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Abstract

Tax cuts can deepen a recession if the short-term nominal interest rate is zero, according to a standard New Keynesian business cycle model. An example of a contractionary tax cut is a reduction in taxes on wages. This tax cut deepens a recession because it increases deflationary pressures. Another example is a cut in capital taxes. This tax cut deepens a recession because it encourages people to save instead of spend at a time when more spending is needed. Fiscal policies aimed directly at stimulating aggregate demand work better. These policies include 1) a temporary increase in government spending; and 2) tax cuts aimed directly at stimulating aggregate demand rather than aggregate supply, such as an investment tax credit or a cut in sales taxes. The results are specific to an environment in which the interest rate is close to zero, as observed in large parts of the world today.

Key words: tax and spending multipliers, zero interest rates, deflation

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Table 1

	Labor Tax Multiplier	**Government Spending Multiplier**
Positive interest rate	0.096	0.32
Zero interest rate	-0.81	2.27

1 Introduction

The economic crisis of 2008 started one of the most heated debates about U.S. fiscal policy in the past half a century. With the federal funds rate close to zero – and output, inflation, and employment at the edge of a collapse – U.S. based economists argued over alternatives to interest rate cuts to spur a recovery. Meanwhile, several other central banks slashed interest rates close to zero, including the European Central Bank, the Bank of Japan, the Bank of Canada, the Bank of England, the Riksbank of Sweden, and the Swiss National Bank, igniting similar debates in all corners of the world. Some argued for tax cuts, mainly a reduction in taxes on labor income (see, e.g., Hall and Woodward (2008), Bils and Klenow (2008), and Mankiw (2008)) or tax cuts on capital (see, e.g., Feldstein (2009) and Barro (2009)). Others emphasized an increase in government spending (see, e.g., Krugman (2009) and De Long (2008)). Yet another group of economists argued that the best response would be to reduce the government, i.e., reduce *both* taxes *and* spending.[2] Even if there was no professional consensus about the correct fiscal policy, the recovery bill passed by Congress in 2009 marks the largest fiscal expansion in U.S. economic history since the New Deal, with projected deficits (as a fraction of GDP) in double digits. Many governments followed the U.S. example. Much of this debate was, explicitly or implicitly, within the context of old-fashioned Keynesian models or the frictionless neoclassical growth model.

This paper takes a standard New Keynesian dynamic stochastic general equilibrium (DSGE) model, which by now is widely used in the academic literature and utilized in policy institutions, and asks a basic question: What is the effect of tax cuts and government spending under the economic circumstances that characterized the crisis of 2008? A key assumption is that the model is subject to shocks so that the short-term nominal interest rate is zero. This means that, in the absence of policy interventions, the economy experiences excess deflation and an output contraction. The analysis thus builds on a large recent literature on policy at the zero bound on the short-term nominal interest rates, which is briefly surveyed at the end of the introduction. The results are perhaps somewhat surprising in the light of recent public discussion. Cutting taxes on labor or capital is *contractionary* under the special circumstances the U.S. is experiencing today. Meanwhile, the effect of temporarily increasing government spending is large, much larger than under normal circumstances. Similarly, some other forms of tax cuts, such as a reduction in sales taxes and investment tax credits, as suggested for example by Feldstein (2002) in the context of Japan's "Great Recession," are extremely effective.[3]

[2] This group consisted of 200 leading economists, including several Nobel Prize winners, who signed a letter prepared by the Cato Institute.

[3] For an early proposal for temporary sales tax cuts as an effective stabilization tool, see for example Modigliani

The contractionary effects of labor and capital tax cuts are special to the peculiar environment created by zero interest rates. This point is illustrated by a numerical example in Table 1. It shows the "multipliers" of cuts in labor taxes and of increasing government spending; several other multipliers are also discussed in the paper. The multipliers summarize by how much output decreases/increases if the government cuts tax rates by 1 percent or increases government spending by 1 percent (as a fraction of GDP). At positive interest rates, a labor tax cut is expansionary, as the literature has emphasized in the past. But at zero interest rates, it flips signs and tax cuts become contractionary. Meanwhile, the multiplier of government spending not only stays positive at zero interest rates, but becomes almost eight times larger. This illustrates that empirical work on the effect of fiscal policy based on data from the post-WWII period, such as the much cited and important work of Romer and Romer (2008), may not be directly applicable for assessing the effect of fiscal policy on output today. Interest rates are always positive in their sample, as in most other empirical research on this topic. To infer the effects of fiscal policy at zero interest rates, then, we can rely on experience only to a limited extent . Reasonably grounded theory may be a better benchmark with all the obvious weaknesses such inference entails, since the inference will never be any more reliable than the model assumed.

The starting point of this paper is the negative effect of labor income tax cuts, i.e., a cut in the tax on wages. These tax cuts cause deflationary pressures in the model by reducing marginal costs of firms, thereby increasing the real interest rate. The Federal Reserve can't accommodate this by cutting the federal funds rate, since it is already close to zero. Higher real interest rates are contractionary. I use labor tax cuts as a starting point, not only because of their prominence in the policy discussion but to highlight a general principle for policy in this class of models. *The principal goal of policy at zero interest rates should not be to increase aggregate supply by manipulating aggregate supply incentives. Instead, the goal of policy should be to increase aggregate demand – the overall level of spending in the economy.* This diagnosis is fundamental for a successful economic stimulus once interest rates hit zero. At zero interest rates, output is demand-determined. Accordingly, aggregate supply is mostly relevant in the model because it pins down expectations about future inflation. The result derived here is that policies aimed at increasing aggregate supply are counterproductive because they create deflationary expectations at zero interest rates. At a loose and intuitive level, therefore, policy should not be aimed at increasing the supply of goods when the problem is that there are not enough buyers.

Once the general principle is established, it is straightforward to consider a host of other fiscal policy instruments, whose effect at first blush may seem puzzling Consider first the idea of cutting taxes on capital, another popular policy proposal in response to the crisis of 2008. A permanent reduction in capital taxes increases investment and the capital stock under normal circumstances, which increases the production capacities of the economy. More shovels and tractors, for example, mean that people can dig more and bigger holes, which increases steady-state output. But at zero interest rate, the problem is not that the production capacity of the economy is inadequate.

and Steindel (1977).

Instead, the problem is insufficient aggregate spending. Cutting capital taxes gives people the incentive to save instead of spend, when precisely the opposite is needed. A cut in capital taxes will reduce output because it reduces consumption spending. One might think that the increase in people's incentive to save would in turn increase aggregate savings and investment. But everyone starts saving more, which leads to lower demand, which in turns leads to lower income for households, thus reducing their *ability* to save. Paradoxically, a consequence of cutting capital taxes is therefore a collapse in *aggregate saving* in general equilibrium because everyone tries to save more! While perhaps somewhat bewildering to many modern readers, others with longer memories may recognize here the classic Keynesian *paradox of thrift* (see, e.g., Christiano (2004))[4].

From the same general principle – that the problem of insufficient demand leads to below-capacity production – it is easy to point out some effective tax cuts and spending programs, and the list of examples provided in the paper is surely not exhaustive. Temporarily cutting sales taxes and implementing an investment tax credit are both examples of effective fiscal policy. These tax cuts are helpful not because of their effect on aggregate supply, but because they directly stimulate aggregate spending. Similarly, a temporary increase in government spending is effective because it directly increases overall spending in the economy. For government spending to be effective in increasing demand, however, it has to be directed at goods that are imperfect substitutes with private consumption (such as infrastructure or military spending). Otherwise, government spending will be offset by cuts in private spending, leaving aggregate spending unchanged.

A natural proposal for a stimulus plan, at least in the context of the model, is therefore a combination of temporary government spending increases, temporary investment tax credits, and a temporary elimination of sales taxes, all of which can be financed by a temporary increase in labor and/or capital taxes. There may, however, be important reasons outside the model that suggest that an increase in labor and capital taxes may be unwise and/or impractical. For these reasons I am not ready to suggest, based on this analysis alone, that raising capital and labor taxes is a good idea at zero interest rates. Indeed, my conjecture is that a reasonable case can be made for a temporary budget deficit to finance a stimulus plan as further discussed in the paper and the footnote.[5]

[4] The connection to the paradox of thrift was first pointed out to me by Larry Christiano in an insightful dicussion of Eggertsson and Woodford (2003). See Christiano (2004). Krugman (1998) also draws a comparison to the paradox of thrift in a similar context.

[5] The contractionary labor tax cuts studied, although entirely standard in the literature, are very special in many respects. They correspond to variations in linear tax rates on labor income, while some tax cuts on labor income in practice resemble more lump-sum transfers to workers and may even, in some cases, imply an effective *increase* in marginal taxes (Cochrane (2008)). Similarly, this form of taxes does not take into account the "direct" spending effect tax cuts have in some old-fashioned Keynesian models and as modeled more recently in a New Keynesian model by Gali, Lopez–Salido, and Valles (2007). A similar comment applies to taxes on capital. There could be a "direct" negative demand effect of increasing this tax through households' budget constraints. Another problem is that an increase in taxes on capital would lead to a decline in stock prices. An important channel not being modeled is that a reduction in equity prices can have a negative effect on the ability of firms to borrow, through collateral constraints as in Kiyotaki and Moore (1995), and thus contract investment spending. This channel is not included in the model and is one of the main mechanisms emphasized by Feldstein (2009) in favor of reducing taxes

The first paper to study the effect of government spending at zero interest rate in a New Keynesian DSGE model is Eggertsson (2001). That paper characterize the optimal policy under commitment and discretion, where the government has as policy instruments the short-term nominal interest rate and real government spending and assumes taxes are lump sum. Relative to that paper, this paper studies much more general menu of fiscal instruments, such as the effect various distortinary taxes, and gives more attention to the quantitative effect of fiscal policy. Moreover, the current paper does not take a direct stance on the optimality of fiscal policy but instead focuses on "policy multipliers", i.e. the effect of policy at the margin. This allows me to obtain clean closed form solutions and illuminate the general forces at work. This paper also builds upon a large literature on optimal monetary policy at the zero bound, such as Summers (1991), Fuhrer and Madigan (1997), Krugman (1998), Reifschneider and Williams (2000), Svensson (2001, 2003), Eggertsson and Woodford (2003 and 2004), Christiano (2004), Wolman (2005), Eggertsson (2006a), Adam and Billi (2006), and Jung et al. (2005).[6] The analysis of the variations in labor taxes builds on Eggertsson and Woodford (2004), who study value added taxes (VAT) that show up in a similar manner. A key difference is that while they focus mostly on commitment equilibrium (in which fiscal policy plays a small role because optimal monetary commitment does away with most of the problems). The assumption here is that the central bank is unable to commit to future inflation, an extreme assumption, but an useful benchmark. This assumption can also be defended because the optimal monetary policy suffers from a commitment problem, while fiscal policy does not to the same extent, as first illustrated in Eggertsson (2001).[7] The contractionary effect of cutting payroll taxes is closely related to Eggertsson (2008b), who studies the expansionary effect of the National Industrial Recovery Act (NIRA) during the Great Depression. In reduced form, the NIRA is equivalent to an increase in labor taxes in this model. The analysis of real government spending also builds on Eggertsson (2004, 2006b) and Christiano (2004), who find that increasing real government spending is very effective at zero interest rates if the monetary authority cannot commit to future inflation and Eggertsson (2008a), who argues based on those insights that the increase in real government spending during the Great Depression contributed more to the recovery than is often suggested.[8]. Christiano, Eichenbaum and Rebelo (2009) calculate the size

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on capital.

