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Can tax cuts deepen recessions?[1]

May 2009
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— (Preliminary) —

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 the recession because it encourages people to save instead of spend when more spending is needed. Policies aimed directly at stimulating aggregate demand work better. These policies include (i) a temporary increase in government spending, (ii) tax cuts directly aimed at stimulating aggregate demand rather than aggregate supply, such as an investment tax credit or a cut in sales taxes and (iii) a commitment to inflate. The results derived are special to an environment in which the interest rate is zero.

Key words: tax and spending multipliers, zero interest rates, deflation
JEL classification: E52

[1] This paper was written following an interesting email exchange with Gregory Mankiw about my paper "Was the New Deal Contractionary?" I thank Matthew Denes for outstanding research assistance. I also thank Larry Christiano and Mike Woodford for several discussions on this topic. Disclaimer: This paper presents preliminary findings and is being distributed to economists and other interested readers solely to stimulate discussion and elicit comments. The views expressed in the paper are those of the author and are not necessarily reflective of views at the Federal Reserve Bank of New York or the Federal Reserve System. Any errors or omissions are the responsibility of the author.

Table 1

	Labor tax Multiplier	**Government Spending Multiplier**
Positive interest rate	0.11	0.45
Zero interest rate	-0.71	2.1

1 Introduction

The economic crisis of 2008 started one of the most heated debates about US fiscal policy in the past half a century. With the Federal Funds rate close to zero – and output, inflation and employment on the edge of a collapse – US based economists argued over alternatives to interest rate cuts to spur a recovery. Meanwhile, several other central banks slashed interest rates close to zero, such as the European Central Bank, Bank of Japan, Bank of England, the Riksbank of Sweden, 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), Mankiw (2008)) or tax cuts on capital (see e.g. Feldstein (2009), Barro (2009)). Others emphasized an increase in government spending (see e.g. Krugman (2008), De Long (2008)). Yet another group of economists argued that the best response would be to reduce the government, i.e. reducing *both* taxes *and* spending.[2] Even if there was no professional consensus about the right fiscal policy, the recovery bill passed by US Congress in 2009 marks the largest fiscal expansion in US economic history since the New Deal, with projected deficits in double digits. Many governments followed the US example, while others, such Germany complained about US' "crass Keynesism". Much of this debate was, explicitly or implicitly, within the context of old fashion Keynesian models or the frictionless neoclassical growth model.

This paper takes a standard New Keynesian dynamic stochastic general equilibrium model (DSGE), that by now has become standard in academic journals and 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 (which explains the different findings reported in a recent paper by Cogan, Cwik, Taylor and Wieland (2009)). 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 the recent public discussion. Cutting taxes on labor or capital is *contractionary* under the special circumstances the US is experiencing today. Meanwhile, the effect of temporarily increasing government spending is large, much larger than under normal circumstances. Similarly, some other form of tax cuts, such as a reduction in sales taxes and investment tax credits, as first suggested by Feldstein (2002) in the context of Japan's "Great Recession", are extremely effective.

[2] This group consisted, for example, of 200 leading economist, including several Nobel prize winners, that signed a letter prepared by the Cato Institute.

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 one percent or increases government spending by one 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, it becomes four times larger. This illustrates that empirical work on the effect of fiscal policy based on data from the post war period, such as the much cited work of Romer and Romer (2008), cannot be used to draw reliable conclusions about the effect of fiscal policy on output today. Interest rates were 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 only to a limited extent rely on experience. Reasonably grounded theory may be a better benchmark.

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, and thereby increase the real interest rate. The Fed can't accommodate this by cutting the Fed Funds rates, since they are already close to zero. Higher real interest rates are contractionary. I use labor tax cuts as a starting point, not only because of its prominence in the policy discussion but to highlight a general principle for policy in this class of models, that by now have become standard. 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. Then 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 straight forward to consider a host of other fiscal policy instruments, whose effect at first blush may seem counterintuitive. Consider first the idea of cutting taxes on capital, another popular policy proposal in response to the crisis of 2008. Permanent reduction in capital taxes increases investment and the capital stock under normal circumstances. This increases the production capacities of the economy. More shovels and tractors, for example, means that people can dig more and bigger holes. This increases steady state output. But at zero interest rates the problem is not that the production capacity of the economy is too little. Instead it 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 peoples' incentive to save would in turn increase aggregate savings and investment. But because everyone starts saving more, this 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 memory may recognize here the classic Keynesian *paradox of thrift* (see Christiano [2004])[3].

From the same general principle – that the problem is insufficient demand so production is below capacity – 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 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 that 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 to increase 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, that can be financed by a temporary increase in labor and/or capital taxes. There are, however, some reasons outside the model suggesting that an increase in labor and capital taxes may be unwise and/or impractical, implying that a temporary budget deficits to finance a stimulus plan can be justified, as further discussed in the paper and the footnote.[4]

This paper builds on 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 (2003,2004), Christiano (2004), Wolman (2005), Eggertsson (2006,8), Adam and Billi (2006) and Jung et al (2006).[5] The analysis of the

[3] 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).

