can fall despite the constraint on disinvestment when it is lower than it would be without the ARRA consumption component.

stimulus spent uniformly over four quarters. The consumption-only multipliers exceed one in the short-run. With distortionary taxes, however, the long-run consumption multipliers are centered in negative territory.

[Table III about here.]

[Table IV about here.]

Are the results driven by our priors over tax adjustment speed or the fraction of rule of thumb consumers?¹² Considering different priors, we find that they are not. We consider six different priors which deviate from our benchmark as follows: Tax adjustment speed fixed at our point-estimate of $\psi_\tau = 0.038$ (model 1), a slower tax-adjustment speed of $\psi_\tau = 0.025$ (model 2), the same tax adjustment speeds except for fixed costs constant at our point estimate $\Phi = 1.94$ (models 3 and 4), and the same adjustment speeds with constant fixed cost and 40% rule of thumb consumers (models 5 and 6). Absent the ZLB, the median short-run multipliers associated with these six models are increasing in the above order from 0.11 to 0.19.¹³ Despite wide and sometimes very wide prior confidence intervals in the presence of the ZLB, posterior short-run multipliers for models without 40% RoT agents are basically the same as in benchmark estimates. Posterior long-run multipliers are also close to our benchmark estimates, with the model most favored by the data centered at -0.35, with a 90% confidence interval of (-0.61, -0.04). With 40% RoT agents, both long-run and short-run multipliers are about +0.08 points higher with an eight quarter ZLB, but the associated Bayes factors are 50 log-points lower, implying strong evidence against these models.

[Figure 9 about here.]

¹²We thank an anonymous referee for suggesting this calculation.

¹³See Tables D.7 and D.8 for marginal data densities as well as prior and posterior multipliers for the short-run and the long-run. Figure D.8 in the Online Appendix also provides results away from the ZLB and with a 12 quarter ZLB.

5.3 Connecting to the literature

Our model largely reproduces the multipliers reported for different scenarios in the literature, but gives slightly lower estimates. Table V shows step by step how changing different modeling assumptions largely reproduces the short-run multipliers reported in Christiano et al. (2011) and Coenen et al. (2012). We start with the Christiano et al. (2011) scenario. They consider an 8 quarter ZLB with a flat, consumption-only stimulus. In this scenario, we estimate a median multiplier of 1.13, compared to their reported value of 1.2. Adding rule-of-thumb consumers yields the Coenen et al. (2012) scenario and increases the multiplier by 0.31 to 1.44, close to their reported value of 1.55. Changing the composition from a consumption-only stimulus to the empirical ARRA stimulus lowers the median multiplier by 0.70 to 0.74. Introducing distortionary taxes and the empirical ARRA timing lowers the multiplier further, by about 0.12 each, closing the remaining gap to our baseline estimate of 0.53.

[Table V about here.]

6 Understanding multipliers

To understand the main qualitative features of our model, a modified version of the three-equation New Keynesian textbook model is useful. The key is the addition of rule-of-thumb agents with rigid wages instead of rigid prices. This model helps to explain the estimated effects of the ZLB duration, distortionary taxes, the role of RoT agents, the stimulus composition, and stickiness.

We show that when wages are sticky, workers are off their labor supply curve, and changes in labor taxes affect the disposable income of RoT agents and thereby affect aggregate demand directly. This novel aggregate demand effect can partially crowd out private consumption even at a persistent ZLB and push the multiplier below one. Deficit-financing stimulus avoids this problem, but at the cost of depressed future output, as higher taxes lower work incentives and tighter monetary policy in response to inflation hit the economy.

The simple model abstracts from additional mechanisms in the full model, such as capital and the timing of the stimulus. Capital accumulation as in Uhlig (2010b) is an important omission from the simple model. It amplifies the distortionary effects of increased labor taxes: The predicted negative effects on output after exit from the ZLB and the phasing out of the stimulus lowers the return on capital and causes investment to fall. The timing of the stimulus relative to the duration of the ZLB also matters, as shown by Woodford (2011): When government spending persists beyond the duration of the ZLB, it lowers the multiplier. Since a small portion of the stimulus persists for up to six years, this timing effect is also present in our empirical model. Timing by itself is, however, not crucial for our main quantitative results: Figure D.11 in the Online Appendix compares labor-tax- with transfer-financing when the entire stimulus is spent uniformly over the first four quarters. When transfers are adjusted, the multiplier is larger than one, whereas the median multiplier with distortionary taxes falls in the long run to almost minus one.

6.1 Simple New Keynesian model

We modify the textbook New Keynesian model (e.g., Galí, 2008, ch. 3 and 6) to resemble our baseline model by including rule-of-thumb agents as in Galí et al. (2007), with sticky wages as in Smets and Wouters (2007) and Christiano et al. (2005). We abstract from steady state government consumption and debt. The result is a modified version of the standard three-equation model consisting of an Euler equation, a Phillips curve, and an interest rate rule.

In difference to the full model, there is no capital and no indexation of wages or prices. We consider log-utility ($\sigma = 1$). The fraction ϕ of RoT households does not receive profit income, so that their individual share of income and consumption is equal to $\frac{\epsilon_p - 1}{\epsilon_p}$, the labor share. $\frac{\epsilon_p}{\epsilon_p - 1}$ is the steady state markup in the goods market. Away from the ZLB, the monetary authority follows a Taylor rule with a constant intercept and reacts only to current inflation with

a coefficient γ_π . In deviations from the steady state:

$$\hat{R}_t = (1 - \mathbf{1}_{ZLB,t})\gamma_\pi \hat{\pi}_t. \quad (6.1)$$

Lemma 1 in Appendix B.9.9 shows that the Taylor Principle $\gamma_\pi > 1$ is sufficient to guarantee stability despite the presence of RoT agents if $\phi \frac{\epsilon_p - 1}{\epsilon_p} (1 + \nu) < 1$.

We consider spending processes as in Eggertsson (2011) and Christiano et al. (2011): The government targets the stimulus perfectly to the length of the ZLB: $\hat{g}_t = \mathbf{1}_{ZLB,t} \bar{g}$. In the steady state, all fiscal variables are zero.

The description of this simple economy is then completed by specifying the government tax policy. Starting from the zero debt steady state, a stylized representation of our tax policy rule is:

$$\text{labor share} \times d\tau_t^n + d\tau_t^c - \hat{s}_t^e = \psi_\tau (\hat{g}_t + \hat{s}_t^x), \quad \hat{d}_t = (1 - \psi_\tau)(\hat{g}_t + \hat{s}_t^x) \quad \text{at ZLB,} \quad (6.2a)$$

$$\text{labor share} \times d\tau_t^n + d\tau_t^c - \hat{s}_t^e = (1 - \psi_\tau) \bar{R}^g \hat{d}_{t-1}, \quad \hat{d}_t = 0 \quad \text{after ZLB,} \quad (6.2b)$$

where transfers $\hat{s}_t$ are the sum of endogenous transfers $\hat{s}_t^e$, and exogenous stimulus transfers $\hat{s}_t^x$. $\bar{R}^g$ is the gross real return on government bonds and ψ_τ governs the tax adjustment speed as in our full model.