[6] This list is not nearly complete. See Svensson (2003) for an excellent survey of this work. All these papers treat the problem of the zero bound as a consequence of real shocks that make the interest rate bound binding. Another branch of the literature has studied the conseqence of binding zero bound in the context of self-fulfilling expectations. See, e.g., Benhabib, Schmitt-Grohe, and Uribe (2002), who considered fiscal rules that eliminate those equilibria.

[7] Committing to future inflation may not be so trivial in practice. As shown by Eggertsson (2001,2006a), the central bank has an incentive to promise future inflation and then renege on this promise; this is the deflation bias of discretionary policy. In any event, optimal monetary policy is relatively well known in the literature, and it is of most interest in order to understand the properties of fiscal policy in the "worst case" scenario if monetary authorities are unable and/or unwilling to inflate.

[8] Other papers that studied the importance of real government spending and found a substantial fiscal policy multiplier effect at zero interest rate include Williams (2006). That paper assumes that expectations are formed according to learning, which provides a large role for fiscal policy.

of the multiplier of real government spending in a much more sophisticated empirically estimated model than previous studies, taking the zero bound explicitly into account, and find similar quantitative conclusions as reported here, see Denes and Eggertsson (2009) for further discussion (that paper describes the estimation strategy I follow in this paper and compares it to other recent work in the field). Cogan, Cwik, Taylor, and Wieland (2009) study the effect on increasing government spending in a DSGE model which is very similar to the one used here and report small multipliers. The main reason for the different finding appears to be that they assume that the increase in spending is *permantent*, while in this paper I assume that the fiscal spending is a *temporary* stimulus in response to temporary contractionary shocks. This is explained in more detail in Eggertsson (2009).

2 A Microfounded Model

This section summarizes a standard New Keynesian DSGE model.[9] (Impatient readers can skip directly to the next section.) At its core, this is a standard stochastic growth model (real business cycle model) but with two added frictions: a monopolistic competition among firms, and frictions in the firms' price setting through fixed nominal contracts that have a stochastic duration as in Calvo (1983). Relative to standard treatments, this model has a more detailed description of taxes and government spending. This section summarizes a simplified version of the model that will serve as the baseline illustration. The baseline model abstracts from capital, but Section 10 extends the model to include it.

There is a continuum of households of measure 1. The representative household maximizes

$$E_t \sum_{T=t}^{\infty} \beta^{T-t} \xi_T \left[u(C_T + G_T^S) + g(G_T^N) - \int_0^1 v(l_T(j))dj \right], \tag{1}$$

where β is a discount factor, C_t is a Dixit-Stiglitz aggregate of consumption of each of a continuum of differentiated goods, $C_t \equiv \left[\int_0^1 c_t(i)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$ with an elasticity of substitution equal to $\theta > 1$, P_t is the Dixit-Stiglitz price index, $P_t \equiv \left[\int_0^1 p_t(i)^{1-\theta} di \right]^{\frac{1}{1-\theta}}$, and $l_t(j)$ is the quantity supplied of labor of type j. Each industry j employs an industry-specific type of labor, with its own wage $W_t(j)$. The disturbance ξ_t is a preference shock, and $u(.)$ and $g(.)$ are increasing concave functions while $v(.)$ is an increasing convex function. G_T^S and G_T^N are government spending that differ only in how they enter utility and are also defined as Dixit-Stiglitz aggregates analogous to private consumption. G_t^S is perfectly substitutable for private consumption, while G_t^N is not. For simplicity, we assume that the only assets traded are one-period riskless bonds, B_t. The period

[9] See, .e.g., Clarida, Gali, and Gertler (1999), Benigno and Woodford (2003), Smets and Wouters (2007), and Christiano, Eichenbaum, and Evans (2005). Several details are omitted here, but see, e.g., Woodford (2003) for a textbook treatment.

budget constraint can then be written as

$$\begin{aligned} & (1+\tau_t^s)P_tC_t + B_t + \qquad (2) \\ = \quad & (1-\tau_{t-1}^A)(1+i_{t-1})B_{t-1} + (1-\tau_t^P)\int_0^1 Z_t(i)di + (1-\tau_t^w)\int_0^1 W_t(j)l_t(j)dj - T_t, \end{aligned}$$

where $Z_t(i)$ is profits that are distributed lump sum to the households. I do not model optimal stock holdings (i.e., the optimal portfolio allocation) of the households, which could be done without changing the results.[10] There are five types of taxes in the baseline model: a sales tax τ_t^s on consumption purchases, a payroll tax τ_t^w, a tax on financial assets τ_t^A, a tax on profits τ_t^p, and finally a lump-sum tax T_t, all represented in the budget constraint. Observe that I allow for different tax treatments of the risk-free bond returns and dividend payments, while in principle we could write the model so that these two underlying assets are taxed in the same way. I do this to clarify the role of taxes on capital. The profit tax has no effect on the household consumption/saving decision (it would only change how stocks are priced in a more complete description of the model) while taxes on the risk-free debt have a direct effect on households' saving and consumption decisions. This distinction is helpful to analyze the effect of capital taxes on households' spending and savings (τ_t^A) on the one hand, and the firms' investment, hiring, and pricing decisions on the other (τ_t^P), because we assume that the firms maximize profits net of taxes. Households take prices and wages as given and maximize utility subject to the budget constraint by their choices of $c_t(i)$, $l_t(j), B_t$ and $Z_t(i)$ for all j and i at all times t.

There is a continuum of firms in measure 1. Firm i sets its price and then hires the labor inputs necessary to meet any demand that may be realized. A unit of labor produces one unit of output. The preferences of households and the assumption that the government distributes its spending on varieties in the same way as households imply a demand for good i of the form $y_t(i) = Y_t(\frac{p_t(i)}{P_t})^{-\theta}$, where $Y_t \equiv C_t + G_t^N + G_t^S$ is aggregate output. We assume that all profits are paid out as dividends and that the firm seeks to maximize post-tax profits. Profits can be written as $d_t(i) = p_t(i)Y_t(p_t(i)/P_t)^{-\theta} - W_t(j)Y_t(p_t(i)/P_t)^{-\theta}$, where i indexes the firm and j the industry in which the firm operates. Following Calvo (1983), let us suppose that each industry has an equal probability of reconsidering its price in each period. Let $0 < \alpha < 1$ be the fraction of industries with prices that remain unchanged in each period. In any industry that revises its prices in period t, the new price p_t^* will be the same. The maximization problem that each firm faces at the time it revises its price is then to choose a price p_t^* to maximize

$$\max_{p_t^*} E_t \left\{ \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} Q_{t,T}(1-\tau_T^P)[p_t^* Y_T(p_t^*/P_T)^{-\theta} - W_T(j)Y_T(p_t^*/P_T)^{-\theta}] \right\}.$$

An important assumption is that the price the firm sets is *exclusive* of the sales tax. This means that if the government cuts sales taxes, then consumers face a lower store price of exactly the amount of the tax cuts for firms that have not reset their prices. An equilibrium can now be defined as a set of stochastic processes that solve the maximization problem of households and

[10] It would simply add asset-pricing equations to the model that would pin down stock prices.

firms, given government decision rules for taxes and nominal interest rates, which close the model (and are specified in the next section). Since the first-order conditions of the household and firm problems are relatively well known, I will report only a first-order approximation of these conditions in the next section and show how the model is closed in the approximate economy.[11] This approximate economy corresponds to a log-linear approximation of the equilibrium conditions around a zero-inflation steady state defined by no shocks.

3 Approximated model

This section summarizes a log-linearized version of the model. It is convenient to summarize the model by "aggregate demand" and "aggregate supply." By the aggregate demand, I mean the equilibrium condition derived from the optimal consumption decisions of the household where the aggregate resource constraint is used to substitute out for consumption. By aggregate supply, I mean the equilibrium condition derived by the optimal production and pricing decisions of the firms. Aggregate demand (AD) is

$$\hat{Y}_t = E_t\hat{Y}_{t+1} - \sigma(i_t - E_t\pi_{t+1} - r_t^e) + (\hat{G}_t^N - E_t\hat{G}_{t+1}^N) + \sigma E_t(\hat{\tau}_{t+1}^s - \hat{\tau}_t^s) + \sigma\hat{\tau}_t^A, \tag{3}$$

where i_t is the one-period risk-free nominal interest rate[12], π_t is inflation, r_t^e is an exogenous shock, and E_t is an expectation operator and the coefficient is $\sigma > 0$[13]. $\hat{Y}_t$ is output in log deviation from steady state, $\hat{G}_t^N$ is government spending in log deviation from steady state, $\hat{\tau}_t^s$ is sales taxes in log deviation from steady state, $\hat{\tau}_t^A$ is log deviation from steady state,[14] and r_t^e is an exogenous disturbance.[15] The aggregate supply (AS) is

$$\pi_t = \kappa\hat{Y}_t + \kappa\psi(\hat{\tau}_t^w + \hat{\tau}_t^s) - \kappa\psi\sigma^{-1}\hat{G}_t^N + \beta E_t\pi_{t+1}, \tag{4}$$

where the coefficients $\kappa, \psi > 0$ and $0 < \beta < 1$.[16] Without getting into the details about how the central bank implements a desired path for the nominal interest rates, let us assume that it cannot be negative so that

$$i_t \geq 0. \tag{5}$$

Monetary policy follows a Taylor rule, with a time-varying intercept, that takes the zero bound into account:

$$i_t = \max(0, r_t^e + \phi_\pi\pi_t + \phi_y\hat{Y}_t), \tag{6}$$

[11] Details are available from the author upon request. See also standard treatments such as Woodford (2003).

[12] In terms of our previous notation, i_t now actually refers to $log(1 + i_t)$ in the log-linear model. Observe also that this variable, unlike the others, is not defined in deviations from steady state. I do this so that we can still express the zero bound simply as the requirement that i_t is nonnegative.

[13] The coefficients of the model are defined as $\sigma \equiv -\frac{\bar{u}_{cc}}{\bar{u}_c\bar{Y}}$, $\omega \equiv \frac{\bar{v}_y\bar{Y}}{\bar{v}_{yy}}$, $\psi \equiv \frac{1}{\sigma^{-1}+\omega}$, $\kappa \equiv \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}\frac{\sigma^{-1}+\omega}{1+\omega\theta}$, where bar denotes that the variable is defined in steady state.

[14] Here, $\hat{G}_t^N$ is the percentage deviation of government spending from steady-state over steady-state aggregate output. In the numerical examples, $\hat{\tau}_t^A$ is scaled to be comparable to percent deviation in annual capital income taxes in steady state so that it corresponds to $\hat{\tau}_t^A \equiv 4 * (1 - \beta)\log\{\tau_t^A/(1 - \bar{\tau}^A)\}$.

[15] It is defined as $\mathrm{r}_t^e \equiv \log\beta^{-1} + E_t(\hat{\xi}_t - \hat{\xi}_{t+1})$, where $\hat{\xi}_t \equiv \log\xi_t/\bar{\xi}$.