[4] The contractionary labor tax cuts studied, although entirely standard in the literature, are quite special in many respects. They corresponds to variations in linear tax rates on labor income, while some tax cuts on labor income in practice resembles 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 fashion Keynesian models, and as modelled 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 of 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 on capital.

[5] This list is not nearly complete, see Svensson (2003) for an excellent survey of this work. All these papers

variations in labor taxes builds on Eggertsson and Woodford (2004) that study Value Added Taxes (VAT) that show up in a similar manner. A key difference is that while they mostly focus 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 a 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.[6] The contractionary effect of cutting payroll taxes is closely related to Eggertsson (2008b) that 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 builds on Christiano (2004) and Eggertsson (2004,2006) that also 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 often suggested.[7]

2 A Microfounded Model

This section summarizes a standard New Keynesian DSGE model.[8] 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 stochastic nominal contracts 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 which will be the baseline illustration. The baseline model abstracts from capital but section 8.2 extends the model to include it.

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

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

treat the problem of the zero bound as a conseqence 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), and considered fiscal rules that eliminate those equilibria.

[6] Committing to future inflation may not be so trivial in practice. As shown by Eggertsson (2006), 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 to understand the properties of fiscal policy in the "worst case" scenario if monetary authorties are unable and/or unwilling to inflate.

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

[8] See .e.g. Clarida Gali and Gertler (1999), Benignio and Woodford (2003), Smets and Wouters (2007), Christiano, Eichenbaum and Evans (2005), and Woodford (2003) for a textbook treatment.

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, $P_t \equiv \left[\int_0^1 p_t(i)^{1-\theta} di\right]^{\frac{1}{1-\theta}}$, $l_t(j)$ 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, $u(.)$ 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 budget constraint can then be written as

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

where $Z_t(i)$ is profits that are distributed lump sum to the households. I do not model optimal stock holdings of the households, this could be done without changing the results.[9] There are four 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 riskfree 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 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 the 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. The household takes prices and wages as given and maximizes utility subject to the budget constraint by its choice $c_t(i)$, $l_t(j), B_t$ and $Z_t(i)$ for all j and i at all times t.

There is a continuum of firms of 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 the 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 assume 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), suppose that each industry has an equal probability of reconsidering its price each period. Let $0 < \alpha < 1$ be the fraction

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

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 price in stores of exactly the amount of the tax cuts for firms that have not reset their price. An equilibrium can now be defined as a set of stochastic processes that solve the maximization problem of the household and the 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 only report a first order approximation of these conditions in the next section and show how the model is closed in the approximate economy. 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 I have used the aggregate resource constraint 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

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

where i_t is the one period risk-free nominal interest rate[10], π_t is inflation, r_t^e is an exogenous shock and E_t is an expectation operator and the coefficient is $\sigma > 0$[11]. $\hat{Y}_t$ 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, and $\hat{\tau}_t^A$ is log deviation from steady state[12] and r_t^e is an exogenous disturbance.[13] The aggregate supply (AS) is

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

[10] 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 non-negative.

[11] 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.

[12] 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 correspond to percent deviation in annual capital income taxes so that it corresponds to $\hat{\tau}_t^A \equiv 4 * (1-\beta)\log\{\tau_t^A/(1-\bar{\tau}^A)\}$

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

where the coefficients $\kappa, \psi > 0$ and $0 < \beta < 1$.[14] Without going into details about how the central bank implements a desired path for the nominal interest rates it is assumed 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

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

where the coefficients $\phi_\pi > 1$ and $\phi_y > 0$. For a given rule 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).[15]

4 An output collapse at the Zero Bound

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 most simple 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 want to save more so that the real interest rate has to decline for output to stay constant. More sophisticated interpretations are possible, however. Eggertsson and Curdia (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 rate and a interest rate paid on risky loans. Both rates are observed in the data. The wedge implied by these interest rates exploded in the US economy during the crisis of 2008, giving empirical evidence for a large negative shock to r_t^e. A banking

[14] See second to last footnote.

[15] 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 seems like the most natural first step.