To model a more gradual tax adjustment after exiting the ZLB, we also consider a tax rule which rolls over the remaining debt and only pays the interest.¹⁴ In that case equation (6.2a) is unchanged, but (6.2b) is replaced by:

$$\text{labor share} \times d\tau_t^n + d\tau_t^c - \hat{s}_t^e = (1 - \psi_\tau)(\bar{R}^g - 1)\hat{d}_{t-1}, \quad \hat{d}_t = \hat{d}_{t-1} \quad \text{after ZLB} \quad (6.2b')$$

Appendix B.9.3 derives the Phillips curve and the Euler equation in the

¹⁴Unless otherwise stated, we consider the tax rule (6.2b) when analyzing our simple model.

limit of perfectly flexible wages, $\lim \zeta_w \searrow 0$, and sticky prices $\zeta_p > 0$ as:

$$\begin{aligned} \hat{y}_t &= \frac{\hat{g}_t + \phi_c \frac{\epsilon_p}{\epsilon_p - 1} \hat{s}_t}{1 - \phi_c(1 + \nu)} + \mathbb{E}_t \left[\hat{y}_{t+1} - \frac{\hat{g}_{t+1} + \phi_c \frac{\epsilon_p}{\epsilon_p - 1} \hat{s}_{t+1}}{1 - \phi_c(1 + \nu)} \right] \\ &\quad - \frac{1}{1 - \phi_c(1 + \nu)} (\hat{R}_t - \mathbb{E}_t[\hat{\pi}_{t+1} + d\tau_{t+1}^c - d\tau_t^c]) \end{aligned} \quad (6.3a)$$

$$\hat{\pi}_t = \beta \mathbb{E}_t[\hat{\pi}_{t+1}] + \lambda_p \left(\left(\nu + (1 - \phi_c(1 + \nu)) \right) \hat{y}_t - \hat{g}_t - \phi_c \frac{\epsilon_p}{\epsilon_p - 1} \hat{s}_t + d\tau_t^n + d\tau_t^c \right) \quad (6.3b)$$

where $\lambda_p = \frac{(1 - \zeta_p)(1 - \beta\zeta_p)}{\zeta_p}$ is a measure of price flexibility and $\phi_c = \phi \times$ labor share $= \phi \frac{\epsilon_p - 1}{\epsilon_p}$ is the RoT consumption share.

When wages are sticky $\zeta_w > 0$ but prices are fully flexible, $\lim \zeta_p \searrow 0$, the Phillips curve and the Euler equation are (cf. Appendix B.9.4):

$$\begin{aligned} \hat{y}_t &= \frac{\hat{g}_t + \phi_c \frac{\epsilon_p}{\epsilon_p - 1} \hat{s}_t - \phi_c(d\tau_t^n + d\tau_t^c)}{1 - \phi_c} + \mathbb{E}_t \left[\hat{y}_{t+1} + \frac{-\hat{g}_{t+1} - \phi_c \frac{\epsilon_p}{\epsilon_p - 1} \hat{s}_{t+1} + \phi_c(d\tau_{t+1}^n + d\tau_{t+1}^c)}{1 - \phi_c} \right] \\ &\quad - (\hat{R}_t - \mathbb{E}_t[\hat{\pi}_{t+1} + d\tau_{t+1}^c - d\tau_t^c]) \end{aligned} \quad (6.4a)$$

$$\hat{\pi}_t = \beta \mathbb{E}_t[\hat{\pi}_{t+1}] + \lambda_w \left((1 + \nu) \hat{y}_t + \frac{-\hat{g}_t - \phi_c \frac{\epsilon_p}{\epsilon_p - 1} \hat{s}_t + \phi_c(d\tau_t^n + d\tau_t^c)}{1 - \phi_c} + d\tau_t + d\tau_t^c \right) \quad (6.4b)$$

where $\lambda_w = \frac{(1 - \zeta_w)(1 - \beta\zeta_w)}{\zeta_w}$ is a measure of wage flexibility.

Without RoT agents, $\phi_c = 0$, equations (6.3) and (6.4) are isomorphic and the source of nominal rigidity is irrelevant. Once there is a positive mass of RoT agents, the source of nominal rigidity makes a qualitative difference. Transfers also drop out of the private-sector equilibrium conditions without RoT agents because of Ricardian Equivalence.

Taxes only have a direct effect on output under sticky wages through the Euler equation. The direct contemporaneous effect is due to reduced income lower consumption demand of RoT agents when taxes increase and gross wages are sticky. Known future taxes also lower future demand by RoT agents, but for given output, this requires unconstrained agents to consume more in the

future. Trying to smooth consumption, unconstrained agents demand higher consumption today. This wealth effect results, all else being equal, in higher current output. In contrast, with flexible wages, net real wages are invariant to labor taxes and no demand effect arises. Indirect effects of taxes result from the pass-through of taxes to price inflation through the Phillips curve under both sticky prices and sticky wages.

Present in both Euler equations is a traditional Keynesian multiplier: For given output and wages, when the government consumes $\hat{g}$ extra units of output, hours rise by $\hat{n} = \hat{g}$ given the labor-only production function. The real income by RoT agents rises therefore. This raises aggregate demand by an additional $\phi_c \hat{g}$ units, increasing labor demand further. The total effect adds up to $\sum_{j=0}^{\infty} (\phi_c)^j = \frac{1}{1-\phi_c}$ per unit of government purchases $\hat{g}$ under sticky wages in (6.4a). If wages are flexible, unions demand additional increases in the real wage which cause the multiplier to rise to $\frac{1}{1-\phi_c(1+\nu)}$ in (6.3a).

When analyzing our empirical results through the lens of the simple model, we often consider limits of a slow speed of tax adjustment ψ_τ and high degree of nominal rigidities ζ_w, ζ_p , in line with the full model posterior mean. Numerical examples use the following quarterly calibration: We set the rate of time preference to $\beta^{-1} - 1 = 0.01$ and choose $\zeta_w = \zeta_p = \frac{4}{5}$ for price and wage stickiness. We set the elasticity of substitution between intermediate inputs equal to $\epsilon_p = 3$ to generate a labor share of $\frac{\epsilon_p - 1}{\epsilon_p} = \frac{2}{3}$. The fraction of RoT agents is set to 0.25. We choose a reaction coefficient of $\gamma_\pi = 2$ for the monetary authority and impose a Frisch elasticity of $\nu^{-1} = 1$.

6.2 Duration of the ZLB

Our empirical findings imply a short-run multiplier smaller than unity but strictly increasing in the duration of the ZLB. Despite the “paradox of toil” in Eggertsson (2011) we show that this finding can be explained by our simple model with RoT agents when wages, but not prices, are sticky.

[Figure 10 about here.]

Figure 10 shows the posterior distribution of short-run and long-run multipliers when varying the exogenous duration of the ZLB from zero to five years. The median short-run multiplier increases monotonically from 0.23 without a binding ZLB to 0.80 with a duration of five years, while the median long-run multiplier increases from -0.74 to +0.33. However, the posterior uncertainty also increases significantly: With a five-year ZLB length, the 90% credible set for the long-run multiplier ranges from -0.28 to +2.21.

Our simple sticky wage model reproduces the fact that short-run multipliers are below unity even with a persistent ZLB. To that end, we adopt the Markov specification for the ZLB in Eggertsson (2011) and assume immediate taxation to match his analysis of increasing labor taxes during the recession. Proposition 1 shows that the short-run multiplier can be below one with sticky wages even in the presence of a persistent ZLB, but not when only prices are sticky. The simple model attributes the low multiplier to the negative aggregate demand effect from taxing RoT agents. This effect dominates both the expected inflation effect, which increases demand via the neoclassical substitution effect, as well as the Keynesian multiplier effect due to RoT agents.

Proposition 1. *Consider the model in Section 6.1. Assume immediate taxation ($\psi_\tau = 1$), that the Taylor Principle holds and that the ZLB is a nonrecurrent Markov state which persists with probability μ : $\Pr\{\mathbf{1}_{ZLB,t} = 1 | \mathbf{1}_{ZLB,t-1} = 1\} = \mu, \Pr\{\mathbf{1}_{ZLB,t} = 1 | \mathbf{1}_{ZLB,t-1} = 0\} = 0$. In the case of sticky prices and flexible wages, also assume that $0 < \phi < \frac{\epsilon_p}{1+\nu}$. Consider the case of financing through distortionary labor taxes: $\hat{s}_t = d\tau_t^c = 0$.*

(a) *For sufficiently small persistence of the ZLB, μ , the impact multiplier $\frac{y_{ZLB}}{g}$ is strictly smaller than one under flexible prices and sticky wages and strictly larger than one under flexible wages and sticky prices.*

(b) *The multiplier increases monotonically in the expected duration of the ZLB with either sticky wages or sticky prices in the region of determinacy.*

Proof: See Appendix B.9.9, page LVI.

6.3 Distortionary taxes

The premise of this paper is that distortionary taxes matter for the effects of government spending. Figure 11 shows that this is indeed the case: The multiplier is significantly lower with distortionary labor taxes than with lump-sum taxes. This difference is most pronounced in the long run (right panel), when the multiplier is centered around +0.6 with lump-sum taxation and around -0.45 with labor taxes. Short-run multipliers with consumption taxes are about as high as they are with transfer financing, but long-run multipliers are lower than with transfer financing.