[16] See footnote 13.

where the coefficients $\phi_\pi > 1$ and $\phi_y > 0$. For a given policy rule for taxes and spending, equations (3)-(6) close the model. Observe that this list of equations does not include the government budget constraint. I assume that Ricardian equivalence holds, so that temporary variations in either $\hat{\tau}_t^w, \hat{\tau}_t^s$ or $\hat{G}_t^N, \hat{G}_t^S$ are offset either by lump-sum transfers in period t or in future periods $t+j$ (the exact date is irrelevant because of Ricardian equivalence).[17]

4 An output collapse at the zero bound

This section shows that an output collapse occurs in the model under special circumstances when interest rates are zero. This peculiar environment is the key focus of the paper. Observe that when $r_t^e < 0$ then the zero bound is binding, so that $i_t = 0$. This shock generates a recession in the model and plays a key role.

A1 – Structural shocks: $r_t^e = r_L^e < 0$ *unexpectedly at date* $t = 0$. *It returns back to steady state* $r_H^e = \bar{r}$ *with probability* $1-\mu$ *in each period. The stochastic date the shock returns back to steady state is denoted* T^e. *To ensure a bounded solution, the probability* μ *is such that* $L(\mu) = (1-\mu)(1-\beta\mu) - \mu\sigma\kappa > 0$.

Where does this shock come from? In the simplest version of the model, a negative r_t^e is equivalent to a preference shock and so corresponds to a lower ξ_t in period t in 1 that reverts back to steady state with probability $1-\mu$. Everyone suddenly wants to save more so the real interest rate must decline for output to stay constant. More sophisticated interpretations are possible, however. Curdia and Eggertsson (2009), building on Curdia and Woodford (2008), show that a model with financial frictions can also be reduced to equations (3)-(4). In this more sophisticated model, the shock r_t^e corresponds to an exogenous increase in the probability of default by borrowers. What is nice about this interpretation is that r_t^e can now be mapped into the wedge between a risk-free interest rate and an interest rate paid on risky loans. Both rates are observed in the data. The wedge implied by these interest rates exploded in the U.S. economy during the crisis of 2008, providing empirical evidence for a large negative shock to r_t^e. A banking crisis – characterized by an increase in probability of default by banks and borrowers– is my story for the model's recession.

Panel (a) in Figure 1 illustrates assumption A1 graphically. Under this assumption, the shock r_t^e remains negative in the recession state denoted L, until some stochastic date T^e, when it returns to steady state. For starters, let us assume that $\hat{\tau}_t^w = \tau_t^A = \tau_t^s = \hat{G}_t^N = 0$. It is easy to

[17] This assumption simplifies that analysis quite a bit, since otherwise, when considering the effects of particular tax cuts, I would need to take a stance on what combination of taxes would need to be raised to offset the effect of the tax cut on the government budget constaint and at what time horizon. Moreover, I would need to take a stance on what type of debt the government could issue. While all those issues are surely of some interest in future extensions, this approach seems like the most natural first step since it allows us to analyze the effect of each fiscal policy instrument in isolation (abtracting from their effect on the government budget).

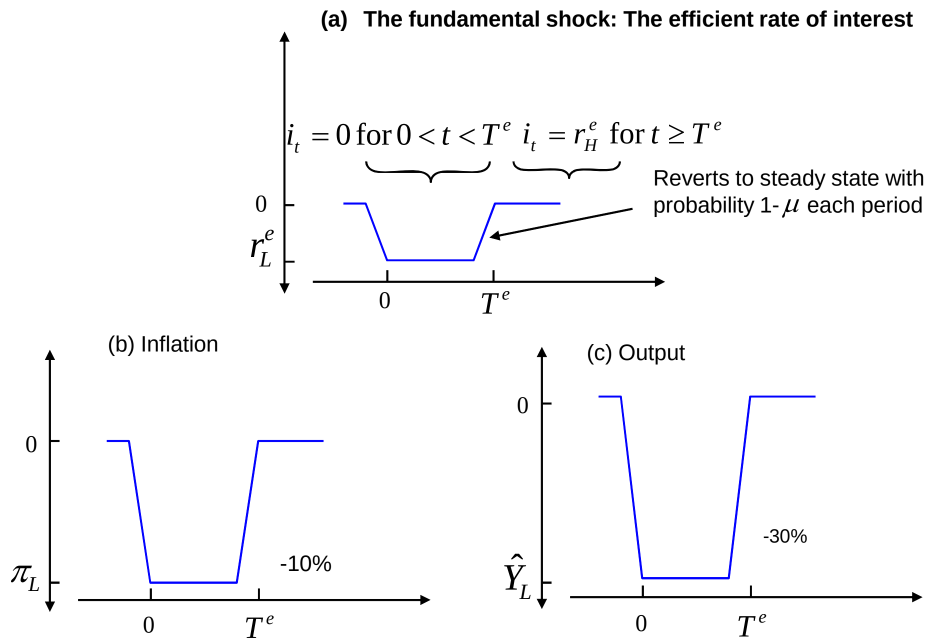

Figure 1: The effect of negative r_t^e on output and inflation.

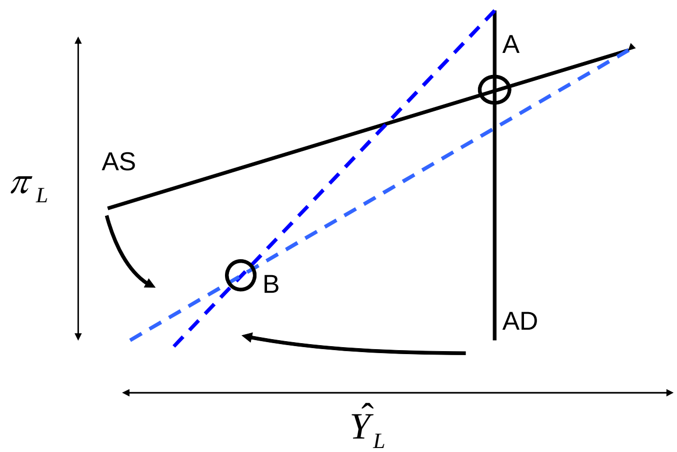

Figure 2: The effect of multiperiod recession.

show that monetary policy now takes the following form:

$$i_t = r^e_H \text{ for } t \geq T^e \tag{7}$$

$$i_t = 0 \text{ for } 0 < t < T^e, \tag{8}$$

We can now derive the solution in closed form for the other endogenous variables, assuming (7)-(8). In the periods $t \geq T^e$, the solution is $\pi_t = \hat{Y}_t = 0$. In periods $t < T^e$, assumption A1 implies that inflation in the next period is either zero (with probability $1 - \mu$) or the same as at time t, i.e., $\pi_t = \pi_L$ (with probability μ). Hence the solution in $t < T^e$ satisfies the AD and the AS equations:

$$AD \qquad \hat{Y}_L = \mu \hat{Y}_L + \sigma \mu \pi_L + \sigma r^e_L \tag{9}$$

$$AS \qquad \pi_L = \kappa \hat{Y}_L + \beta \mu \pi_L \tag{10}$$

It is helpful to graph the two equations in $(\hat{Y}_L, \pi_L)$ space. Consider first the special case in which $\mu = 0$, i.e., the shock r^e_L reverts back to steady state in period 1 with probability 1. This case is shown in Figure 2. It applies only to the equilibrium determination in period 0. The equilibrium is shown where the two solid lines intersect at point A. At point A, output is completely demand-determined by the vertical AD curve and pinned down by the shock r^e_t.[18] For a given level of

[18] A higher efficient rate of interest, r^e_L, corresponds to an autonomous increase in the willingness of the household to spend at a given nominal interest rate and expected inflation and thus shifts the AD curve. Note that the key feature of assumption A1 is that we are considering a shock that results in a negative efficient interest rate, which in turn causes the nominal interest rate to decline to zero. Another way of stating this is that it corresponds to an "autonomous" decline in spending for given prices and a nominal interest rate. This shock thus corresponds to what the old Keynesian literature referred to as "demand" shocks, and one can interpret it as a stand-in for any

output, then, inflation is determined by where the AD curve intersects the AS curve. It is worth emphasizing again: *Output is completely demand-determined, i.e., it is completely determined by the AD equation.*

Consider now the effect of increasing $\mu > 0$. In this case, the contraction is expected to last for longer than one period. Because of the simple structure of the model, and the two-state Markov process for the shock, the equilibrium displayed in the figure corresponds to all periods $0 \leq t < T^e$. The expectation of a possible future contraction results in movements in both the AD and the AS curves, and the equilibrium is determined at the intersection of the two dashed curves, at point B. Observe that the AD equation is no longer vertical but upward sloping in inflation, i.e., higher inflation *expectations* $\mu\pi_L$ increase output. The reason is that, for a given nominal interest rate ($i_L = 0$ in this equilibrium), any increase in expected inflation reduces the real interest rate, making current spending relatively cheaper and thus increasing demand. Conversely, expected deflation, a negative $\mu\pi_L$, causes current consumption to be relatively more expensive than future consumption, thus suppressing spending. Observe, furthermore, the presence of the expectation of future contraction, $\mu\hat{Y}_L$, on the right-hand side of the AD equation. The expectation of future contraction makes the effect of both the shock and the expected deflation even stronger.

Let us now turn to the AS equation (10). Its slope is now steeper than before because the expectation of future deflation will lead the firms to cut prices by more for a given demand slack, as shown by the dashed line. The net effect of the shift in both curves is a more severe contraction and deflation shown by the intersection of the two dashed curves at point B in Figure 2.

The more severe depression at point B is triggered by several contractionary forces. First, because the contraction is now expected to last more than one period, output is falling in the price level because there is expected deflation, captured by $\mu\pi_L$ on the right-hand side of the AD equation. This increases the real interest rate and suppresses demand. Second, the expectation of future output contraction, captured by the $\mu\hat{Y}_L$ term on the right-hand side of the AD equation, creates an even further decline in output. Third, the strong contraction, and the expectation of it persisting in the future, implies an even stronger deflation for given output slack, according to the AS equation.[19] Note the role of the aggregate supply, or the AS equation. It is still really important to determine the expected inflation in the AD equation. This is the sense in which the output is demand-determined in the model even when the shock lasts for many periods. That

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exogenous reason for a decline in spending. Observe that in the model all output is consumed. If we introduce other sources of spending, such as investment, a more natural interpretation of a decline in the efficient interest rate is an autonomous shock to the cost of investment in addition to the preference shock (see further discussion in Eggertsson in the section of the paper with endogenous capital).

[19] Observe the vicious interaction between the contractionary forces in the AD and AS equations. Consider the pair $\hat{Y}_L^A, \pi_L^A$ at point A as a candidate for the new equilibrium. For a given $\hat{Y}_L^A$, the strong deflationary force in the AS equation reduces expected inflation so that we need to have $\pi_L < \pi_L^A$. Owing to the expected deflation term in the AD equation, this again causes further contraction in output, so that $\hat{Y}_L < \hat{Y}_L^A$. The lower $\hat{Y}_L$ then feeds again into the AS equation, triggering even further deflation and thus a further drop in output according to the AD equation, and so on and on, leading to a vicious deflation-output contractionary spiral that converges to point B in panel (a), where the dashed curves intersect.

is what makes tax policy so tricky, as we soon will see. It is also the reason why government spending and cuts in sales taxes have a big effect.