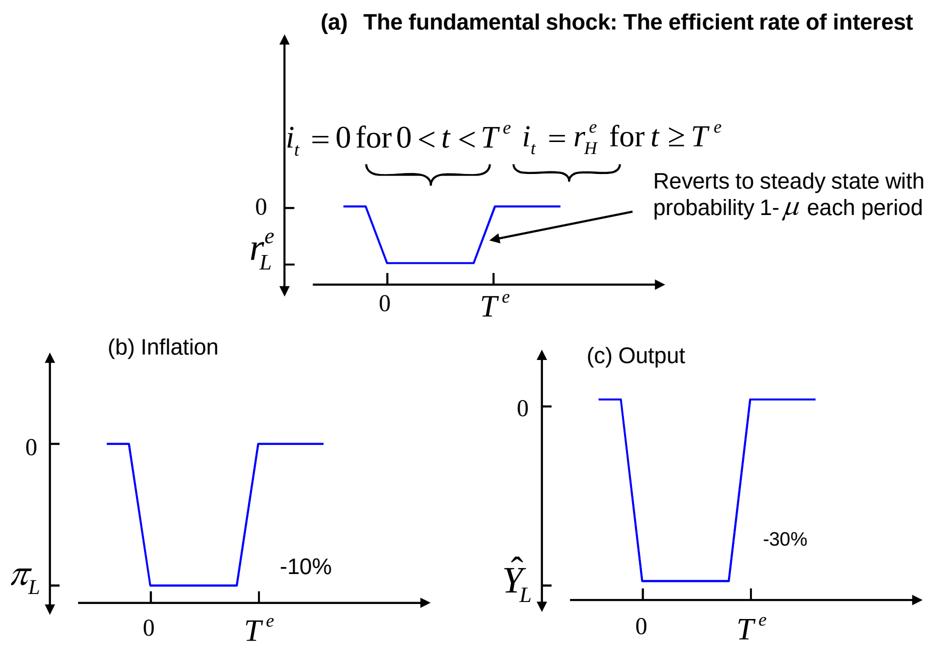

Figure 1: The effect of negative r_t^e on output and inflation.

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 $\hat{\tau}_t = \hat{G}_t = 0$. It is easy to show that monetary policy now takes the form

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

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

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

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

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

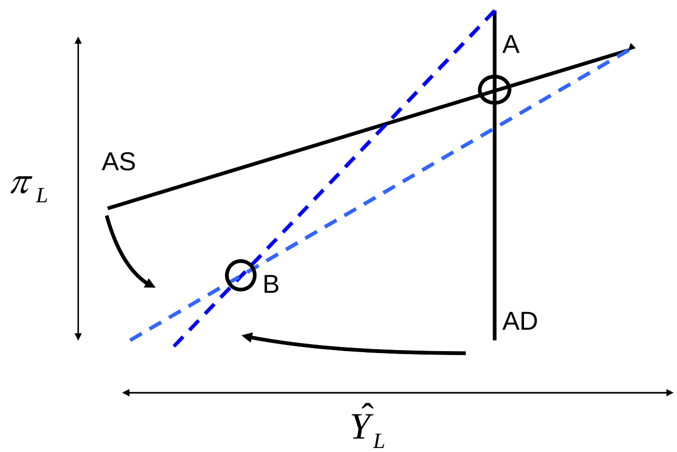

Figure 2: The effect of multiperiod recession.

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_L^e reverts back to steady state in period 1 with probability 1. This case is shown in Figure 2. It only applies 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_t^e.[16] For a given level of output, then, inflation is determined by where the AD curve intersects the AS curve. Its worth emphasizing again: *Output is completely demand determined, i.e. 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.,

[16] A higher efficient rate of interest, r_L^e, 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 CE curve. Note that the key feature of assumption A1 is that we are considering a shock that results in a negative efficient interest rate, that 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 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. If 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 (2008a)).

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 CE 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.[17] Note the role of the aggregate supply, or the AS equation. It is still really just 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 is what makes tax policy so tricky as we soon will see. It is also the reason why government spending and sale-tax cuts have such a big effect.

[17] Observe the vicious interaction between the contractionary forces in the CE and FE 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 FE equation reduces expected inflation so that we have to have $\pi_L < \pi_L^A$. Due to the expected deflation term in the CE 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 FE equation, triggering even further deflation, and thus triggering a further drop in output according to the CE 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.

To summarize, solving the AD and AS equations with respect to π_t and $\hat{Y}_t$, we obtain (the footnote comments on why the denominator has to be positive)[18]

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

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

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 in 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 10 percent deflation in the r_L^e state. Both these numbers correspond to the through of the Great Depression in the first quarter of 1933 before FDR 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	β	ω	α	θ	ϕ_π	ϕ_y
parameters	0.88	0.99	1.5	0.77	12.5	1.5	0.25

	r_L^e	μ
Shocks	-0.01	0.9

5 Why labor tax cuts are contractionary

Under normal circumstances a payroll-tax cut is expansionary in the baseline model. Consider a 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

[18] The vicious dynamics described in last footnote amplify the contraction without a bound as μ increases. As μ increases, the CE curve becomes flatter and the FE 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 0 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.