[Figure 11 about here.]

To understand the results on taxation, we turn again to the simple model with sticky wages. Fixing the duration of the ZLB at one period, we focus first on the type of taxation while allowing for a varying speed of tax adjustment. Part (a) of Proposition 2 implies that the multiplier is higher with lump-sum taxation than it is with labor taxes. Lump-sum taxes have the same Keynesian demand effects through RoT agents, but do not cause the monetary authority to raise interest rates due to inflationary pressure. Labor taxes therefore depress future output and consumption by lowering demand in the short run via a negative wealth effect that is absent with lump-sum taxes. Because increasing consumption taxes generate consumer price inflation, short-run multipliers can be higher with consumption taxes than they are with transfers when taxes are adjusted slowly. However, with sufficiently sticky wages, long-run multipliers are the highest with transfer financing. The reason is that the future consumption tax hike lowers consumption demand, and the monetary authority does not react much with sufficiently sticky wages.

Proposition 2. *Consider the model in Section 6.1 with sticky wages, flexible prices, and a one period ZLB and stimulus. Assume the Taylor Principle is satisfied.*

(a) *The impact multiplier is strictly lower when financed with labor taxes rather than lump-sum taxes if $\psi_\tau < 1$ and equal otherwise. The long-run*

multiplier is lower with both labor taxes and consumption taxes than it is with lump-sum taxes if $\psi_\tau < 1$ and wages are sufficiently sticky ($\zeta_w \nearrow 1$).

If taxes are adjusted sufficiently slowly, $\psi_\tau < \bar{\psi}^n < 1$, the impact multiplier is higher with consumption taxes than it is with labor taxes. The impact multiplier is higher with consumption taxes than it is with transfer financing if $\psi_\tau < \bar{\psi}^s$, where $\bar{\psi}^s < \bar{\psi}^n$.

The following results assume financing through labor taxes: $\hat{s}_t = d\tau_t^c = 0$.

(b) If wages are sufficiently sticky ($\zeta_w \nearrow 1$) and $\phi > 0$, increasing the tax adjustment speed ψ_τ lowers the impact multiplier. Without RoT agents, $\phi = 0$, increasing the tax adjustment speed ψ_τ increases the impact multiplier.

(c) If $\psi_\tau < 1$, the baseline model with the tax rule (6.2b) yields a lower short-run multiplier than financing stimulus through permanently higher debt according to (6.2b') if $\gamma_\pi > 1 + (\bar{R}^g - 1) \left(1 + \frac{1}{\lambda_w(1+\nu)}\right)$.

(d) Lowering the labor share $\frac{\epsilon_p - 1}{\epsilon_p}$ lowers the multiplier if the impact multiplier is positive. A sufficient condition is that wages are sufficiently sticky ($\zeta_w \nearrow 1$). If the impact multiplier is nondecreasing in the labor share, the long-run multiplier is strictly lower for lower labor shares for all $\psi_\tau < 1$.

Proof: See Appendix B.9.9, page LVIII.

Two important determinants of the effect of distortionary taxes are the speed of tax adjustment and the size of the tax base. Parts (b) and (c) of Proposition 2 characterize the effect of the tax adjustment speed. Part (b) says that without RoT agents, it is always better not to rely on deficit financing and to repay government debt immediately: This avoids the negative wealth effects coming from the response of the monetary authority to future inflation. However, with very sticky wages and RoT agents, the demand effect dominates and adjusting taxes more slowly increases the short-run multiplier. Part (c) says that the limit of slow tax adjustment in the form of simply rolling over debt increases multipliers further under mild assumptions on the monetary policy rule. Last, the negative wealth effects of distortionary taxes are more pronounced the smaller the tax base (i.e., the smaller the labor share) according to part (d). Since output in both periods falls, the long-run multi-

plier is more sensitive to the labor share than the short-run multiplier.¹⁵ These three implications of the simple model also show up in our full model.

[Figure 12 about here.]

In the full model, increasing the budget-balance speed ψ_τ leads to lower multipliers, as shown in Tables III and IV, within the range of stable parameters. This range is, however, very narrow. To allow for a comparison over a wider range, we set the degree of habit formation to $h = 0.5$, as compared with the posterior median of $h = 0.85$, so that adjusting taxes fully and immediately is consistent with a unique locally bounded equilibrium. Figure 12 shows in the left panel the effect of varying the speed of tax adjustment in the full model with adjusted habit (solid blue line).¹⁶ In line with the results in the simple model (right panel), adjusting taxes faster lowers the multiplier with RoT agents and the estimated high degree of wage stickiness. Without RoT agents, the simple model implies that the short-run multiplier is almost flat, but slightly increasing in the tax adjustment speed. This implication holds only for high-enough tax adjustment speeds in the empirical model.¹⁷

Our findings that slower tax adjustment raises the short-run multiplier are in line with Erceg and Linde (2014): They introduce distortionary taxes with gradual tax adjustment towards a target level $d\tau_t^*$ that depends on government debt. Actual taxes in their model evolve as

$$d\tau_t^l = \rho d\tau_{t-1}^l + (1 - \rho)d\tau_t^*. \quad (6.5)$$

As detailed in their web appendix (Figure A.3) and summarized in our Table VI they find that, with an eight quarter ZLB, gradual adjustment with $\rho = 0.98$ undoes most of the short-run effects of distortionary taxes. The resulting multiplier is only slightly lower than with lump-sum taxes. With

¹⁵A smaller labor share also lowers the Keynesian multiplier effect $\frac{1}{1-\phi_c} = \frac{1}{1-\phi \times \text{labor share}}$.

¹⁶See Figure D.13 in the Online Appendix for analogous results for the long-run multiplier and Figure B.1 for an illustration of a three-period model generating the non-monotonicity.

¹⁷Appendix B.9.8 explains the difference in a three-period version of the simple model because the inflationary pressure upon exit from the ZLB is no longer proportional to ψ_τ but to $\psi_\tau(1 - \psi_\tau)$ so that the cost of taxation is minimized for intermediate values of ψ_τ .

slightly longer durations of the ZLB, even gradual adjustment of taxes eliminates only about half of the effect of distortionary taxes. We similarly find that when actual taxes $d\tau_t^l$ in our full model adjust gradually towards our benchmark tax rule $d\tau_t^*$ according to (6.5), the multiplier closes about half of the gap to the multiplier with lump-sum taxes: The median short-run multiplier with distortionary taxes increases from 0.53 to 0.57 for $\rho = 0.98$ and 0.58 for $\rho = 0.995$. The results are similar for a flat 4-quarter consumption only stimulus (see Table VI).

[Table VI about here.]

Besides the tax adjustment speed, the size of the tax base matters. Figure 13 reveals that long-run multipliers are quite sensitive to the capital share. The long-run multiplier declines monotonically in the capital share, as predicted in Proposition 2. In the simple model this is explained by two channels. First, textbook economic analysis shows that taxes are less distortionary when raised from a wider base. Second, a higher capital share lowers the Keynesian multiplier effect, which is based on labor income. The estimated capital share is around 0.24 rather than 0.35, often used in the calibration literature (see Cooley and Prescott, 1995).

[Figure 13 about here.]

6.4 Role of rule-of-thumb agents

Rule-of-thumb households are important in two respects. First, a sizable portion of the population violates Ricardian equivalence: This amplifies the stimulus effects on output via a traditional Keynesian multiplier. Second, the distribution of transfers between these households and the unconstrained households has aggregate effects. It turns out that the second effect is more important than the first.

Table VII analyzes the relative importance of the population share and the distribution of transfer payments. Panel (a) of Table VII shows the change in the fiscal multipliers when we change the share of the population that is

credit-constrained. In this experiment, the transfers are equally distributed across the population (i.e., the share of the transfers to the credit-constrained population equals the share of that population). This confounds two effects, however. The first effect is the mere rise in the share of credit-constrained households, keeping their share of transfer receipts the same. This is shown in panel (b) of Table VII. The second effect comes from the share of transfers received by the RoT households. Panel (c) of Table VII therefore varies the share of transfers received by these households but keeps their share of the population constant at the benchmark value of 25 percent. While the second experiment has a rather modest impact on the short-run multiplier, the third experiment has a larger short-run impact. Both effects contribute to raising long-run multipliers considerably. For example, and for the last experiment, the median long-run fiscal multiplier changes from -0.51 to 0.29, as the fraction of targeted transfers is varied from zero to 100 percent.