To summarize, solving the AD and AS equations with respect to π_t and $\hat{Y}_t$, we obtain (see the footnote comments on why the denominator has to be positive)[20]

$$\pi_t = \frac{1}{(1-\mu)(1-\beta\mu)-\mu\sigma\kappa}\kappa\sigma r_L^e < 0 \text{ if } t < T^e \text{ and } \pi_t = 0 \text{ if } t \geq T^e \tag{11}$$

$$\hat{Y}_t = \frac{1-\beta\mu}{(1-\mu)(1-\beta\mu)-\mu\sigma\kappa}\sigma r_L^e < 0 \text{ if } t < T^e \text{ and } \hat{Y}_t = 0 \text{ if } t \geq T^e. \tag{12}$$

The two-state Markov process for the shock allows us to collapse the model into two equations with two unknown variables, as shown in Figure 2. It is important to keep in mind, however, the stochastic nature of the solution. The output contraction and the deflation last only as long as the stochastic duration of the shock, i.e., until the stochastic date T^e, and the equilibrium depicted in Figure 2 applies only to the "recession" state. This is illustrated in Figure 1, which shows the solution for an arbitrary contingency in which the shock lasts for T^e periods. I have added for illustration numerical values in this figure, using the parameters from Table 2. The values assumed for the structural parameters are relatively standard. (The choice of parameters and shocks in Table 2 is described in more detail in Appendix A and in Eggertsson and Denes (2009).) The values are obtained by maximizing the posterior distribution of the model to match a 30 percent decline in output and a 10 percent deflation in the r_L^e state. Both these numbers correspond to the trough of the Great Depression in the first quarter of 1933 before President Franklin D. Roosevelt assumed power, when the nominal interest rate was close to zero. I ask the model to match the data from the Great Depression, because people have often claimed that the goal of fiscal stimulus is to avoid a dire scenario of that kind.

Table 2: parameters, mode

	σ^{-1}	β	ω	α	θ	ϕ_π	ϕ_y
Parameters	1.1599	0.9970	1.5692	0.7747	12.7721	1.5	0.25

	r_L^e	μ
Shocks	-0.0104	0.9030

[20] The vicious dynamics described in the previous footnote amplify the contraction without a bound as μ increases. As μ increases, the AD curve becomes flatter and the AS curve steeper, and the cutoff point moves further down in the $(\hat{Y}_L, \pi_L)$ plane in panel (a) of Figure 2. At a critical value $1 > \bar{\mu} > 0$ when $L(\bar{\mu}) = 0$ in A1, the two curves are parallel, and no solution exists. The point $\bar{\mu}$ is called a *deflationary black hole.* In the remainder of the paper we assume that μ is small enough so that the deflationary black hole is avoided and the solution is well defined and bounded (this is guaranteed by the inequality in assumption A1). A deflationary solution always exists as long as the shock μ is close enough to zero because $L(0) > 0$ (at $\mu = 0$, the shock reverts back to steady state with probability 1 in the next period). Observe, furthermore, that $L(1) < 0$ and that in the region $0 < \mu < 1$ the function $L(\mu)$ is strictly decreasing, so there is some critical value $\bar{\mu} = \mu(\kappa, \sigma, \beta) < 1$ in which $L(\mu)$ is zero and the model has no solution.

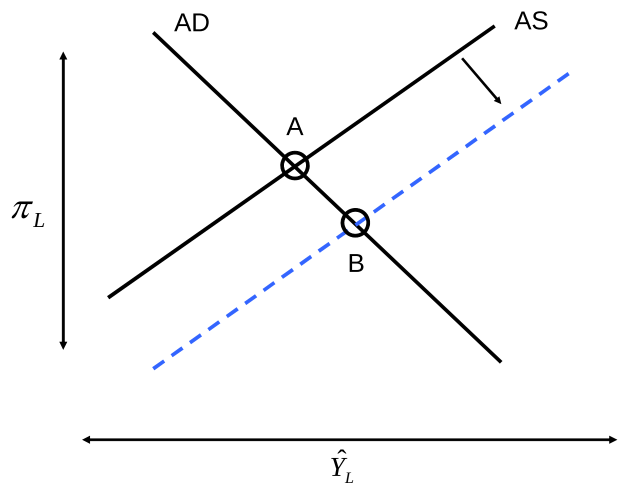

Figure 3: The effect of cutting taxes at a positive interest rate.

5 Why labor tax cuts are contractionary

Can fiscal policy reverse the output collapse shown in the last section? We start with considering tax cuts on labor. Before going further, it is helpful to study tax cuts under regular circumstance, i.e., *in the absence of the shock*. Under normal circumstances, a payroll-tax cut is *expansionary* in the baseline model. This is presumably why this policy proposal has gained much currency in recent policy discussions. Consider a temporary tax cut $\hat{\tau}_t^w = \hat{\tau}_L^w < 0$ in period t that is reversed with probability $1 - \rho$ in each period to steady state $\hat{\tau}_t^w = 0$. Let us call the date on which the tax cut reverses to steady state T^τ. Let $\hat{G}_t^N = \hat{\tau}_t^s = \hat{\tau}_t^A = 0$. Because the model is perfectly forward-looking, this allows us again to collapse the model into only two states, the "low state" when $\hat{\tau}_L^w < 0$ and the "steady state" when $\hat{\tau}_t^w = \hat{\tau}_H^w = 0$. Observe that in the steady state $t > T^e$ then $\hat{Y}_t = \pi_t = 0$. Substituting 6 into the AD equation, we can write the AD and AS equation in the low state as

$$\hat{Y}_L = -\sigma \frac{\phi_\pi - \rho}{1 - \rho + \sigma\phi_y} \pi_L \tag{13}$$

$$(1 - \beta\rho)\pi_L = \kappa \hat{Y}_L + \kappa\psi\tau_L^w. \tag{14}$$

Figure 3 shows the AS and AD curves (13) and (14). This figure looks like any undergraduate textbook AS-AD diagram! A tax cut shifts down the AS curve. Why? Now people want to work more since they get more money in their pocket for each hour worked. This reduces real wages, so that firms are ready to supply more goods for less money, creating some deflationary pressure. In response, the central bank accommodates this shift by cutting interest rates in order to curb deflation, which is why the AD equation is downward sloping.[21] A new equilibrium is

[21] A case where the central bank targets a particular inflation rate, say zero, corresponds to $\phi_\pi -> \infty$. In this

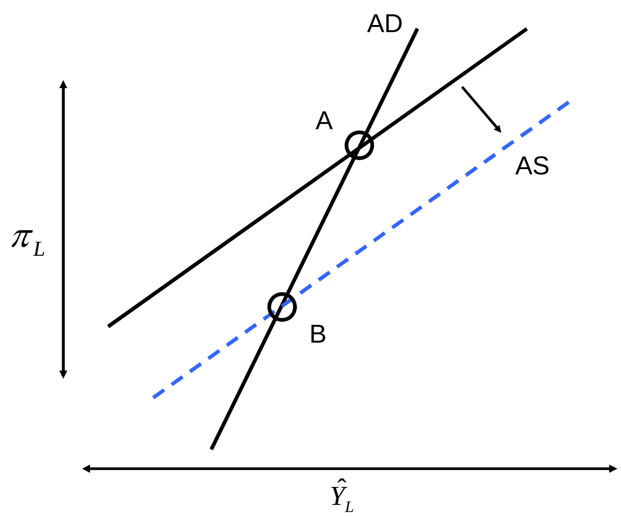

Figure 4: The effect of cutting taxes at a zero interest rate.

found at point B. We can compute the multiplier of tax cuts by using the method of undetermined coefficients.[22] The tax cut multiplier is

$$\frac{\Delta \hat{Y}_L}{-\Delta \hat{\tau}_L^w} = \frac{\sigma \phi_\pi \kappa \psi}{(1-\rho+\sigma\phi_y)(1-\rho\beta)+\sigma\phi_\pi\kappa} > 0. \tag{15}$$

Here, Δ denotes change relative to the benchmark of no variations in taxes. To illustrate the multiplier numerically, I use the values reported in Table 2 and assume $\rho = \mu$. The multiplier is 0.097. If the government cut the tax rate $\hat{\tau}_L^w$ by 1 percent in a given period, then output increases by 0.097 percent. Table 2 also reports 5 percent and 95 percent posterior bands for the multiplier, giving the reader a sense of the sensitivity of the result, given the priors distributions described in more detail in Appendix A. We can also translate this into dollars. Think of the tax cuts in terms of dollar cuts in tax collections in the absence of shocks, i.e., tax collection in a "steady state." Then the meaning of the multiplier is that each dollar of tax cuts buys you a 9.7 cent increase in output.

We now show that this very same tax cut has the opposite effect under the special circumstances when the zero bound is binding Again, consider a temporary tax cut, but now one that is explicitly aimed at "ending the recession" created by the negative shock that caused all the trouble in the last section. Assume the tax cut takes the following form:

$$\hat{\tau}_L^w = \phi_\tau r_L^e < 0 \text{ when } 0 < t < T^e \tag{16}$$

case, the AD curve is horizonal and the effect of the tax cut is very large because the central bank will accomodate it with aggressive interest rates cuts.

[22] Note that the two-state Markov process we assumed gives the same result as if we had assumed the stochastic process $\hat{\tau}_t = \mu_\tau \hat{\tau}_{t-1} + \epsilon_t$ where ϵ_t is normally distributed iid. In that case, the multiplier applies to output in period 0.

with $\phi_\tau > 0$ and

$$\hat{\tau}_t = 0 \text{ when } t \geq T^e. \tag{17}$$

Consider now the solution in the periods when the zero bound is binding but the government follows this policy. The AS curve is exactly the same as under the "normal circumstance" shown in equation 14, but now we have replaced ρ with the probability of the duration of the shock, i.e., $\rho = \mu$ The big difference is the AD curve, because of the shock r_L^e and because the zero bound is binding. Hence we replace equation (13) with equation (9) from the last section. These two curves are plotted in Figure 4, and it should now be clear that the effect of the tax cut is the opposite from what we had before. Just as before, the increase in $\hat{\tau}_L^w$ shifts the AS curve outwards as denoted by a dashed line in Figure 4. As before, this is just a traditional shift in "aggregate supply" outwards; the firms are now in a position to charge lower prices on their products than before. But now the slope of the AD curve is different from before, so that a new equilibrium is formed at the intersection of the dashed AS curve and the AD curve at lower output and prices, i.e., at point B in Figure 4. The general equilibrium effect of the tax cut is therefore an output contraction!