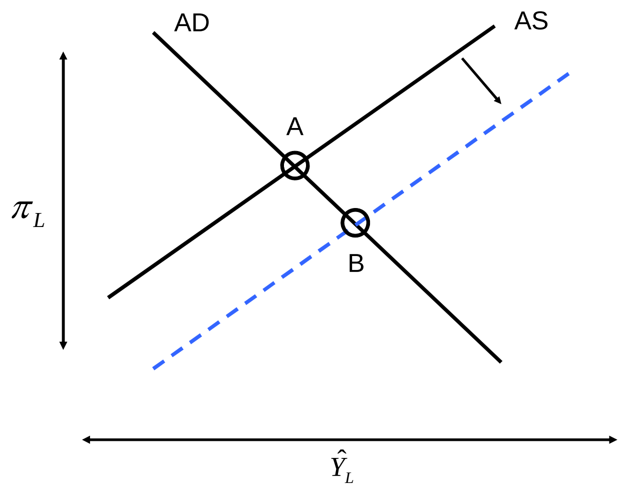

Figure 3: The effect of cutting taxes at a positive interest rate.

state $\hat{\tau}^w_t = 0$. (This assumption will be convenient for comparisons). Call the date the tax cut reverses to steady state T^τ. Let $\hat{G}_t = \hat{\tau}^s_t = \hat{\tau}^A_t = 0$. Because the model is perfectly forward looking this allows us to collapse the model into only two states, the "low state" when $\hat{\tau}^w_L < 0$ and the "steady state" when $\hat{\tau}^w_t = \hat{\tau}^w_H = 0$. Observe 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

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

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

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 because now people want to work more since they get more money in their pocket for each hour worked. In response the central bank accommodates this shift by cutting interest rates in order to curb deflation – this is why the AD equation is downward sloping.[19] A new equilibrium is found at point B. We can compute the multiplier of tax cuts by using method of undetermined coefficients.[20] The tax cut multiplier is

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

[19] A case where the central bank targets a particular inflation rate, say 0, corresponds to $\phi_\pi - > \infty$. IN this 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.

[20] Note that the two-state markov process we assumed gives the same result as if we 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.

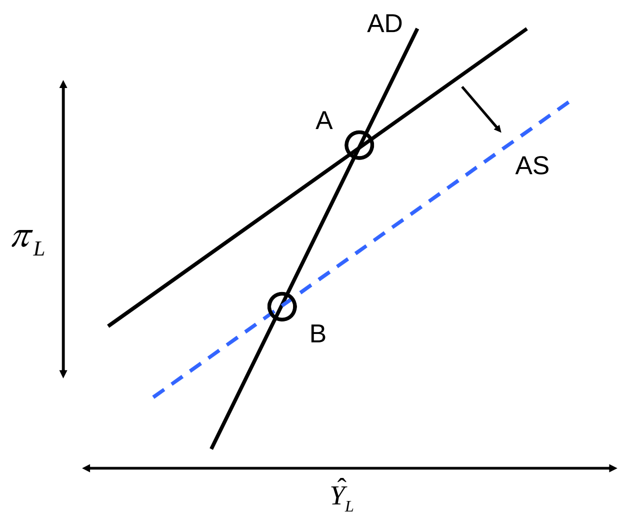

Figure 4: The effect of cutting taxes at a zero interest rate.

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 $\rho = \mu$. Then the multiplier is 0.12. If the government cut the tax rate $\hat{\tau}_L^w$ by 1 percent in a given period, this increases output by 0.097 percent. We can also translate this into dollars. Think of the tax cuts in terms of dollar cut in tax collection in the absence of shocks, i.e. tax collection in "steady state". Then the meaning of the multiplier is then that each dollar of tax cuts buys you 0.097 cents increase in output.

Let us now consider the effect of payroll tax cuts when the zero bound is binding. In particular, consider a temporary tax cut aimed at ending the recession. Assume the tax cut takes the form

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

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. Output and inflation again solve the AD and AS equations. While the AD equation is unchanged, the AS equation is now

$$\pi_L = \kappa \hat{Y}_L + \beta \mu \pi_L + \kappa \psi \hat{\tau}_L^w \tag{18}$$

where the tax appears on the right-hand side. An increase in $\hat{\tau}_L^w$ shifts the AS curve outwards denoted by a dashed line in Figure 4. Why does the AS curve shift? This is just a traditional shift in "aggregate supply" outwards. Consider a reduction in taxes. The firms are now in a position to charge lower price on their products than before. This suggests that they will reduce their prices relative to the prior period for any given level of production in the recession state, hence shifting the AS curve. 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 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 equation together to yield

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

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

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

$$\frac{\Delta\hat{Y}_L}{-\Delta\hat{\tau}_L^w} = -\frac{\mu\kappa\sigma\varphi}{(1-\mu)(1-\beta\mu)-\mu\sigma\kappa} < 0 \tag{19}$$