[Table VII about here.]

Proposition 3 states that when the budget is balanced slowly, the simple sticky-wage model reproduces our empirical findings: First, more RoT agents in the population increase the multiplier. Traditional Keynesian multiplier logic explains this effect. Second, the transfer multiplier lies below the government spending multiplier because the cost of financing is the same, while only the fraction targeted to RoT agents translates into spending.

Proposition 3. *Consider the model in Section 6.1 with sticky wages, flexible prices, and a one period ZLB and stimulus. Assume the Taylor Principle is satisfied. Consider the case of financing through distortionary labor taxes: $\hat{s}_t^e = d\tau_t^c = 0$.*

(a) *If taxes are adjusted sufficiently slowly ($\psi_\tau < \frac{\epsilon_p - 1}{\epsilon_p}$), the impact multiplier increases strictly in the share of RoT agents ϕ .*

(b) *The multiplier on transfers is strictly increasing in the fraction of transfers RoT agents receive and weakly smaller than the government spending multiplier.*

Proof: See Appendix B.9.9, page LIX.

One may wish to conclude from this that “fiscal stimulus” in the form of transfers to constrained agents may be quite effective in increasing output. That may be so. However, the modeling of the credit-constrained agents is done here with the simple short cut of assuming that these agents do not keep savings and cannot borrow. For a more sophisticated exercise, the bounds to borrowing and savings should be endogenized, and may actually depend on the size and persistence of the government transfers.¹⁸ Furthermore, microdata can potentially be informative about the degree to which households are credit-constrained or refrain from saving. A more detailed investigation is called for, if future “fiscal stimulus” programs are to focus on this particular group.

6.5 Nominal rigidities

Our empirical findings suggest that the multiplier is increasing in the degree of nominal rigidities over the relevant range. This finding is apparently at odds with the literature: As Farhi and Werning (2012) show, the multiplier falls monotonically in the degree of nominal rigidities in the workhorse New Keynesian model with Ricardian equivalence. Cochrane (2013), however, argues that these positive effects of nominal rigidities depend crucially on equilibrium selection via assumptions on monetary policy upon exit from the ZLB. Here we focus on the monetary policy as in Farhi and Werning (2012) and still find that the multiplier can rise with the degree of price rigidity in the simple sticky wage model. The reason is the cost of adjusting distortionary taxes after exiting the ZLB.

[Figure 14 about here.]

The left panel in Figure 14 documents that the short-run multiplier is increasing in the degree of stickiness, over most of the range of stickiness.¹⁹ The

¹⁸Oh and Reis (2012) investigate the role of targeted transfers as fiscal stimulus in an incomplete markets model with borrowing constraints. However, in their model, the increased transfers last only one period and are conditioned on exogenous attributes only. Even so, their model implies an upper limit for targeted transfers thresholds to avoid transfers that “would turn the rich into poor and vice versa” (p. S61).

¹⁹Cf. Figure D.9 in the Online Appendix for the corresponding long-run multipliers and the implied inflation response.

estimated nominal rigidities are very strong, but lower than the estimates in Del Negro et al. (2013): The mean estimates are $\zeta_p = 0.81$ and $\zeta_w = 0.83$ for the Calvo parameter for prices and wages. In Figure 14, we consider values of 10% to 115% of these mean estimates, scaling both parameters proportionately. The median short-run multiplier increases from a value of 0.1, when stickiness is only 10% of the mean estimates, to slightly above 0.5 at the posterior mean, before falling slightly when increasing stickiness further.

The simple sticky wage model with a one period ZLB reproduces the main finding, as the right panel of Figure 14 illustrates for different labor supply elasticities. Proposition 4 shows that this is a generic outcome of our sticky wage model with slow taxation. In the simple model, the negative effect of more flexible wages on the impact multiplier of tax-financed government expenditure is due to more monetary tightening upon exit from the ZLB. When taxes are adjusted only slowly, i.e. mostly upon exit from the ZLB, this negative wealth effect is stronger. It depresses private consumption also in the short run, lowering the multiplier.²⁰

Proposition 4. *Consider the model in Section 6.1 with sticky wages, flexible prices, and a one period ZLB and stimulus. Assume the Taylor Principle is satisfied. Consider the case of financing through distortionary labor taxes: $\hat{s}_t = d\tau_t^c = 0$.*

If $\psi_\tau < 1$ and $\phi < \frac{\epsilon_p}{\epsilon_p - 1} \frac{1}{1 + \nu}$, increasing wage flexibility ($\zeta_w \searrow 0$) lowers the impact multiplier.

Proof: See Appendix, page LIX.

Does the role of wage stickiness change when debt is repaid more slowly than the simple tax rule considered here? We now analyze this possibility by assuming that the government never repays the debt used to finance the fiscal intervention. Instead of the previous fiscal rule the government only raises taxes enough to finance the resulting interest payments after exit from the ZLB according to equation (6.2b'). To analyze this case, it is instructive to

²⁰Slow tax adjustment means here that taxes are adjusted in the period after exit from the ZLB and debt returns to its steady state.

generalize the simple Taylor rule in (6.1) in this case by introducing a concern for output stabilization:

$$\hat{R}_t = (1 - \mathbf{1}_{ZLB,t})(\gamma_\pi \hat{\pi}_t + \gamma_y \hat{y}_t). \quad (6.6)$$

Proposition 5 summarizes the implications of the simple model with permanently higher debt: Part (a) states that when the monetary authority has no concern for output stabilization, as we assumed before for simplicity, there is no effect of stickiness on the short-run multiplier: Since the monetary authority does not permit any inflation, the degree of stickiness is irrelevant. But without a concern for output stabilization, the short-run multiplier is also the lowest: Proposition 5(b) says that the short-run multiplier is increasing in γ_y . Wage stickiness matters with positive γ_y because it determines the output-inflation tradeoff. More flexibility worsens this tradeoff. Proposition 5(c) formalizes that with a concern for output stabilization the multiplier is decreasing in the degree of price flexibility, even when debt is never repaid.

Proposition 5. *Consider the model in Section 6.1 with sticky wages, flexible prices, a one period ZLB and stimulus, and the modified Taylor rule with $\gamma_y \geq 0$. Assume the Taylor Principle is satisfied. Assume the stimulus is partially debt financed. Consider the case of financing permanently higher debt $\hat{b} = (1 - \psi)\bar{R}^g g > 0$ through distortionary labor taxes: $\hat{s}_t = d\tau_t^c = 0$.*

- (a) *The short-run multiplier is independent of wage stickiness if $\gamma_y = 0$.*
- (b) *The short-run multiplier is increasing in γ_y .*
- (c) *If $\gamma_y > 0$ and $\gamma_\pi > 1 + \gamma_y$, increasing wage flexibility ($\zeta_w \searrow 0$) lowers the impact multiplier.*

Proof: See Appendix, page LX.

7 Welfare effects

Multipliers are silent on welfare implications of the ARRA package. If the output increase is driven by a disproportionate increase in hours worked, consumers are likely to be worse off, even if the multiplier is large and positive.

While our model is designed for the positive analysis of the ARRA, we now illustrate the normative implications of taking it at face value.²¹

Given perfect foresight of the stimulus plan, we calculate the compensating variation that makes consumers indifferent between ARRA and the historic path of the economy without ARRA. To make the results interpretable, we express the compensating variation in percent of lifetime balanced growth path consumption. Let $\Gamma_i \times 100$ be the percentage of consumption without the stimulus that consumers of type $i, i \in \{RA, RoT\}$ would be willing to give up each period to implement ARRA. We provide an explicit formula in the Online Appendix for backing out Γ_i from the net present value of future utility changes. The discount rates for each consumer type are crucial here.