The intuition for this result (as clarified in the following paragraphs) is that the expectation of lower taxes in the recession creates deflationary expectations *in all states of the world in which the shock r_t^e is negative.* This makes the real interest rate higher, which reduces spending according to the AD equation. We can solve the AD and AS equations together to show analytically that output and inflation are reduced by these tax cuts:

$$\begin{aligned}
\hat{Y}_L^{taxcut} &= \frac{1}{(1-\mu)(1-\beta\mu)-\mu\sigma\kappa}[(1-\beta\mu)\sigma r_L^e + \mu\kappa\sigma\psi\hat{\tau}_L^w] < \hat{Y}_t^{notax} \text{ if } t < T^e \\
\text{and } \hat{Y}_L^{taxcut} &= 0 \text{ if } t \geq T^e
\end{aligned}$$

$$\pi_t^{taxcut} = \frac{\kappa}{1-\beta\mu}(\hat{Y}_t^{tax} + \psi\hat{\tau}_L^w) < \pi_t^{notax} \text{ if } t < T^e \text{ and } \hat{\pi}_t^{tax} = 0 \text{ if } t \geq T^e.$$

Figure 5 clarifies the intuition for why labor tax cuts become contractionary at zero interest rates while being expansionary under normal circumstances. *The key is aggregate demand.* At positive interest rates the AD curve is downward-sloping in inflation. The reason is that as inflation decreases, the central bank will cut the nominal interest rate more than 1 to 1 with inflation (i.e., $\phi_\pi > 1$, which is the Taylor principle; see equation 6). Similarly, if inflation increases, the central bank will increase the nominal interest rate more than 1 to 1 with inflation, thus causing an output contraction with higher inflation. As a consequence, the real interest rate *will decrease with deflationary pressures* and expanding output, because any reduction in inflation will be met by a more than proportional change in the nominal interest rate. This, however, is no longer the case at zero interest rates, because interest rates can no longer be cut. This means that the central bank will no longer be able to offset deflationary pressures with aggressive interest rate cuts, shifting the AD curve from downward-sloping to upward-sloping in (Y_L, π_L) space, as shown in Figure 5. The reason is that lower inflation will now mean *a higher real rate*, because the reduction in inflation can no longer be offset by interest rate cuts. Similarly, an increase

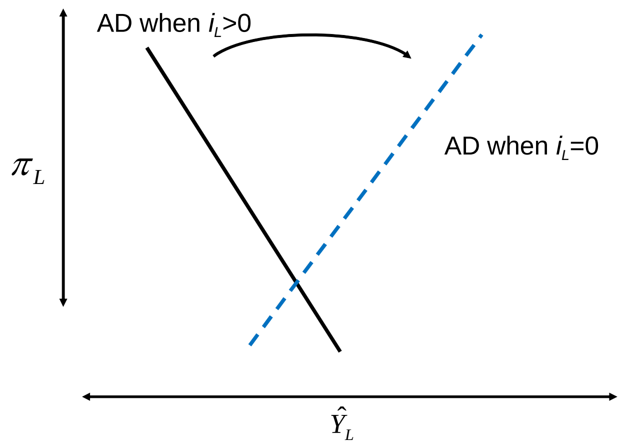

Figure 5: How aggregate demand changes once the short-term interest rate hits zero.

in inflation is now expansionary because the increase in inflation will no longer be offset by an increase in the nominal interest rate; hence, higher inflation implies lower real interest rates and thus higher demand.

We can now compute the multiplier of tax cuts at zero interest rates. It is negative and given by

$$\frac{\Delta \hat{Y}_L}{-\Delta \hat{\tau}_L^w} = -\frac{\mu\kappa\sigma\varphi}{(1-\mu)(1-\beta\mu)-\mu\sigma\kappa} < 0. \tag{18}$$

Using the numerical values in Table 2, this corresponds to a multiplier of -0.69 (with the 5 percent and 95 percent posterior bands corresponding to -0.11 and -1.24). This means that if the government reduces taxes rate $\hat{\tau}_L^w$ by 1 percent at zero interest rates, then aggregate output declines by 0.69 percent. To keep the multipliers (15) and (18) comparable, I assume that the expected persistence of the tax cuts is the same across the two experiments, i.e., $\mu = \rho$.

Table 3: Multipliers of temporary policy changes

(First line denotes mode while the second line denotes 5-95 percent posterior bands.)

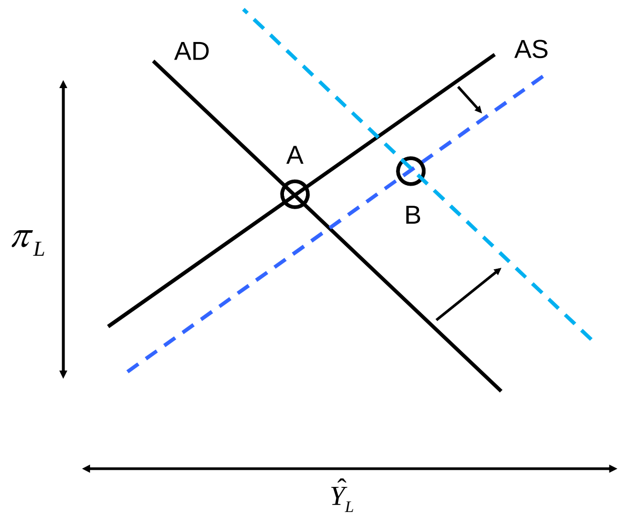

Figure 6: Increasing government spending at positive interest rates.

	Multiplier (mode) $i_t > 0$ (5%,95%)	Multiplier (mode) $i_t = 0$ (5%,95%)
τ_t^w(Payroll Tax Cut)	0.0962 (0.0476, 0.1434)	-0.8153 (-1.3890, -0.2132)
G_t^S(Government Spending 1 Increase)	**0** (0)	**0** (0)
G_t^N (Government Spending 2 Increase)	0.3247 (0.2911, 0.4038)	2.2793 (1.4295, 3.2064)
τ_t^S (Sales Tax Cut)	0.3766 (0.2541, 0.6578)	2.6438 (1.4883, 4.1760)
τ_t^K (Capital Tax Cut)	-0.0033 -0.0049, -0.0024)	-0.4048 (-0.6748, -0.1605)

6 Why government spending can be expansionary

Let us now consider the effect of government spending. Consider first the effect of increasing $\hat{G}_t^S$. It is immediate from our derivation of the model in Section 3 that increasing government spending, which is a perfect substitute for private spending, has no effect on output or inflation. The reason is that the private sector will reduce its own consumption by exactly the same amount. The formal way to verify this is to observe that the path for $\{\pi_t, \hat{Y}_t\}$ is fully determined by equations (3)-(6), along with a policy rule for the tax instruments and $\hat{G}_t^N$, which makes no reference to the policy choice of $\hat{G}_t^S$. Let us now turn to government spending, which is not a perfect substitute for private consumption, $\hat{G}_t^N$.

Consider the effect of increasing government spending, $\hat{G}_t^N$, in the absence of the deflationary shock so that the short-term nominal interest rate is positive. In particular, consider an increase $\hat{G}_L^N > 0$ that is reversed with probability $1-\rho$ in each period to steady state. Substituting the Taylor rule into the AD equation we can write the AD and AS equations as

$$(1-\rho+\sigma\phi_y)\hat{Y}_L = -\sigma(\phi_\pi - \rho)\pi_L + (1-\rho)\hat{G}_L^N \quad (19)$$

$$(1-\beta\rho)\pi_L = \kappa\hat{Y}_L - \kappa\psi\sigma^{-1}\hat{G}_L^N. \quad (20)$$

The experiment is shown in Figure 6. It looks identical to a standard undergraduate textbook AD-AS diagram. An increase in $\hat{G}_L^N$ shifts out demand for all the usual reasons, i.e., it is an "autonomous" increase in spending. In the standard New Keynesian model, there is an additional kick, however, akin to the effect of reducing labor taxes. Government spending also shifts out aggregate supply. Because government spending takes away resources from private consumption, people want to work more in order to make up for lost consumption, shifting out labor supply and reducing real wages. This effect is shown in the figure by the outward shift in the AS curve. The new equilibrium is at point B. Using the method of undetermined coefficients, we can compute the multiplier of government spending at positive interest rates as

$$\frac{\Delta\hat{Y}_L}{\Delta\hat{G}_L^N} = \frac{(1-\rho)(1-\rho\beta) + (\phi_\pi - \rho)\kappa\psi}{(1-\rho+\sigma\phi_y)(1-\rho\beta) + (\phi_\pi - \rho)\sigma\kappa} > 0.$$

Using the parameter values in Table 1, we find that one dollar in government spending increases output by 0.33, which is more than three times the multiplier of tax cuts at positive interest rates.

Consider now the effect of government spending at zero interest rates. In contrast to tax cuts, increasing government spending is very effective at zero interest rates. Consider the following fiscal policy:

$$\hat{G}_t^N = \hat{G}_L^N > 0 \text{ for } 0 < t < T^e \quad (21)$$

$$\hat{G}_t^N = 0 \text{ for } t \geq T^e. \quad (22)$$

Under this specification, the government increases spending in response to the deflationary shock and then reverts back to steady state once the shock is over.[23] The AD and AS equations can be written as

$$\hat{Y}_L = \mu\hat{Y}_L + \sigma\mu\pi_L + \sigma r_L^e + (1-\mu)\hat{G}_L^N \quad (23)$$

$$\pi_L = \kappa\hat{Y}_L + \beta\mu\pi_L - \kappa\psi\sigma^{-1}\hat{G}_L^N. \quad (24)$$

Figure 7 shows the effect of increasing government spending. Increasing $\hat{G}_L$ shifts out the AD equation, stimulating both output and prices. At the same time, however, it shifts out the AS equation as we discussed before, so there is some deflationary effect of the policy, which arises

[23] This equilibrium form of policy is derived from microfoundations in Eggertsson (2008a) assuming a Markov perfect equilibrium.

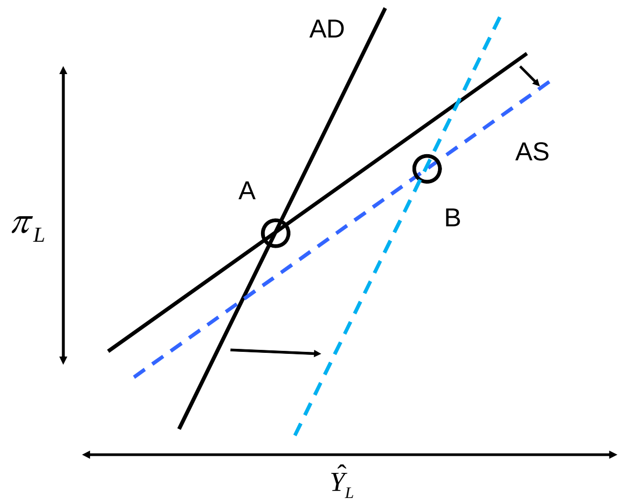

Figure 7: The effect of increasing government spending at zero interest rates.

from an increase in the labor supply of workers. This effect, however, is too small to overcome the stimulative effect of government expenditures. In fact, solving these two equations together, we can show that the effect of government spending is always positive and always greater than 1. Solving (23) and (24) together yields the following multiplier:[24]

$$\frac{\Delta\hat{Y}_L}{\Delta\hat{G}_L^N} = \frac{(1-\mu)(1-\beta\mu)-\mu\kappa\psi}{(1-\mu)(1-\beta\mu)-\sigma\mu\kappa} > 1, \tag{25}$$

i.e., one dollar of government spending, according to the model, has to increase output by more than 1. In our numerical example, the multiplier is 2.45, i.e., each dollar of government spending increases aggregate output by 2.45 dollars. Why is the multiplier so large? The main cause of the decline in output and prices was the expectation of a future *slump* and *deflation*. If the private sector expects an increase in future government spending in all states of the world in which the zero bound is binding, contractionary expectations are changed in all periods in which the zero bound is binding, thus having a large effect on spending in a given period. Thus, expectations about future policy play a key role in explaining the power of government spending, and a key element of making it work *is to commit to sustain the spending spree until the recession is over*. One of the consequences of expectations driving the effectiveness of government spending is that it is not of crucial importance if there is an implementation lag of a few quarters. It is the announcement of the fiscal stimulus that matters more than the exact timing of its implementation. This is in sharp contrast to old-fashioned Keynesian models.