Using the numerical values in Table 2 this corresponds to a multiplier of -0.73. It means that if the government reduces taxes rate $\hat{\tau}_L^w$ by 1 percent at zero interest rates, then aggregate output declines by -0.73 percent. To keep the multipliers (15) and (19) 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 in the model without capital

	Multiplier $i_t > 0$	Multiplier $i_t = 0$
τ_t^w(Payroll Tax Cut)	0.097	-0.73
G_t^S(Government Spending 1 Increase)	0	0
G_t^N (Government Spending 2 Increase)	0.33	2.12
τ_t^S (Sales Tax Cut)	0.37	2.41
τ_t^K (Capital Tax Cut)	-0.012	-1.15

6 Why government spending can be expansionary

Let us now consider the effect of government spending. First consider the effect of increasing $\hat{G}_t^S$. It is immediate from our derivation of the model in section 3 that increasing government spending that is a perfect substitute to private spending has no effect on output or inflation. The reason for this 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 $\hat{G}_t^N$, that makes no reference to the policy choice of $\hat{G}_t^S$. Let us now turn to government spending that is not perfect substitute with private consumption, $\hat{G}_t^N$.

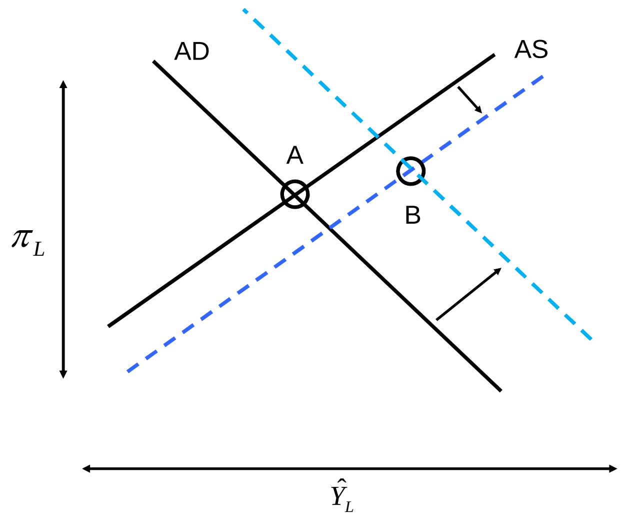

Figure 5: Increasing government spending at positive interest rates

Consider first 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

$$(1-\rho+\sigma\phi_y)\hat{Y}_L = -\sigma(\phi_\pi - \rho)\pi_L + (1-\rho)\hat{G}_L^N \tag{20}$$

$$(1-\beta\rho)\pi_L = \kappa\hat{Y}_L - \kappa\psi\sigma^{-1}\hat{G}_L^N \tag{21}$$

The experiment is shown in Figure 5. It looks identical to a standard undergraduate text book 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 to make up for lost consumption, shifting out labor supply and reducing real wages. This effect is shown by the outward shift in the AS curve in the figure. 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 3 times bigger than the multiplier of tax cuts at positive interest rates.

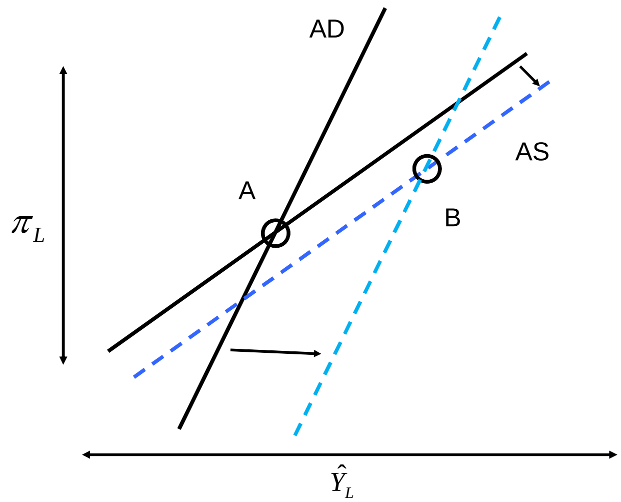

Figure 6: The effect of increasing government spending at zero interest rates.