Two caveats complicate the welfare calculation. First, the calculation is numerically challenging because, at our estimates, the effective discount factor $\beta_{RA}\mu^{1-\sigma}$ is close to unity so that convergence is slow. Numerical error is important to address because we are relating the cost of an intervention over about 10 years to lifetime consumption so that errors of a small magnitude might be important for the results. Second, our parameter estimates are only directly applicable to unconstrained households, whereas we need to consider both types of households in the welfare analysis. If constrained households are sufficiently impatient and receive a high weight in the social welfare function, the results presented previously could be overturned if constrained agents value the initial consumption increase enough. The calibration of the discount rate for the constrained households is a challenge, however. Lawrance (1991) finds that rates of time preference vary by 7 percent on an annual basis across rich and poor households. Using data on individual choices between lump-sum and annuity payments, Warner and Pleeter (2001) find differences in annual rates of time preference of up to 30 percent, depending on various characteristics. We therefore consider two discount factors for the RoT agents by adding 7%

²¹ To the extent that government investment is chosen to maximize the present value of resources, it can be expected that exogenous deviations of government investment from the endogenous investment dynamics contribute to lower welfare.

or 30% to the annual discount factor of unconstrained agents, i.e.,

$$1/\beta_{RoT} \in \{1/\beta_{RA} + 0.07/4, 1/\beta_{RA} + 0.3/4\}$$

noting that our model is for quarterly data. We also vary β_{RoT} over a wider range.

The welfare effects are small but significantly negative for unconstrained households, according to our calculations in Table VIII. The median effect on constrained agents is -0.02 percent, independent of the length of the ZLB, with the 90 percent posterior confidence intervals ranging from -0.03 percent to -0.01 percent. The small magnitude is unsurprising given that small deviations from the optimum have small effects on the welfare of unconstrained agents. Unconstrained agents have less leisure and, for most parameter values considered, also have lower consumption, explaining the negative sign.

The effect on constrained agents is ambiguous, as lines two and three in Table VIII show. If the discount factor of the RoT agents is just 7% higher than that of the unconstrained agents, the welfare effect is negative, but it is significantly positive, if their discount factor is at least 15%–20% higher than that of unconstrained agents, as shown in Figure D.14 in the Online Appendix.

[Table VIII about here.]

8 Conclusions

We have quantified the size, uncertainty and sensitivity of fiscal multipliers in response to the ARRA. To that end, we have extended the benchmark Smets and Wouters (2007) New Keynesian model, allowing for credit-constrained households, a central bank constrained by the ZLB, government capital, and a government raising taxes with distortionary taxation. These model components, together with the ARRA stimulus composition and its slow build-up are crucial for our results. We have distinguished between short-run and long-run multipliers. For a benchmark parameterization, we find modestly

positive short-run multipliers with a posterior mean of 0.53 and modestly negative long-run multipliers centered around -0.36.

The multiplier is particularly sensitive to the type of taxes used to finance the ARRA, the fraction of transfers given to credit-constrained households, the anticipated length of the ZLB, and to the capital share. The multiplier is nonlinear in the degree of price and wage stickiness. Reasonable specifications are consistent with substantially negative multipliers within a short time frame. Furthermore, the policy intervention may lower the welfare of agents in the economy. Unconstrained agents would have a higher lifetime utility without the ARRA, and even impatient constrained agents may be better off without the intervention: The disutility of hours worked during the expansion and lower consumption in the transition to the long-run offset short-run gains from higher consumption.

References

- Aruoba, S. Borogan and Frank Schorfheide (2012). “Macroeconomic Dynamics Near the ZLB: A Tale of Two Equilibria”. University of Pennsylvania, mimeo.
- Barro, Robert J. and Charles J. Redlick (2011). “Macroeconomic Effects From Government Purchases and Taxes”. *The Quarterly Journal of Economics*, 126(1):51–102.
- Barro, Robert J. and Xavier Sala-i Martin (1992). “Public Finance in Models of Economic Growth”. *The Review of Economic Studies*, 59(4):645–661.
- Bernstein, Jared and Christina Romer (2009). “The Job Impact of the American Recovery and Reinvestment Act”. *press release, January 9, Office of the Vice President Elect*.
- Braun, R. Anton, Lena Mareen Körber, and Yuichiro Waki (2012). “Some unpleasant properties of log-linearized solutions when the nominal rate is zero”. Working Paper 2012-05, Federal Reserve Bank of Atlanta.
- Buiter, Willem (2009). “The unfortunate uselessness of most ‘state of the art’ academic monetary economics”. *www.voxeu.org, March 6, 2009*.
- Carlstrom, Charles, Timothy Fuerst, and Matthias Paustian (2013). “Policy multipliers under an interest rate peg of deterministic versus stochastic duration”. Bank of England working papers 475, Bank of England.
- CBO, Congressional Budget Office (2009). “Cost estimate for conference agreement for H.R.1.” <http://www.cbo.gov/ftpdocs/99xx/doc9989/hr1conference.pdf>.
- Christiano, Lawrence, Martin Eichenbaum, and Sergio Rebelo (2011). “When is the government spending multiplier large?” *Journal of Political Economy*, 78–121.
- Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans (2005). “Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy”. *Journal of Political Economy*, 113(1):1–45.
- Clemens, Jeffrey and Stephen Miran (2012). “Fiscal Policy Multipliers on Sub-national Government Spending”. *American Economic Journal: Economic Policy*, 4(2):46–68.

- Cochrane, John H. (2013). “The New-Keynesian Liquidity Trap”. NBER Working Papers 19476, National Bureau of Economic Research.
- Coenen, G., C. J. Erceg, C. Freedman, D. Furceri, M. Kumhof, R. Lalonde, J. Linde, D. Muir, S. Mursula, A. Mourougane, J. Roberts, W. Roeger, S. Snudden, M. Trabandt, and J. in’t Veld (2012). “Effects of Fiscal Stimulus in Structural Models”. Tech. Rep. 1.
- Cogan, John F., Tobias Cwik, John B. Taylor, and Volker Wieland (2010). “New Keynesian versus old Keynesian government spending multipliers”. *Journal of Economic Dynamics and Control*, 34(3):281 – 295.
- Conley, Timothy G. and Bill Dupor (2013). “The American Recovery and Reinvestment Act: Solely a government jobs program?” *Journal of Monetary Economics*, 60(5):535–549.
- Cooley, Thomas F. and Edward C. Prescott (1995). “Economic Growth and Business Cycles”. In Cooley, Thomas F. (ed.) “Frontiers of Business Cycle Research”, chap. 1, 1–38. Princeton University Press.
- Correia, Isabel, Emmanuel Fahri, Juan Pablo Nicolini, and Pedro Teles (2010). “Unconventional Fiscal Policy at the Zero Bound”. *draft, Banco de Portugal*.
- Davig, Troy and Eric M. Leeper (2009). “Monetary-Fiscal Policy Interactions and Fiscal Stimulus”. NBER Working Papers 15133, National Bureau of Economic Research.
- Del Negro, Marco, Marc P. Giannoni, and Frank Schorfheide (2013). “Inflation in the Great Recession and New Keynesian models”. Staff Reports 618, Federal Reserve Bank of New York.
- Dupor, William and Rong Li (2013). “The Expected Inflation Channel of Government Spending in the Postwar U.S”. Tech. rep.
- Eggertsson, Gauti B. (2010). “The Paradox of Toil”. *draft, Federal Reserve Bank of New York*.
- (2011). *What Fiscal Policy is Effective at Zero Interest Rates?*, 59–112. University of Chicago Press.
- Eichenbaum, Martin and Jonas D.M. Fisher (2007). “Estimating the frequency of price re-optimization in Calvo-style models”. *Journal of Monetary Economics*, 54(7):2032–2047.