The 5 percent and 95 percent posterior bands for the government spending correspond to 1.4350 and 3.6189. Thus, while the government spending multiplier cannot be smaller than 1,

[24] Note that the denominator is always positive according to A1. See the discussion in footnote 6.

it can be much larger, and there is even 5 percent of the posterior for the multiplier larger than 3.6, given the prior distribution for the parameters we assume (and that are explained in the Appendix). Eggertsson and Denes (2009) explain in more detail the parameter configurations that give rise to such large multipliers. As can be seen in expression 25, this occurs when the denominator is close to zero, i.e., when the AD and AS curves are close to parallel as in figure (2). As $(1-\mu)(1-\beta\mu)-\sigma\mu\kappa$ approaches zero, the multiplier approaches infinity in the limit.

7 The case for a sale tax holiday

Not all tax cuts are contractionary in the model. Perhaps the most straightforward expansionary one is a cut in sales taxes.[25] Observe that, according to the AD and AS equations (3) and (4), the sales tax enters these two equations in exactly the same form as the negative of government spending, except that it is multiplied by the coefficient σ. Hence, the analysis from the last section about the expansionary effect of increases in government spending goes through unchanged by replacing $\hat{G}_t^N$ with $-\sigma\hat{\tau}_t^s$, and we can use both the graphical analysis and the analytical derivation of the multiplier from the last section.

Why do sales tax cuts increase demand? A temporary cut in sales taxes makes consumption today relative to the future cheaper and thus stimulates spending. Observe also that it increases the labor supply because people want to work more because their marginal utility of income is higher. The relative impact of a 1 percent decrease in the sale tax versus a 1 percent increase in spending depends on σ and, in the baseline calibration, because $\sigma > 1$, sales tax cuts have a smaller effect in the numerical example.

One question is of practical importance: Is reducing the sales tax temporarily enough to stimulate the economy out of the recession in the numerical example? In the baseline calibration, it is not, because it would imply a cut in the sales tax rate about 23 percent percent. Since sales takes in the U.S. are typically in the range of 3-8 percent, this would imply a large *sales subsidy in the model*. A subsidy for consumption is impractical, because it would give people the incentive to sell each other the same good ad infinitum and collect subsidies. However, the case for a temporary sales tax holiday appears relatively strong in the model and could go a long way toward eliminating the recession in the model. Another complication with sales taxes in the U.S. is that they are collected by each individual state, so it might be politically complicated to use them as a stimulative device.

It is worth pointing out that the model may not support the policy of cutting value added taxes (VAT). As emphasized by Eggertsson and Woodford (2004), VAT of the kind common in Europe enter the model differently from American sales taxes, because of how VAT typically interact with price frictions. We assumed in the case of sale taxes that firms set their price exclusively of the tax, so that a 1 percent reduction in the tax will mean that the customer faces a 1 percent lower

[25] This is essentially Feldstein's (2002) idea in the context of Japan, although he suggested that Japan should *commit to raising future VAT*. As documented below, there are some subtle reasons for why VAT may not be well suited for this proposal because of how they typically interact with price frictions.

purchasing price for the goods he/she purchases even if the firms themselves have not revised their own pricing decisions. This assumption is roughly in line with empirical estimates of the effect of variations in sales taxes in the United States; see, e.g., Poterba (1996). This assumption is much less plausible for VAT, however, because posted prices usually include the price (often set by law). Let us then suppose the other extreme, as in Eggertsson and Woodford (2004), that the prices the firms post are inclusive of the tax. In this case, if there is a 1 percent decrease in the VAT, this will only lead to a decrease in the price the consumer face if the firms whose goods they are purchasing have revisited their pricing decision (which only happens with stochastic intervals in the model). As a consequence, as shown in Eggertsson and Woodford (2004), the VAT shows up in the AS and AD equations exactly in the same way as the *payroll tax,* so that the analysis in Section 5 goes through unchanged. The implication is that while I have argued that cutting sales taxes is expansionary, cutting VAT works in exactly the opposite way, at least if we assume that the pricing decisions of firms are made inclusive of the tax. The intuition for this difference is straightforward. Sales tax cuts stimulate spending because a cut implies an immediate drop in the prices of goods, and consumers expect them to be relatively higher as soon as the recession is over. In contrast, because VAT are included in the posted price, eliminating them will show up in prices only once the firm revisits its price (which happens with a stochastic probability). This could take a some time. As a consequence, people may hold off their purchases to take advantage of lower prices in the future.

8 Taxes on savings (capital)

So far, we have only studied variations in taxes on labor and consumption expenditures. A third class of taxes are taxes on capital, i.e., a tax on the financial wealth held by households. In the baseline specification, I included a tax that is proportional to aggregate savings, i.e., the amount people hold in equities and/or the one-period riskless bond, through τ_t^A, and then I assumed there was tax τ_t^P on dividends. Observe that even if the firm maximizes profits net of taxes, τ_t^p, it drops out of the first-order approximation of the firm Euler equation (AS). Capital taxes thus appear only in the consumption Euler equation (AD) through τ_t^A.

Consider, at positive interest rates, a tax cut in period t that is reversed with a probability $1-\rho$ in each period. A cut in this tax will reduce demand, according to the AD equation. Why? Because saving today is now relatively more attractive than before and this will encourage households to save instead of consume. This means that the AD curve shifts backward in Figure 3, leading to a contraction in output and a decline in the price level. The multiplier of cutting this tax is given by

$$\frac{\Delta \hat{Y}_L}{-\Delta \hat{\tau}_L^A} = -\frac{\sigma(1-\rho\beta)}{1-\rho+\sigma\phi_y+\sigma(\phi_\pi-\rho)\kappa} < 0$$

and is equal to -0.0064 in our numerical example, a small number. Recall that, in reporting this number, I have scaled $\hat{\tau}_L^A$ so that a 1 percent change in this variable corresponds to a tax cut that is equivalent to a cut in the tax on real *capital income* of 1 percent per year in steady state (see

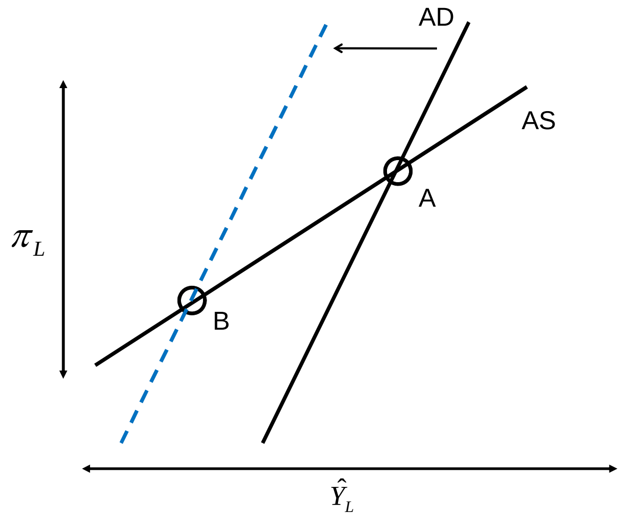

Figure 8: The effect of cutting capital taxes.

footnote 14).

This effect is much stronger at zero interest rates. As shown in Figure 8, a cut in the tax on capital shifts the AD curve backward and thus again reduces both output and inflation. The multiplier is again negative and given by

$$\frac{\Delta \hat{Y}_L}{-\Delta \hat{\tau}_L} = -\frac{1-\beta\mu}{(1-\mu)(1-\beta\mu)-\mu\sigma\kappa} < 0.$$

In this case, however, the quantitative effect is much bigger and corresponds to -0.21 in our numerical example. This means that a tax cut that is equivalent to a 1 percent reduction in the tax rate on real capital income reduces output by -0.21 percent.

Observe that the contractionary effect of capital tax cuts is prevalent at either positive or zero interest rates. It is worth pointing out, however, that in principle the central bank can fully offset this effect at positive interest rates by cutting the nominal interest rates further, so the degree to which this is contractionary at positive interest rates depends on the reaction function of the central bank.[26] Accommodating this tax cut, however, is not feasible at zero interest rates. This tax cut is therefore always contractionary at zero short-term interest rates.

There is an important institutional difference between the capital tax in the model and capital taxes in the U.S. today. The tax in the model is a tax on the *stock* of *savings, i.e., on the stock of all financial assets.* The way in which capital taxes work in practice, however, is that they are a tax on *nominal capital income*. Let us call a tax on nominal capital income τ_t^{AI}. In the case of a one-period riskless bond, therefore, the tax on nominal capital income τ_t^{AI} is equivalent to the

[26] If the time-varying coefficient in the Taylor rule depends on taxes, for example, there could be no effect. In the rule we assume, then, once $\phi_\pi \to \infty$ there is also no effect.

tax on financial assets in the budget constraint (2) if we specify that tax as

$$\tau_t^A = \frac{i_t}{1+i_t}\tau_t^{AI}.$$

We can then use our previous equations to study the impact of changing taxes on capital income. Observe, however, *that at zero interest rates this tax has to be zero by definition, because at that point the nominal income of owning a one-period risk-free bond is zero.* The relevant tax rate τ_t^A on one-period bonds – which is the pricing equation that matters for policy – is therefore constrained to be zero under the current institutional framework in the U.S. Hence this tax instrument cannot be used absent institutional changes. It follows that the government would need to rewrite the tax code and directly tax savings if it wants to stimulate spending by capital tax increases, a proposal that may be harder to implement than other alternatives outlined in this paper.

One argument in favor of cutting taxes on capital is that, in equilibrium, savings is equal to investment, so that higher savings will equal higher investment spending and thus can stimulate demand. Furthermore, higher capital increases the capital stock and thus the production capacities of the economy. In the baseline specification, we have abstracted from capital accumulation. Hence a cut in capital taxes reduced the willingness of consumers to consume at given prices without affecting investment spending or the production capacity of the economy.

Section 10considers how our results change by explicitly modeling investment spending. This enriched model, however, precludes closed-form solutions, which is why I abstract from capital accumulation in the baseline model. To preview the result, I find that capital accumulation does not affect the results in a substantive way. It does, however, allow us to consider investment tax credits and also how taxes on savings affect aggregate savings, which will fall in response to tax cuts. It also puts a nice structure on the old Keynesian idea of the paradox of thrift.

9 The scope for monetary policy: A commitment to inflate and credibility problems

Here, I consider another policy to increase demand: a commitment to inflate the currency. For this exercise, I consider the baseline model without capital to obtain closed-form solutions. Expansionary monetary policy is modeled as a commitment to a higher growth rate of the money supply in the future, i.e., at $t \geq T^e$. As shown by several authors, such as Eggertsson and Woodford (2003) and Auerbach and Obstfeld (2005), it is only the expectation about future money supply (once the zero bound is no longer binding) that matters at $t < T^e$ when the interest rate is zero. Consider the following monetary policy rule:

$$i_t = \max\{0, r_t^e + \pi^* + \phi_\pi(\pi_t - \pi^*) + \phi_y(\hat{Y}_t - \hat{Y}^*)\}, \tag{26}$$

where π^* denotes the implicit inflation target of the government and $\hat{Y}^* = (1-\beta)\kappa^{-1}\pi^*$ is the implied long-run output target. Under this policy rule, a higher π^* corresponds to a credible inflation commitment. Consider a simple money constraint as in Eggertsson (2008a), $M_t/P_t \geq$

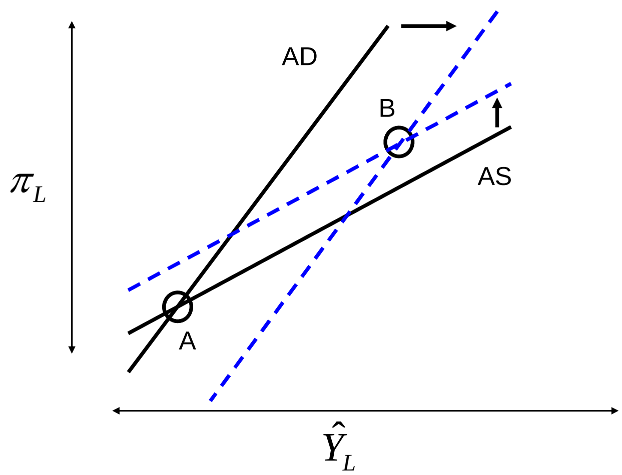

Figure 9: Commitment to inflate at zero nominal interest rates.