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:

$$\hat{G}_t^N = \hat{G}_L^N > 0 \quad \text{for} \quad 0 < t < T^e \tag{22}$$

$$\hat{G}_t^N = 0 \quad \text{for} \quad t \geq T^e \tag{23}$$

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.[21] The AD and AS equations can be are written as:

$$\hat{Y}_L = \mu \hat{Y}_L + \sigma \mu \pi_L + \sigma r_L^e + (1-\mu)\hat{G}_L^N \tag{24}$$

$$\pi_L = \kappa \hat{Y}_L + \beta \mu \pi_L - \kappa \psi \sigma^{-1} \hat{G}_L^N. \tag{25}$$

Figure 6 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 because there is 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 one. Solving (24) and (25) together yields the following multiplier[22]

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

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

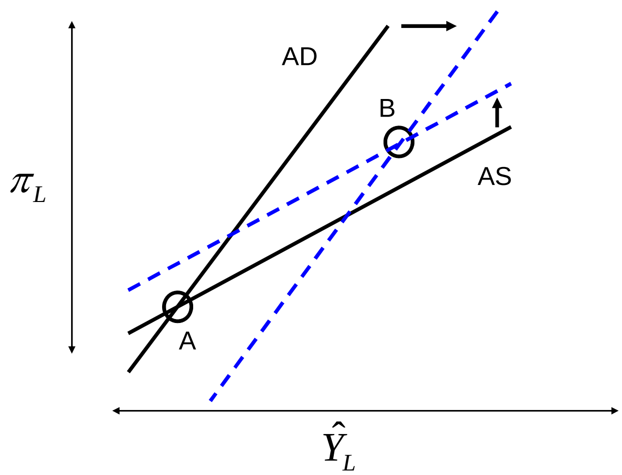

Figure 7: Commitment to inflate at zero nominal interest rates

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

i.e. one dollar of government spending, according to the model, has to increase output by more than one. In our numerical example the multiplier is 2.12, i.e., each dollar of government spending increases aggregate output by 2.12 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 fashion Keynesian models.

7 The case for a sale tax holiday

Not all tax cuts are contractionary in the model. Perhaps the most straight forward expansionary on is a cut in sales taxes.[23] Observe that according to the AD and AS equation (3) and (4)

[23] This is essentially Feldstein's (2002) idea in the context of Japan, although he suggested that Japan should *commit to raise future VAT taxes*. As documented below, there are some subtle reasons for why VAT tax may not

the sales tax enters these two equations in exactly the same form as the negative of government spending, except 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 both use 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 tax makes consumption today relative to the future cheaper and thus stimulates spending that way. Observe also that it increases labor supply because people want to work more because their marginal utility of income is higher. The relative impact of a one percent decrease in the sale tax versus a one percent increase in spending depends on σ and in the baseline calibration, because $\sigma < 1$, sales tax cuts have a bigger effect in the numerical example.

One question of practical importance is if reducing the sales taxes temporarily is in itself 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 sales tax rate of 12.5 percent. Since sales takes in the US are typically in range 3-8 percent (depending on states) this would imply a *sales-subsidy in the model*. A subsidy for consumption is impractical, since 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 to eliminate the recession in the model. Another complication with sales taxes in the US is that it is collected by each individual states, so it might be politically complicated to use it 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 taxes of the kind common in Europe enter the model differently than American sales taxes, because of how VAT taxes 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 one percent reduction in the tax will mean that the customer faces 1 percent lower purchasing price for the goods they purchase 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 taxes, however, because posted prices usually include the price (often by law). Let us then suppose the other extreme, as in Eggertsson and Woodford (2004), that the prices the firm post are inclusive of the tax. In this case if there is a one percent decrease in the VAT tax, 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 tax shows up in the AS and AD equation exactly in the same way as the *pay-roll 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 taxes work in exactly

be well suited for this proposal because of how they typically interact with price frictions.

the opposite way, at least if we assume the pricing decisions of firms are made inclusive of the tax. The intuition for this difference is straight forward. Sales tax cuts stimulates spending because a cut implies an immediate drop in the prices of goods the consumers face and they expect them to be relatively higher as soon as the recession is over. In contrast, because VAT taxes are included in the posted price, eliminating them will only show up in prices 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 and capital

8.1 Baseline specification: Why cutting taxes on capital is contractionary

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 the households. In the baseline specification I included a tax which 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 only appear in the consumption Euler equation (AD) through τ_t^A.

At positive interest rate, again consider 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 savings today is now relatively more attractive than before and this will encourage household to save instead of consuming. This means that the AD curve shifts backwards in Figure 3, leading to 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 equal to -0.012 in our numerical example, a small number. Recall that in reporting this number I have scaled $\hat{\tau}_L^A$ so that a one 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 footnote 12).

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 backwards 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 -1.15 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 -1.15 percent.

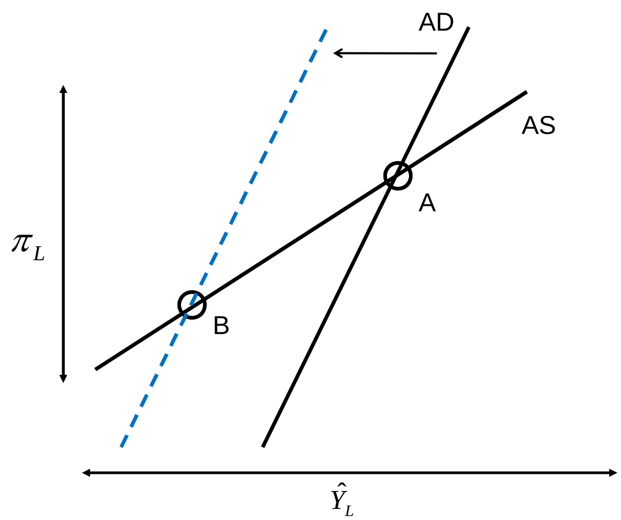

Figure 8: The effect of cutting capital taxes.