- Erceg, Christopher and Jesper Linde (2014). “Is There A Fiscal Free Lunch In A Liquidity Trap?” *Journal of the European Economic Association*, 12(1):73–107.
- Farhi, Emmanuel and Ivan Werning (2012). “Fiscal Multipliers: Liquidity Traps and Currency Unions”. NBER Working Papers 18381, National Bureau of Economic Research.
- Fernandez-Villaverde, Jesus, Pablo A. Guerron-Quintana, and Juan Rubio-Ramirez (2011). “Supply-Side Policies and the Zero Lower Bound”. NBER Working Papers 17543, National Bureau of Economic Research.
- Galí, Jordi (2008). *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton University Press, Princeton, NJ.
- Galí, Jordi, J. David Lopez-Salido, and Javier Valles (2007). “Understanding the Effects of Government Spending on Consumption”. *Journal of the European Economic Association*, 5(1):227–270.
- Gust, Christopher, David López-Salido, and Matthew E. Smith (2013). “The Empirical Implications of the Interest-Rate Lower Bound”. Federal Reserve Board.
- Hall, Robert E. (2011). “The Long Slump”. *American Economic Review*, 101(2):431–69.
- Ilut, Cosmin and Martin Schneider (2011). “Ambiguous Business Cycles”. *draft, Duke University*.
- Juillard, Michel (1996). “Dynare: A program for the resolution and simulation of dynamic models with forward variables through the use of a relaxation algorithm”. *CEPREMAP, Couverture Orange 9602*.
- Krugman, Paul (2009). “How Did Economists Get It So Wrong?” *New York Times*, September 2, 2009.
- Lawrance, Emily C (1991). “Poverty and the Rate of Time Preference: Evidence from Panel Data”. *Journal of Political Economy*, 99(1):54–77.
- Leeper, Eric M., Michael Plante, and Nora Traum (2010). “Dynamics of fiscal financing in the United States”. *Journal of Econometrics*, 156(2):304–321.
- Leeper, Eric M., Nora Traum, and Todd B. Walker (2011). “Clearing up the Fiscal Multiplier Morass: A Bayesian Perspective”. *Draft, University of Indiana*.

- Leeper, Eric M., Todd B. Walker, and Shu-Chun Susan Yang (2009). “Government Investment and Fiscal Stimulus in the Short and Long Runs”. NBER Working Papers 15153, National Bureau of Economic Research.
- Mertens, Karel and Morten O. Ravn (2013). “Fiscal Policy in an Expectations Driven Liquidity Trap”. draft, Cornell University.
- Oh, Hyunseung and Ricardo Reis (2012). “Targeted transfers and the fiscal response to the great recession”. *Journal of Monetary Economics*, 59, Supplement:S50 – S64.
- Ramey, Valerie (2011). “Government Spending and Private Activity”. *draft*.
- Shoag, Daniel (2010). “The Impact of Government Spending Shocks: Evidence on the Multiplier from State Pension Plan Returns”. *draft, Harvard University*.
- Smets, Frank and Raf Wouters (2007). “Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach”. *The American Economic Review*, 97(3):586–606.
- Trabandt, Mathias and Harald Uhlig (2011). “The Laffer Curve revisited.” *Journal of Monetary Economics*, 58(4):305–327.
- Uhlig, Harald (2010a). “Economics and Reality”. Working Paper 16416, National Bureau of Economic Research.
- (2010b). “Some Fiscal Calculus”. *American Economic Review, Papers and Proceedings*, 100:30–34.
- Warner, John T. and Saul Pleeter (2001). “The Personal Discount Rate: Evidence from Military Downsizing Programs”. *American Economic Review*, 91(1):33–53.
- Woodford, Michael (2011). “Simple Analytics of the Government Expenditure Multiplier”. *American Economic Journal: Macroeconomics*, 3(1):1–35.

9 Appendix

9.1 Data

The different series come from the NIPA tables, the FRED 2 database and the Bureau of Labor Statistics (BLS) database. Federal debt data is taken from database of the Federal Reserve Bank of Dallas. Nominal series for wages, consumption, government expenditures, and private investment are deflated with the general GDP deflator.

Generally we follow Smets and Wouters (2007) when creating our dataset with the following exceptions: we use civilian noninstitutionalized population throughout, although the series is not seasonally adjusted before 1976. The base year for real GDP is 2005 instead of 1996. We include durables consumption in investment instead of consumption. Using the same definition, all series but real wages exhibit a correlation of almost 100 percent across the two datasets. For the change in real wages, the correlation is 0.9. Including durables consumption in investment causes the correlation for the investment series to drop to 0.70 and for consumption to drop to 0.78.

Since no data for the Corporate-Treasury bond yield spread is available before 1953:1 we set it to zero for the missing periods. We use the secondary market rate for three-months T-bills before 1954:3, as the FFR is not available.

The categorization of the various stimulus components is shown in detail in Tables A.1, A.2, and A.3 in the Online Appendix. Our source is the CBO (2009), specifically “Table 2: Estimated cost of the conference agreement for H.R. 1, the American Recovery and Reinvestment Act of 2009, as posted on the website of the House Committee on Rules.” The annual time path for these expenditures is taken from CBO (2009) and the annual sum for each component is split across quarters in proportion to the aggregate series in Cogan et al. (2010).

9.2 Estimation

Tables IX and X contain the results from estimating our model, using Dynare and a Bayesian prior.

[Table IX about here.]

[Table X about here.]

Tables

Table I: *Calibrated parameters*

	SW (1966:1–2004:4)	This paper (1948:2–2008:4)
Depreciation δ	0.025	0.0145
Wage markup λ_w	0.5	0.5
Kimball curvature goods mkt. $\hat{\eta}_p$	10	10
Kimball curvature labor mkt. $\hat{\eta}_w$	10	10
Capital tax τ^k	n/a	0.36
Consumption tax τ^c	n/a	0.05
Labor tax τ^n	n/a	0.28
Share credit constrained ϕ	n/a	0.25
Gov. spending, net exports-GDP $\frac{\bar{g}}{\bar{y}}$	0.18	0.153
Gov. investment-GDP $\frac{\bar{x}^g}{\bar{y}}$	n/a	0.04
Debt-GDP $\frac{\bar{b}}{\bar{y}}$	n/a	4×0.63

Table II: *Historical decomposition of recent recession and overall variance decomposition for output. All numbers are at the Bayesian posterior mean.*

Shock	2008:4 vs. 2007:4		Total Sample
	Historical decomposition total	percent	Variance decomposition percent
Gov. bond	-3.76	81.69	5.11
Priv. bond	-1.41	30.63	1.38
Technology	0.89	-19.44	19.23
Price markup	-0.74	16.14	6.68
Gov. spending	0.60	-12.95	3.49
Priv. inv.	-0.30	6.57	14.04
Labor tax	-0.26	5.60	19.63
Monetary pol.	0.22	-4.69	17.37
Wage markup	0.14	-3.11	8.38
Gov. inv.	0.03	-0.65	4.59
Initial values	-0.01	0.22	n/a
Sum	-4.60	100.00	100.00

Table III: Sensitivity of long-run fiscal multipliers to changing assumptions

(a) Complete ARRA composition and timing

Scenario	5 percent	16.5 percent	median	83.5 percent	95 percent
Benchmark	-0.63	-0.53	-0.36	-0.18	-0.01
Consumption tax	0.22	0.32	0.48	0.65	0.78
Lump-sum tax	0.35	0.45	0.61	0.79	0.94
0 quarters ZLB	-0.95	-0.87	-0.74	-0.62	-0.51
12 quarters ZLB	-0.43	-0.30	-0.05	0.22	0.46
20 quarters ZLB	-0.28	-0.11	0.33	1.17	2.21
Endogenous ZLB, Taylor rule	-0.77	-0.67	-0.52	-0.33	-0.11
15 p.c. RoT population share	-0.77	-0.67	-0.52	-0.35	-0.18
35 p.c. RoT population share	-0.47	-0.36	-0.17	0.02	0.22
0 p.c. RoT transfer share	-0.76	-0.68	-0.56	-0.45	-0.35
100 p.c. RoT transfer share	-0.39	-0.16	0.24	0.69	1.12
Stickiness scale=0.10	-1.07	-0.99	-0.89	-0.79	-0.72
Stickiness scale=1.15	-0.67	-0.56	-0.38	-0.19	0.03
Capital share $\alpha = 0.35$	-1.00	-0.86	-0.65	-0.42	-0.20
Gradual labor tax	-0.42	-0.31	-0.11	0.10	0.25
Tax adjustment speed $\psi_\tau = 0.025$	-0.60	-0.49	-0.32	-0.15	0.02
Tax adjustment speed $\psi_\tau = 0.050$	-0.66	-0.55	-0.39	-0.22	-0.06