$\chi\hat{Y}_t$, where M_t is the money supply and $\chi > 0$. A higher π^* corresponds to a commitment to a higher growth rate of the money supply in $t \geq T^e$ at the rate of π^*. The assumption about policy in (6) is a special case of this policy rule with $\pi^* = 0$.

What is the effect of an increase in the inflation target? It is helpful to write out the AD and AS equations in periods $0 < t < \tau$ when the zero bound is binding:

$$AD \qquad \hat{Y}_L = \mu\hat{Y}_L + (1-\mu)\hat{Y}^* + \sigma\mu\pi_L + \sigma(1-\mu)\pi^* + \sigma r_L^e \tag{27}$$

$$AS \qquad \pi_L = \kappa\hat{Y}_L + \beta\mu\pi_L + \beta(1-\mu)\pi^*. \tag{28}$$

Consider the effect of increasing $\pi^* = 0$ to a positive number $\pi^* > 0$. As shown in Figure 9, this shifts the AD curve to the right and the AS curve to the left, increasing both inflation and output. The logic is straightforward: A higher inflation target in period $t \geq T^e$ reduces the real rate of interest in period $t < T^e$, thus stimulating spending in the depression state. This effect can be quite large, owing to a similar effect as described in the case of fiscal policy. The effect of π^* not only increases inflation expectations at dates $t \geq T^e$, but also increases inflation in all states of the world in which the zero bound is binding. In general equilibrium, the effect of inflating the currency is very large for this reason.

Expansionary monetary policy can be difficult if the central bank cannot commit to future policy. The problem is that an inflation promise is not credible for a discretionary policy maker. The welfare function in the model economy is given by the utility of the representative household, which to a second order can be approximated as[27]

$$E_t \sum_{t=0}^{\infty} \beta^t \{\pi_t^2 + \lambda_Y \hat{Y}_t^2 + \lambda_G (G_t^N)^2\}.$$

The central bank has an incentive to promise future inflation at date $t < T^e$, but then to renege on this promise at data $t \geq T^e$ since at that time the bank can achieve both zero inflation and set output at trend, which is the ideal state of affairs according to this welfare function. This credibility problem is what Eggertsson (2006) calls the "deflation bias" of discretionary monetary policy at zero interest rates. Government spending does not have this problem. In fact, the policy under full discretion will take exactly the same form as the spending analyzed in Section 6 (see, e.g., Eggertsson (2004, 2006a), who analyzes the Markov perfect equilibrium). The intuition is that fiscal policy not only requires promises about what the government will do in the future, but also involves direct actions today. And those actions are fully consistent with those the government promises in the future (namely, increasing government spending throughout the recession period).

It seems quite likely that, in practice, a central bank with a high degree of credibility, can make credible announcements about its future policy and thereby have considerable effect on expectations. Moreover, many authors have analyzed explicit steps, such as expanding the central bank balance sheet through purchases of various assets such as foreign exchange, mortgage-backed securities, or equities, that can help make an inflationary pledge more credible (see, e.g., Eggertsson (2006), who shows this in the context of an optimizing government, and Jeanne and Svensson (2004), who extend the analysis to show formally that an independent central bank that cares about its balance sheet can also use real asset purchases as a commitment device). Finally, if the government accumulates large amounts of nominal debt, this, too, can be helpful in making an inflation pledge credible. However, the assumption of no credible commitment by the central bank, as implied by the benchmark policy rule here, is a useful benchmark for studying the usefulness of fiscal policy.

10 The paradox of thrift

We conclude the paper by illustrating the paradox of thrift in the extended model that allows for endogenous capital. Besides confirming our previous conclusion and illustrating the paradox of thrift, this model is also interesting because it allows us to consider investment tax credits. Consider now an economy in which each firm uses both capital and labor as inputs in production, i.e., $y_t(i) = K_t(i)^\gamma l_t(i)^{1-\gamma}$, and $K_t(i)$ is firm-specific capital. Following Christiano (2004) and Woodford (2003), let us assume that, in order to increase the capital stock to $K_{t+1}(i)$ from $K_t(i)$, the firm invests at time t

$$I_t(i) = \phi(\frac{K_{t+1}(i)}{K_t(i)}, \xi_t) K_t(i),$$

[27] See, e.g., Eggertsson and Woodford (2004). Our assumption about the shocks is such that $\hat{Y}_t^* = 0$ in their notation. See the discussion in Section 1.2 of that paper and also Eggertsson (2008a), who discusses this assumption in some detail.

where the function ϕ satisfies $\phi(1,\bar{\xi}) = \zeta$, $\phi^I(1,\bar{\xi}) = 1$, $\phi^{II} \geq 0$, $\phi^{\xi}(1,\bar{\xi}) = 0$ and $\phi^{I\xi}(1,\bar{\xi}) \neq 0$. The variable λ corresponds to the depreciation rate of capital. At time t, the capital stock is predetermined. I allow for the shock to appear in the cost-of-adjustment function. The shock to the cost of adjustment, in addition to taxes, is the only difference relative to Christiano (2004) and Woodford (2003). Accordingly, the description of the model below is brief (readers can refer to these authors for details).

Here, $I_t(i)$ represents purchases of firm i of the composite good, defined over all the Dixit-Stiglitz good varieties, so that we can write

$$y_t(i) = Y_t(\frac{p_t(i)}{P_t})^{-\theta}.$$

Firm i in industry j maximizes present discounted value of profits. The pre-capital-tax profit is

$$Z_t(i)^{pretax} = p_t(i)y_t(i) - W_t(j)l_t(i) - (1+\tau_t^s)P_tI_t(i).$$

However, we assume that profits are taxed at a rate τ_t^P, owing to the tax on dividends. Furthermore, we assume that there is an investment tax credit given by τ_t^I. The tax bill is

$$\tau_t^P[p_t(i)y_t(i) - P_tn_t(i)h_t(i) - P_td(\frac{p_t(i)}{p_{t-1}(i)}) - (1+\tau_t^I)(1+\tau_t^s)P_tI_t(i)].$$

The firm maximizes after-tax profits by its choice of investment and its price. Let us denote $I_t^N(i) \equiv \frac{K_{t+1}(i)}{K_t(i)}$ as the net increase in the capital stock in each period. Endogenous capital accumulation gives rise to the following first-order condition:

$$\begin{aligned} &-\phi^I(I_t^N(i),\xi_t)(1-\tau_t^P(1+\tau_t^I))(1+\tau_t^s) \qquad (29)\\ &+E_tQ_{t+1}\Pi_{t+1}[\rho_{t+1}(i) + \phi I(I_{t+1}^N(i),\xi_{t+1})I_{t+1}^N(1-\tau_{t+1}^P(1+\tau_{t+1}^I))(1+\tau_{t+1}^s) - \phi(I_{t+1}^A(i),\xi_{t+1})], \end{aligned}$$

where

$$\rho_t(i) \equiv \frac{\gamma}{1-\gamma}\frac{l_t(i)}{K_t(i)}W_t(j)\frac{1-\tau_t^w}{1+\tau_t^s}. \qquad (30)$$

Below, I summarize the equations of the model that define an equilibrium once that model has been approximated around steady state:[28]

$$\hat{C}_t = E_t\hat{C}_{t+1} - \sigma(i_t - E_t\pi_{t+1} - r_t^e - \hat{\tau}_t^A) + \sigma E_t(\hat{\tau}_{t+1}^s - \hat{\tau}_t^s)$$

$$\begin{aligned} \hat{I}_t^N &= \beta E_t\hat{I}_{t+1}^N - \sigma_I(i_t - E_t\pi_{t+1} - r_t^e - \hat{\tau}_t^A) + \chi E_t\hat{\rho}_{t+1} \\ &+\frac{\bar{\tau}^P}{1-\tau^P}[\hat{\tau}_t^I - \beta(1-\lambda)E_t\hat{\tau}_{t+1}^I] + [\hat{\tau}_t^P - \beta(1-\lambda)E_t\hat{\tau}_{t+1}^P] - [\hat{\tau}_t^s - \beta(1-\lambda)E_t\hat{\tau}_{t+1}^s] \end{aligned}$$

$$\hat{\rho}_t = (1+\nu)\hat{L}_t + \sigma^{-1}\hat{C}_t - \hat{K}_t + \hat{\tau}_t^s + \hat{\tau}_t^w - \hat{\tau}_t^P$$

$$\hat{Y}_t = \hat{C}_t + \hat{G}_t + \delta_K\hat{I}_t^N + \lambda\delta_K\hat{K}_t$$

[28] In steady state, we have $\rho = (\beta^{-1} - 1 + \zeta)(1-\tau^P)(1+\tau^s)$, $\frac{K}{Y} = \frac{\alpha}{\rho}\frac{\theta-1}{\theta}(1-\tau^p)$.

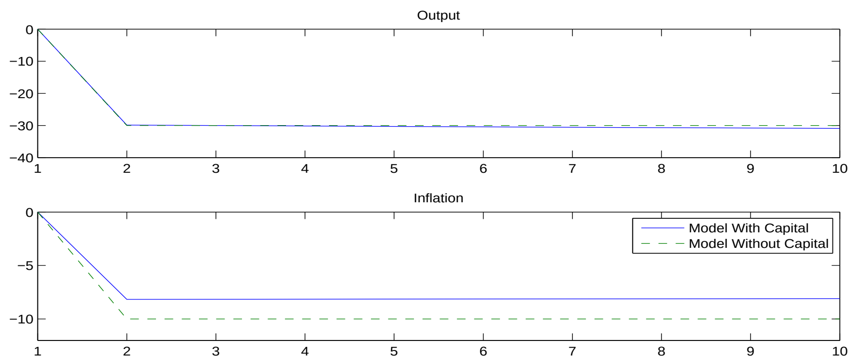

Figure 10: Comparing the model with and without capital

$$\hat{I}_t^N = \hat{K}_{t+1} - \hat{K}_t$$

$$\hat{Y}_t = \gamma \hat{K}_t + (1-\gamma)\hat{L}_t = 0$$

$$\pi_t = \kappa \hat{Y}_t - \kappa\psi\sigma^{-1}[\hat{G}_t + \delta_K \hat{I}_t^N] - \kappa_K \hat{K}_t + \beta E_t \pi_{t+1} + \kappa\psi(\hat{\tau}_t^s + \hat{\tau}_t^w)$$

where κ_K, ν, σ_I, and χ are coefficients greater than zero.[29] Observe that, instead of one aggregate demand equation as in previous sections, there are now two Euler equations that determine aggregate demand: the investment Euler equation and the consumption Euler equation. The basic form of the two equations is the same, however; both investment spending and consumption spending depend on the current and expected path of the short-term real interest rate. The firm-pricing Euler equation is the same as in the model without capital, but with an additional term involving the capital stock. An important assumption is that we assume that the shock enters the cost of adjustment of investment, which is a key difference from Christiano (2004). This assumption is consistent with the interpretation that this disturbance is due to banking troubles that raise the cost of loans, which should affect investment spending and consumption spending in the same way.