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 rate by cutting the nominal interest rates so the degree to which this is contractionary at positive interest rates depends on the reaction function of the central bank.[24] 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 US 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 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 rate 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 US. Hence this tax instrument cannot be used absent institutional changes. It follows that the government would need to rewrite the tax

[24] 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.

code and directly tax saving 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 only reduced the willingness of consumers to consume at given prices without affecting investment spending or the production capacity of the economy. The next section considers how our results change by explicitly modeling investment spending. This enriched model, however, precludes closed form solutions, which is why I abstracted from capital accumulation it 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 we find will fall in response to tax cuts.

8.2 Endogenous capital, expansionary investment tax credit and the paradox of thrift

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 a firm specific capital. Following Christiano (2004) and Woodford (2005), 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

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

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 (2005). Accordingly the description of the model below is brief [readers can refer to these authors for details].

Here $I_t(i)$ represents to 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 profits is

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

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

$$\tau_t^P[p_t(i)y_t(i) - P_t n_t(i)h_t(i) - P_t d(\frac{p_t(i)}{p_{t-1}(i)}) - (1+\tau_t^I)(1+\tau_t^s)P_t I_t(i)]$$

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.

$$\begin{aligned} &-\phi^I(I_t^N(i),\xi_t)(1-\tau_t^P(1+\tau_t^I))(1+\tau_t^s) \qquad (26)\\ &+E_tQ_{t+1}\Pi_{t+1}[\rho_{t+1}(i)+\phi I(I_{t+1}^N(i),\xi_{t+1})I_{t+1}^N(1-\tau_{t+1}^P(1+\tau_{t+1}^I))(1+\tau_{t+1}^s)-\phi(I_{t+1}^A(i),\xi_{t+1})] \end{aligned}$$

where

$$\rho_t(i) \equiv \frac{\gamma}{1-\gamma}\frac{l_t(i)}{K_t(i)}W_t(j)\frac{1-\tau_t^w}{1+\tau_t^s} \qquad (27)$$

Below I summarize the equations of the model that define an equilibrium once that model has been approximated around steady state[25]

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

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

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

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

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

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

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

where $\kappa_K, \nu, \sigma_I, \chi$ are coefficients greater than zero.[26] 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 and consumption spending depends 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 to 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 and consumption spending in the same way.

The calibration reported here is a bit preliminary and mostly done to compare to previous sections, hence the quantitative results are only suggestive. Future work will use an identical

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

[26] 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 two 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 (2005), it solves a polynomial defined in that paper.

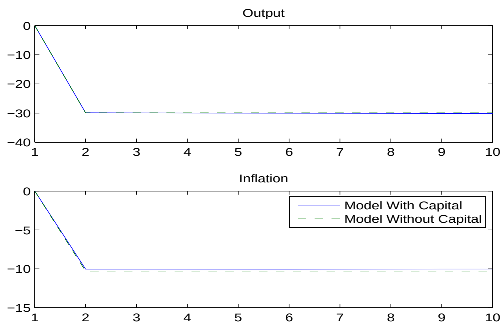

Figure 9: Comparing the model with and without capital

calibration strategy as in the model without capital. To calibrate the model I assume the same coefficients as in the model without capital, i.e. I choose parameters so that ω, σ β, κ correspond to one another in the two models and assume the same value for shocks. I then need to choose values for τ^P, γ, λ and ϕ_{II}. The values are summarized in Table 4. The parameters λ and γ are taken from the literature but the values for ϕ_{II} is chosen so that output in quarter 4 of the "contraction" is -30 percent. Figure 9 compares the dynamics of output and inflation in the model with and without endogenous capital stock. They are almost identical. To achieve this fit the degree of capital adjustment is relatively high, so that the collapse in investment spending is "only" 25 percent, which is a bit below what is observed in the data. Future work aims at a more systematic analysis of the model, taking investment data more explicitly into account. 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. I suspect the main reason for this is that I have added a similar shock to the investment Euler equation as 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 extensions given the calibration strategy just described. As the table reveals, they do not change much.

While preliminary, there are several things interesting with this extension apart from confirming the robustness of the previous analysis. Endogenous investment allows us to consider one alternative instrument, i.e. investment tax credit. Table 5 shows the multiplier of a tax credit. It shows that a tax credit which allows firms to deduct one additional percent on top of the purchasing price of their investment from taxable profits would lead to 0.05 percent increase in output. This expansionary effect is because an investment tax credit gives firms an incentive to invest today relative to in the future, thus stimulating spending.