(b) Alternative stimulus composition and timing

Scenario	5 percent	16.5 percent	median	83.5 percent	95 percent
Labor tax, 4 qtr cons stimulus	-1.55	-1.22	-0.72	-0.20	0.14
Lump-sum tax, 4 qtr cons stimulus	1.50	1.64	1.91	2.21	2.49
Labor tax, ARRA consumption	-0.59	-0.45	-0.19	0.09	0.32
Labor tax, ARRA investment	0.15	0.21	0.28	0.37	0.45
Labor tax, ARRA transfers	-0.92	-0.80	-0.62	-0.43	-0.28

Table IV: Sensitivity of short-run fiscal multipliers to changing assumptions

(a) Complete ARRA composition and timing					
Scenario	5 percent	16.5 percent	median	83.5 percent	95 percent
Benchmark	0.46	0.49	0.53	0.57	0.60
Consumption tax	0.57	0.59	0.63	0.68	0.71
Lump-sum tax	0.55	0.58	0.62	0.67	0.71
0 quarters ZLB	0.16	0.19	0.23	0.27	0.30
12 quarters ZLB	0.58	0.61	0.67	0.74	0.80
20 quarters ZLB	0.64	0.69	0.80	1.01	1.29
Endogenous ZLB, Taylor rule	0.32	0.36	0.43	0.50	0.58
15 p.c. RoT population share	0.40	0.42	0.46	0.50	0.53
35 p.c. RoT population share	0.53	0.56	0.61	0.65	0.70
0 p.c. RoT transfer share	0.26	0.27	0.30	0.32	0.34
100 p.c. RoT transfer share	1.05	1.11	1.21	1.32	1.40
Stickiness scale=0.10	0.08	0.10	0.13	0.17	0.19
Stickiness scale=1.15	0.45	0.47	0.50	0.53	0.56
Capital share $\alpha = 0.35$	0.45	0.48	0.53	0.59	0.63
Gradual labor tax	0.50	0.53	0.57	0.62	0.66
Tax adjustment speed $\psi_\tau = 0.025$	0.49	0.51	0.55	0.59	0.62
Tax adjustment speed $\psi_\tau = 0.050$	0.44	0.47	0.50	0.54	0.57
(b) Alternative stimulus composition and timing					
Labor tax, 4 qtr cons stimulus	1.26	1.29	1.33	1.37	1.40
Lump-sum tax, 4 qtr cons stimulus	1.39	1.42	1.46	1.50	1.53
Labor tax, ARRA consumption	1.03	1.08	1.13	1.20	1.24
Labor tax, ARRA investment	0.15	0.22	0.33	0.44	0.52
Labor tax, ARRA transfers	0.24	0.25	0.29	0.32	0.35

Table V: Short-run fiscal multipliers with 8 quarter ZLB: Comparison to the literature

Specification	ARRA composition	ARRA timing	Dist. taxes	RoT agents	Multiplier		
					median	5 pc	95 pc
Christiano et al. (2011)	x	flat, 8 qtrs.	x	x	1.2		
Our model	x	flat, 8 qtrs.	x	x	1.13	1.08	1.19
Coenen et al. (2012)	x	flat, 8 qtrs.	x	y	1.55		
Our model	x	flat, 8 qtrs.	x	y	1.44	1.36	1.54
Our model	y	flat, 8 qtrs.	x	y	0.74	0.67	0.83
Our model	y	y	x	y	0.62	0.55	0.71
Our model	y	flat, 8 qtrs.	y	y	0.62	0.56	0.70
Our model	y	y	y	y	0.53	0.46	0.60

Table VI: Tax smoothing increases short-run fiscal multipliers : Comparison to Erceg and Linde (2014)

Specification	ZLB duration	ARRA composition	ARRA timing	Dist. taxes	Tax smoothing	Multiplier		
						median	5 pc	95 pc
Erceg and Linde (2014)	10 qtrs.	x	AR(1)	x	n/a	≈ 4.0		
Erceg and Linde (2014)	10 qtrs.	x	AR(1)	y	$\rho = 0.98$	≈ 3.4		
Erceg and Linde (2014)	10 qtrs.	x	AR(1)	y	x	≈ 2.9		
Erceg and Linde (2014)	8 qtrs.	x	AR(1)	x	n/a	≈ 2.03		
Erceg and Linde (2014)	8 qtrs.	x	AR(1)	y	$\rho = 0.98$	≈ 2.0		
Erceg and Linde (2014)	8 qtrs.	x	AR(1)	y	x	≈ 1.8		
Our model	8 qtrs.	x	4 qtrs.	x	n/a	1.46	1.39	1.53
Our model	8 qtrs.	x	4 qtrs.	y	$\rho = 0.995$	1.41	1.34	1.48
Our model	8 qtrs.	x	4 qtrs.	y	$\rho = 0.98$	1.38	1.32	1.45
Our model	8 qtrs.	x	4 qtrs.	y	x	1.33	1.26	1.40
Our model	8 qtrs.	y	y	x	n/a	0.62	0.55	0.71
Our model	8 qtrs.	y	y	y	$\rho = 0.995$	0.58	0.51	0.68
Our model	8 qtrs.	y	y	y	$\rho = 0.98$	0.57	0.50	0.66
Our model	8 qtrs.	y	y	y	x	0.53	0.46	0.60

Results for Erceg and Linde (2014) are taken from their Figure A.3 in the web appendix. Erceg and Linde (2014) specify that actual labor taxes evolve according to $d\tau_t^l = \rho d\tau_{t-1}^l + (1 - \rho)d\tau_t^*$, i.e. equation (6.5), where $d\tau_t^*$ is given by a tax rule relating $d\tau_t^*$ to government debt. When computing results for our model, we use the full model and augment it with equation (6.5) in the “tax smoothing” scenarios. We take $d\tau_t^*$ to be the tax rate implied by our tax rule in Section 3.3.

Table VII: *Sensitivity of multipliers to the credit-constrained fraction of the population and their transfer share. Panel (a): All households receive the same amount of transfers (i.e., fraction of constrained households and total transfers rise together). Panel (b), only the fraction of constrained household rises, isolating the traditional Keynesian multiplier effect. Panel (c): only the share of transfers going to constrained households rises, highlighting the role of targeted transfers.*

(a) Constant transfers/household			
RoT transfer share = RoT fraction =	0.10	0.25	0.40
One-year multiplier	0.33	0.54	0.82
Long-run multiplier	-0.62	-0.31	0.12
(b) Varying RoT fraction, fixed absolute RoT transfers:			
RoT transfer share = 0.25, RoT fraction =	0.10	0.25	0.40
One year multiplier	0.45	0.54	0.66
Long-run multiplier	-0.53	-0.31	-0.03
(c) Fixed RoT fraction, varying absolute RoT transfers			
RoT fraction = 0.25, RoT transfer share =	0	0.25	1.00
One year multiplier	0.31	0.54	1.23
Long-run multiplier	-0.51	-0.31	0.29

Table VIII: *Welfare effects ($\Gamma \times 100$) of stimulus: Lifetime-consumption equivalent of compensating variation. Posterior median (90% confidence interval).*

Scenario	8 quarters ZLB	0 quarters ZLB	12 quarters ZLB
Unconstrained agents	-0.02(-0.03,-0.01)	-0.02(-0.03,-0.01)	-0.02(-0.03,-0.01)
RoT, 7% higher annual DF	-0.07(-0.13,-0.00)	-0.14(-0.22,-0.08)	-0.08(-0.16,0.03)
RoT, 30% higher annual DF	0.63(0.39,0.95)	0.45(0.22,0.65)	0.58(0.24,0.97)

Table IX: *Estimation, part 1. The calibrated government investment-to-GDP ratio as well as the estimated growth trend μ implies a government share in production of $\zeta = 2.30$ percent.*