I do not attempt to estimate the model, but instead to a preliminary calibration, leaving the estimation to future research. I assume the same coefficients as in the model without capital, i.e., I choose parameters so that ω, σ β, and κ correspond to one another in the two models and assume exactly the same value for shocks. I then need to choose values for τ^P, γ, λ, and $\phi_{II.}$. The values are summarized in Table 4. The parameters λ and γ are taken from the literature, but

[29] σ and ψ are defined as before. Other parameters are defined as follows: $\sigma^I = \frac{(1-\lambda+\rho)}{\phi^{II}} \frac{\beta\rho}{(1-\tau^P)(1+\tau^s)}, \chi \equiv \frac{\beta\rho}{\phi^{II}(1-\tau^P)(1+\tau^s)}, \delta_K \equiv \frac{K}{Y}, \nu \equiv \frac{v_h h}{v_{hh}}$ (Note that ν and ω are related as follows: $\omega = \frac{\nu}{1-\gamma} + \frac{\gamma}{1-\gamma}$). $\kappa_K \equiv \kappa\psi\frac{\gamma}{1-\gamma}\nu$. The parameter κ is defined in Woodford (2003), and it solves a polynomial defined in that paper.

the value for ϕ_{II} is chosen so that the output in the fourth quarter of the "contraction" is -30 percent. (It is assumed that investment declines in the same proportion as consumption). Figure 10 compares the dynamics of output and inflation in the model with and without endogenous capital stock. They are almost identical, although the deflation is slightly less, reflecting the extra terms in the AS equation with endogenous capital tend to increase marginal costs (and thus limit the deflation). To achieve this fit, the degree of capital adjustment is $\phi_{II} = 71.9$. Future work should include a more systematic analysis of the model, taking investment data more explicitly into account, and explicitly pick the parameters to maximize the posterior of the model, as we did in previous sections. As the figure shows, capital dynamics do not add much to the analysis, at least in terms of inflation and output dynamics. This result is somewhat at odds with the findings of Christiano (2004), who finds that adding capital gives somewhat different quantitative conclusions. The main reason for this may be that I have added similar shocks to the investment Euler equation and to the consumption Euler equation (by adding the shock to the investment adjustment cost), together with the strategy I follow in calibrating the model. Table 5 shows how the multipliers change quantitatively with this extension given the calibration strategy just described. As the table reveals, they do not change much. The difference might even be smaller if we followed the same estimation strategy for the model with capital, as the we used with the model with fixed capital stock.

Several things are interesting about this extension apart from confirming the robustness of the previous analysis. Endogenous investment allows us to consider one alternative instrument, i.e., the investment tax credit. Table 5 shows the multiplier of a tax credit: A tax credit that allows firms to deduct one additional percent on top of the purchasing price of their investment from taxable profits would lead to a 0.33 percent increase in output. This expansionary effect occurs because an investment tax credit gives firms an incentive to invest today relative to in the future, thus stimulating spending.

Another interesting statistic is the effect of cutting the tax on capital on savings. Cutting taxes on capital will give consumers an incentive to save more. Since, in equilibrium, savings must be equal to investment, one might expect that this would stimulate investment. The calibrated model, however, gives the opposite conclusion. A 1 percent decrease in $\hat{\tau}_t^A$ at zero interest rates will instead lower investment by 0.44. The main reason is that even if a lower tax on capital gives the household more incentive to save, it reduces aggregate income at the same time. In equilibrium, this effect is strong enough so that even if each household saves more for given income, aggregate saving declines. This is the classic paradox of thrift, first suggested by Keynes.

As before, a decrease in $\hat{\tau}_t^A$ results in a reduction in output, of similar order as in the model without capital, and the logic of the result is the same. The effect of cutting the tax on profits is the same but the reason why cutting taxes on profits reduces output is different. If the tax on profit is reduced, then given the way I model this tax, the firm has an incentive to delay investment in order to pay out as much profits as possible at the lower tax rate in the future. Hence, to stimulate investment, the government should increase the tax on current profits, with a promise to reduce them in the future.

Table 4

	γ	ϕ_{II}	λ	$\bar{\tau}^P$
parameters	0.25	71.935	0.025	0.3

Table 5: Comparing multipliers of temporary policy changes in the model with and without capital

	Without capital $i_t = 0$	With capital $i_t = 0$
τ_t^w(Payroll Tax Cut)	-0.73	-1
G_t^S(Government Spending 1 Increase)	0	0
G_t^N (Government Spending 2 Increase)	2.17	2.7
τ_t^S (Sales Tax Cut)	2.64	2.9
τ_t^A (Capital Tax Cut)	-0.4	-0.445
τ_t^P (Capital Tax Cut)	—	-0.467
τ_t^I	—	0.311

11 Conclusion

The main problem facing the model economy I have studied in this paper is insufficient demand. In this light, the emphasis should be on policies that stimulate spending. Payroll tax cuts may not be the best way to get there. The model shows that they can even be contractionary. What should be done, according to the model? Traditional change in government spending is one approach. Another is a commitment to inflate. Ideally, the two should go together. Government spending has the advantage over inflation policy in that it has no credibility problems associated with it. Inflation policy, however, has the advantage of not requiring any public spending, which may be at its "first best level" in the steady state of the model studied here. Any fiddling around with the tax code should take into account that deflation might be a problem. In that case, shifting out aggregate supply can make things worse.

It is worth stressing that the way taxes are modeled here, although standard, is special in a number of respects. In particular, tax cuts do not have any "direct" effect on spending. The labor tax cut, for example, has an effect only through the incentive it creates for employment and thus "shifts aggregate supply," lowering real wages and stimulating firms to hire more workers. One can envision various environments in which tax cuts stimulate spending, such as old-fashioned Keynesian models or models where people have limited access to financial markets. In those models, there will be a positive spending effect of tax cuts, even payroll tax cuts like the ones in the standard New Keynesian model.

It is also worth raising another channel through which tax cuts can stimulate the economy. Tax cuts would tend to increase budget deficits and thus increase government debt. That gives the government a higher incentive to inflate the economy. As we have just seen in Section 9, higher inflation expectations have a strong positive impact on demand at zero interest rates. Eggertsson (2006) models this channel explicitly. In his model, taxes have no effect on labor supply, but instead generate tax collection costs. In that environment, tax cuts are expansionary because they increase debt and, through that, inflation expectations.

What should we take out of all this? There are two general lessons to be drawn from this paper. The first is that insufficient demand is the main problem once the zero bound is binding, and policy should first and foremost focus on ways in which the government can increase spending. Policies that expand supply, such as some (but not all) tax cuts and also a variety of other policies, can have subtle counterproductive effects at zero interest rates by increasing deflationary pressures. This should – and can – be avoided by suitably designed policy.

The second lesson is that policy makers today should view with some skepticism empirical evidence on the effect of tax cuts or government spending based on post-WWII U.S. data. The number of these studies is high, and they are frequently cited in the current debate. The model presented here, which has by now become a workhorse model in macroeconomics, predicts that the effect of tax cuts and government spending is fundamentally different at zero nominal interest rates than under normal circumstances.

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	Prior 5%	Prior 50%	Prior 95%	Posterior 5%	Posterior 50%	Posterior 95%	Mode
alpha	0.5757	0.6612	0.7402	0.7026	0.7633	0.8164	0.7747
beta	0.9949	0.9968	0.9981	0.9948	0.9967	0.9981	0.9970
1-mu	0.0198	0.0740	0.1788	0.0705	0.1045	0.1523	0.0971
omega	0.1519	0.8200	2.4631	0.7756	1.9033	3.8332	1.5692
reL	-0.0196	-0.0094	-0.0036	-0.0266	-0.0146	-0.0066	-0.0104
sigma^-1	1.2545	1.9585	2.8871	0.8107	1.2161	1.7779	1.1599
theta	3.7817	7.6283	13.4871	8.3394	13.2496	19.7410	12.7721

Figure 11: Priors and posteriors and mode of parameters.

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13 Appendix A: The numerical simulation

Assuming the normally distributed random discrepancy between the model and the data specified in the text, the log of the posterior likelihood of the model is

$$\log L = -\frac{(\pi_L - (-0.1/4))^2}{2\sigma_\pi^2} - \frac{(\hat{Y}_L - (-0.3))^2}{2\sigma_Y^2} + \sum_{\psi_s \in \Omega} f(\psi_s), \tag{31}$$

where Y_L and π_L are given by (11) and (12). I write the likelihood conditional on the hypothesis that the shock r_L is in the "low state." The only data I match are that output is -30 percent and inflation is -10 percent. The functions $f(\psi_s)$ measure the distance of the variables in Ω from the priors imposed where the parameters and shocks are denoted $\psi_s \in \Omega$. The distance functions $f(\psi_s)$ are given by the statistical distribution of the priors listed in Table 6. I use gamma distribution for parameters that are constrained to be positive and beta distribution for parameters that have to be between 0 and 1.

The priors for the parameters are relatively standard. The priors for the shocks, however, are chosen as follows. It is assumed that the mean of the shock r^e_L in the low state is equivalent to a 2-standard-deviation shock to a process fitted to ex ante real interest rates in post-WWII data. While ex ante real rates would be an accurate measure of the efficient rate of interest only in the event output is at its efficient rate at all times, this gives at least some sense of a reasonably "large" shock as a source of the Great Depression. I'm working on forming priors mapping the model into spreads. The prior on the persistence of the shock is that it is expected to reach steady state in ten quarters, which is consistent with the stochastic process of estimated ex ante real rates. It also seems reasonable to suppose that in the midst of the Great Depression people expected it to last for several years. All these priors are specified as distributions, and Table 1 provides information on this. Observe that the values of $\sigma^2_{\pi,t}$ and $\sigma^2_{Y,t}$ measure how much we want to match the data against the priors. The measurement error is there only for computational reasons. I assume that it is extremely small such that the estimation hits the data very accurately

I use a Metropolis algorithm to simulate the posterior distribution (31) . Let y^Tdenote the set of available data and Ω the vector of coefficients and shocks. Moreover, let Ω^j denote the jth draw from the posterior of Ω. The subsequent draw is obtained by drawing a candidate value, $\tilde{\Omega}$, from a Gaussian proposal distribution with mean Ω^j and variance sV. We then set $\Omega^{(j+1)} = \tilde{\Omega}$ with probability equal to

$$\min\{1, \frac{p(\Omega/y^T)}{p(\Omega^j/y^T)}\}.$$

If the proposal is not accepted, we set $\Omega^{(j+1)} = \Omega^j$.

The algorithm is initialized around the posterior mode, found using a standard Matlab maximization algorithm. We set V to the inverse Hessian of the posterior evaluated at the mode, while s is chosen in order to achieve an acceptance rate approximately equal to 25 percent. We run two chains of 100,000 draws and discard the first 20,000 to allow convergence to the ergodic distribution.