Another interesting statistic is to explore 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 one percent decrease in $\hat{\tau}_t^A$ at zero interest rates will instead lower investment by 0.08. The main reason for this 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 savings 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, although it is much smaller, 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 in the model 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	472.36	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	-0.8
G_t^S(Government Spending 1 Increase)	0	0
G_t^N (Government Spending 2 Increase)	2.12	2.26
τ_t^S (Sales Tax Cut)	2.41	2.09
τ_t^A (Capital Tax Cut)	-1.15	-1.10
τ_t^P (Capital Tax Cut)	—	-0.08
τ_t^I	—	0.05

9 The scope for monetary policy: A Commitment to Inflate and Credibility Problems

Finally 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 e.g. 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:

$$i_t = \max\{0, r_t^e + \pi^* + \phi_\pi(\pi_t - \pi^*) + \phi_y(\hat{Y}_t - \hat{Y}^*)\} \tag{28}$$

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), $M_t/P_t \geq \chi\hat{Y}_t$ where M_t is the money supply and $\chi > 0$. Then 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 write out the FE and CE equations in periods $0 < t < \tau$ when the zero bound is binding:

$$AD \qquad \hat{Y}_L = \mu\hat{Y}_L + (1-\mu)\hat{Y}^* + \sigma\mu\pi_L + \sigma(1-\mu)\pi^* + \sigma r_L^e \tag{29}$$

$$AS \qquad \pi_L = \kappa\hat{Y}_L + \beta\mu\pi_L + \beta(1-\mu)\pi^* \tag{30}$$

Consider the effect of increasing $\pi^* = 0$ to a positive number $\pi^* > 0$. As shown in Figure 7 this shifts the CE curve to the right and the FE curve to the left, increasing both inflation and output. The logic is straight forward: 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^* does not only increase inflation expectations at dates $t \geq T^e$, it 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 policymaker. 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 rate. 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.

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

Eggertsson (2004,6), who analyses the Markov Perfect equilibrium). The intuition is that fiscal policy does not only require promises about what the government will do in the future, it 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, especially for a central bank with a high degree of credibility, that a central bank can make credible announcements about its future policy and thereby have considerable effect on expectations. Moreover, many authors have analyzed explicit steps, such as expansion in the central banks 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 (2006) 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 is implied by the benchmark policy rule here, is a useful benchmark to study the usefulness of fiscal policy.

10 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 government spending is one approach. Another is a commitment to inflate. Ideally the two should be put together. Government spending has the advantage over inflation policy that is has no credibility problem associated with it. Inflation policy, however, has the advantage that it does not require 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 modelled 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, only has an effect through the incentive it creates for employment and thus "shifts aggregate supply", thus lowering real wages and stimulating firms to hire more workers. One can envision various environments in which tax cuts stimulate spending, such as old fashion Keynesian models, or models where people have limited access to financial markets. In those models there will be 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 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 as in Barro (1978). In that environment tax cuts are expansionary because they increase debt and through that inflation expectations.

What should we take out of all of this? There are two general lessons I want to draw 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 policymakers today should view with a great deal of scepticism any empirical evidence on the effect of tax cuts or government spending based on post war US 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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Parameters	Distributions		Priors			Posterior		Mode
		10%	50%	90%	10%	50%	90%	
alpha	Beta	0.59495	0.66121	0.72349	0.70251	0.74982	0.79321	0.76818
beta	Beta	0.9887	0.99003	0.99126	0.98874	0.99003	0.99124	0.99007
1-mu	1-Beta	0.042355	0.092403	0.16778	0.092712	0.12164	0.15849	0.10256
omega	Gamma	0.23642	0.82003	2	1.0103	1.8521	3.3185	1.5414
rL	Beta	-0.023026	-0.0069315	-0.0010536	-0.026662	-0.019011	-0.013327	-0.011851
sigma	Gamma	0.26685	0.4736	0.76728	0.63607	0.87312	1.1741	0.87832
theta	Gamma	4.4758	7.6283	12.004	8.7733	12.435	16.658	12.459

Figure 10: Priors and Posteriors and mode of parameters.

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12 Appendix A: The numerical example

Under the assumption about 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 try to match is that output is -30 percent and inflation at -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_L^e in the low state is equivalent to a 2 standard deviation shock to a process fitted to ex ante real interest rates in post-war data. While ex ante real rates would be an accurate measure of the efficient rate of interest only in the event output was 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 10 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 gives 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. I don't really do much with this, and just assume that this number is very small so the estimation hits the data very accurately. It would probably be cleaner to assume that (12) and (11) holds exactly (i.e. no measurement error) and explain the estimation in that way.

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.