	Prior	Prior mean (s.d.)	SW model 66:1-08:4	Our model 49:2-08:4
Adj. cost $S''(\mu)$	norm	4.000 (1.500)	5.93 (1.1)	4.51 (0.78)
Risk aversion σ	norm	1.500 (0.375)	1.42 (0.11)	1.17 (0.08)
Habit h	beta	0.700 (0.100)	0.7 (0.04)	0.85 (0.02)
Calvo wage ζ_w	beta	0.500 (0.100)	0.77 (0.05)	0.83 (0.03)
Inv. labor sup. ela. ν	norm	2.000 (0.750)	1.96 (0.54)	2.16 (0.51)
Calvo prices ζ_p	beta	0.500 (0.100)	0.69 (0.05)	0.81 (0.03)
Wage indexation ι_w	beta	0.500 (0.150)	0.62 (0.1)	0.41 (0.08)
Price indexation ι_p	beta	0.500 (0.150)	0.26 (0.08)	0.28 (0.07)
Capacity util.	beta	0.500 (0.150)	0.59 (0.1)	0.43 (0.07)
$1 + \frac{\text{Fix. cost}}{Y} = 1 + \lambda_p$	norm	1.250 (0.125)	1.64 (0.08)	1.94 (0.05)
Taylor rule infl. ψ_1	norm	1.500 (0.250)	2 (0.17)	1.63 (0.18)
same, smoothing ρ_R	beta	0.750 (0.100)	0.82 (0.02)	0.92 (0.02)
same, LR gap ψ_2	norm	0.125 (0.050)	0.09 (0.02)	0.13 (0.03)
same, SR gap ψ_3	norm	0.125 (0.050)	0.24 (0.03)	0.2 (0.02)
Mean inflation (data)	gamm	0.625 (0.100)	0.76 (0.09)	0.58 (0.08)
100×time pref.	gamm	0.250 (0.100)	0.16 (0.05)	0.12 (0.04)
Mean hours (data)	norm	0.000 (2.000)	1.07 (0.95)	0.04 (0.69)
Trend $(\mu - 1) * 100$	norm	0.400 (0.100)	0.43 (0.02)	0.48 (0.01)
Capital share α	norm	0.300 (0.050)	0.19 (0.02)	0.24 (0.01)
Gov. adj. cost $S_g''(\mu)$	norm	0.000 (0.500)	n/a	7.11 (1.09)
Budget bal speed $\frac{\psi_\tau - 0.025}{0.175}$	beta	0.25 (0.1637)	n/a	0.05 (0.04)
Mean gov. debt	norm	0.000 (0.500)	n/a	-0.16 (0.51)
Mean bond spread	gamm	0.500 (0.100)	n/a	0.47 (0.04)

Table X: *Estimation, part 2*

	Prior	Prior mean (s.d.)	SW model 66:1-08:4	Our model 49:2-08:4
s.d. tech.	inv	0.100 (2.000)	0.46 (0.03)	0.47 (0.02)
AR(1) tech.	beta	0.500 (0.200)	0.95 (0.01)	0.95 (0.01)
s.d. bond	inv	0.100 (2.000)	0.24 (0.03)	0.95 (0.04)
AR(1) bond ρ_q	beta	0.500 (0.200)	0.27 (0.1)	0.67 (0.03)
s.d. gov't	inv	0.100 (2.000)	0.54 (0.03)	0.36 (0.02)
AR(1) gov't	beta	0.500 (0.200)	0.98 (0.01)	0.98 (0.01)
Cov(gov't, tech.)	norm	0.500 (0.250)	0.53 (0.09)	0.3 (0.04)
s.d. inv. price	inv	0.100 (2.000)	0.43 (0.04)	1.25 (0.1)
AR(1) inv. price	beta	0.500 (0.200)	0.73 (0.06)	0.56 (0.06)
s.d. mon. pol.	inv	0.100 (2.000)	0.24 (0.02)	0.22 (0.01)
AR(1) mon. pol.	beta	0.500 (0.200)	0.16 (0.07)	0.22 (0.05)
s.d. goods m-up	inv	0.100 (2.000)	0.14 (0.01)	0.32 (0.02)
AR(1) goods m-up	beta	0.500 (0.200)	0.89 (0.04)	0.91 (0.05)
MA(1) goods m-up	beta	0.500 (0.200)	0.73 (0.08)	0.96 (0.02)
s.d. wage m-up	inv	0.100 (2.000)	0.26 (0.02)	0.23 (0.02)
AR(1) wage m-up	beta	0.500 (0.200)	0.97 (0.01)	0.97 (0.01)
MA(1) wage m-up	beta	0.500 (0.200)	0.91 (0.03)	0.92 (0.02)
s.d. Tax shock	inv	0.100 (2.000)	n/a	1.44 (0.08)
AR(1) tax shock	beta	0.500 (0.200)	n/a	0.98 (0.01)
s.d. gov. inv. price	inv	0.100 (2.000)	n/a	0.79 (0.08)
AR(1) gov. inv. price	beta	0.500 (0.200)	n/a	0.97 (0.01)
s.d. bond spread	inv	0.100 (2.000)	n/a	0.08 (0)
AR(1) bond spread	beta	0.500 (0.200)	n/a	0.91 (0.02)

Figures

Figure 1: *Timing and composition of fiscal stimulus: Compared to CCTW (i.e. Cogan et al., 2010), our stimulus encompasses transfers and distinguishes government consumption and transfers.*

Figure 2: *Comparing our extended sample to the original Smets-Wouters data set. Note the additional variation in government spending in the larger sample.*

Figure 3: *Historical shock decomposition of output after the start of the recession in 2007:4 at the posterior median. The bond premia shocks are the main driver of the recession.*

Figure 4: *Benchmark short-run impact of ARRA: Posterior distribution. ARRA increases output, hours worked, aggregate consumption and government debt in the short-run. Inflation moves little.*

Figure 5: *Benchmark short-run and long-run impact of ARRA: Posterior distribution. Short-run output gains through ARRA are followed by persistent declines in output as taxes adjust to stabilize government debt.*

Figure 6: *Short-run and long-run fiscal multipliers in the benchmark parameterization: Short-run multipliers are positive, but significantly smaller than one. In the long-run, multipliers turn negative.*

Complete stimulus, different scenarios Benchmark scenarios, stimulus components separate

Figure 7: *Comparison of long-run multipliers: posterior medians. Multipliers are sensitive to the duration of the ZLB and whether transfers are targeted (left panel). The overall multiplier aggregates the widely different multipliers of the different ARRA components (right panel).*

Government investment response
to ARRA government consumption

Exogenous ARRA government investment

Figure 8: *Endogenous and exogenous government investment: The 12 quarter non-negativity constraint on government investment is binding.*

Note: Priors and posterior multipliers correspond to six different models (from left to right): (1) Baseline point estimates: $\psi_\tau = 0.0375$, $\phi = 0.25$, free fixed cost Φ . (2) Slower tax adjustment: $\psi_\tau = 0.025$, $\phi = 0.25$, free fixed cost Φ . (3) Baseline point estimates: $\psi_\tau = 0.0375$, $\phi = 0.25$, $\Phi = 1.94$. (4) Slower tax adjustment: $\psi_\tau = 0.025$, $\phi = 0.25$, $\Phi = 1.94$. (5) Large fraction of RoT agents: $\psi_\tau = 0.0375$, $\phi = 0.40$, $\Phi = 1.94$. (6) Slower tax adjustment and large fraction of RoT agents: $\psi_\tau = 0.025$, $\phi = 0.40$, $\Phi = 1.94$. All other parameters are re-estimated. Starting point of the simulations is the steady state.

Figure 9: *Contrasting wide prior and tight posterior distributions of short-run ARRA multipliers with 8 quarter ZLB for different model specifications*

Figure 10: *Sensitivity of multipliers to the deterministic ZLB duration*

Figure 11: *Fiscal multipliers. Comparing distortionary labor taxes (benchmark) to consumption and lump-sum taxation*

Note: The full model results set the habit parameter to $h = 0.5$ and otherwise uses the posterior mean for the simulation.

Figure 12: Short-run multipliers as a function of tax adjustment speed and rule-of-thumb consumers: Short-run multipliers fall in both the full and the simple model with 25% RoT consumers with the tax adjustment speed ψ_τ .

Figure 13: *Short-run and long-run fiscal multipliers as a function of the capital share: Long-run multipliers decrease with the capital share as the base for labor-taxes falls.*

Note: The full model uses the posterior mean for the simulation except for the habit parameter set to $h = 0.5$.

Figure 14: Short-run multipliers increase with the degree of nominal rigidity for most of the parameter range in the full model. The simple model matches this when taxes are adjusted slowly.