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Fiscal Policy and the Inflation Target

Peter Tulip

RDP 2014-02

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Economic Research Department
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Author: tulipp at domain rba.gov.au

Media Office: rbainfo@rba.gov.au

Abstract

Low interest rates in the United States have recently been accompanied by large fiscal stimulus. However, discussions of monetary policy have neglected this fiscal activism, leading to over-estimates of the costs of the zero lower bound and, hence, of the appropriate inflation target. To rectify this, I include countercyclical fiscal policy within a large-scale model of the US economy. I find that fiscal activism can substitute for a high inflation target. An increase in the inflation target is not warranted, despite increased volatility of macroeconomic shocks, so long as fiscal policy behaves as it has recently.

JEL Classification Numbers: E52, E62

Keywords: fiscal policy, zero bound, inflation target

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Fiscal Policy and the Inflation Target

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1. Introduction

The US Federal Reserve has a long-run inflation target of 2 per cent (FOMC 2012). Many considerations influence this choice, but it partly reflects a trade-off: lower inflation has direct welfare benefits but it also means interest rates have a greater probability of falling to their lower bound of zero. The zero lower bound is a problem because it prevents the central bank from fighting recessions with large reductions in interest rates. So the economy would be less stable with a low inflation target. For this reason, some prominent economists, such as Blanchard, Dell’Ariccia and Mauro (2010) and Ball (2013), have argued for a higher inflation target.

Several researchers have quantified this argument. Most prominently, Reifschneider and Williams (2000) conduct stochastic simulations of the Federal Reserve’s FRB/US model and conclude that the zero lower bound noticeably increases the variability of economic activity for inflation targets below 2 per cent or so. Similar studies include Coenen, Orphanides and Wieland (2004), Hunt and Laxton (2004), and Williams (2009). Billi and Kahn (2008) provide an overview. This research has played a central role in the FOMC’s earlier consideration of appropriate inflation targets judging by the transcript and staff materials for the FOMC meeting of 1 February 2005 (FOMC 2005; Elmendorf *et al* 2005). These studies have been emphasised by policymakers such as Bernanke (2003) and Yellen (2009) in discussing their choice of inflation targets. Subsequent research by Coibion, Gorodnichenko and Wieland (2012) supports similar conclusions.

A limitation of much of the policy discussions and the underlying research is that they have assumed that fiscal policy is passive, doing little to stimulate the economy (beyond automatic stabilisers) when interest rates approach zero.¹ That assumption was consistent with both actual fiscal policy and expert policy

¹ I use the terms ‘active’ and ‘passive’ in their everyday sense of responsiveness to economic activity. This usage differs from Leeper’s (1991) well-known definitions in which fiscal policy is ‘active’ or ‘passive’ depending on whether it stabilises the debt.

recommendations until recently. However, as discussed below, there has been a renewed enthusiasm for active countercyclical fiscal policy on the part of both policymakers and advisers. The key finding of this paper is that this new fiscal activism substantially reduces the frequency and severity of hitting the zero bound. By itself, that should significantly lower the inflation target, although increases in perceived macroeconomic volatility operate in the other direction.

Specifically, I develop a fiscal policy reaction function that explains recent US fiscal policy at the zero bound. I then include this rule within the FRB/US model, which is a large-scale model of the US economy maintained by the staff of the Federal Reserve Board, and run stochastic simulations. These simulations suggest that realistic countercyclical fiscal policy permits substantially lower inflation targets for a given variability of activity. For example, I estimate that a 2 per cent inflation target is consistent with a standard deviation of unemployment of 1.4 percentage points when fiscal policy is passive; but if fiscal policymakers behave as they have recently, then the same variability of unemployment could be achieved with a target of zero inflation.

In choosing an inflation target, the central bank needs to assume how fiscal policymakers and other agents will behave. My central scenario assumes that fiscal policymakers behave as they have recently. However, given the controversy over this issue, attitudes to fiscal activism might be expected to evolve. Accordingly, in Section 5, I consider two alternatives to my central scenario. It may be that the recent shift toward fiscal activism is reversed and that the passivity assumed by the earlier literature remains a good guide. If the central bank does not feel it can rely on fiscal stimulus at the zero bound, it should set a higher inflation target. Alternatively, it may be that future recessions are accompanied by larger and earlier fiscal stimulus. For example, if fiscal policy were assumed to be twice as aggressive as it has been recently, then my simulations suggest that the zero bound would cease to be an important constraint on the inflation target.

The idea that fiscal activism might lower the inflation target is not new. For example, it is discussed by Reifschneider and Williams (2000), among others. However, this effect has not been realistically modelled and its effects have not been quantified or shown to be important. That may be why policy discussions and research have overlooked it. To put this in context, Yellen (2009), Blanchard

et al (2010), and others have emphasised the implications of changes in perceived macroeconomic volatility for the target. However, estimates I present below suggest that the change in fiscal policy is of similar importance for the inflation target as the change in volatility.

The previous analysis that comes closest to mine is Williams (2009, section III.B). As in this paper, Williams conducts stochastic simulations of FRB/US with different inflation targets, with and without countercyclical fiscal policy. However, Williams' interest is in whether fiscal stimulus might ameliorate worst-case scenarios: he applies it to a baseline in which the funds rate is at zero 34 per cent of the time (with a 2 per cent inflation target). In contrast, I focus on scenarios that resemble mainstream projections of the US economy. Furthermore, Williams' fiscal rule is illustrative rather than realistic. I develop a rule that is consistent with observed policy. Williams is frank about the limitations of his rule and calls for further research in this area. This paper is partly a response to that demand.

A secondary contribution of this paper is to develop an empirically-based reaction function that describes how US fiscal policy behaves near the zero bound. This may facilitate discussions of fiscal policy near the zero bound in the way the Taylor rule has done for monetary policy. Calibrating this rule to actual policy is important because one of the primary objections to the use of countercyclical fiscal policy has been that lags make it impractical (Blinder 2006). To be clear, precise estimation is not the goal, and would not be feasible. Rather, my rule is intended to roughly capture the size, timing and impact of the recent stimulus, which seems sufficient to assess the relative importance of various factors in different conditions.

Although the titles might suggest otherwise, this paper has little in common with the literature surveyed by Schmitt-Grohé and Uribe (2010) on 'the optimal rate of inflation'. Whereas in this paper the zero bound is of central importance to the inflation target, the research surveyed by Schmitt-Grohé and Uribe assumes that the zero bound is irrelevant. Schmitt-Grohé and Uribe justify this assumption by arguing that under *optimal* monetary policy the probability of hitting the zero bound is very low. However, the recent history of interest rates in the United States, Japan and other countries suggests that under *actual* monetary policy, the chances of hitting the zero bound are considerable.

To be clear, this paper is not intended to evaluate alternative policies for dealing with the zero bound. That issue has been addressed elsewhere by many authors, including Eggertsson and Woodford (2006), and Mankiw and Weinzierl (2011). Rather, I take actual monetary policy, as described by a conventional policy reaction function, as given. And I use a fiscal policy reaction function that describes recent behaviour. This paper examines the implications of these reaction functions for economic stability and the inflation target. Normative analysis of fiscal policy near the zero bound, including its size, timing and composition, would be highly desirable. However, a positive analysis of recent policy behaviour seems a desirable stepping stone and benchmark for that.

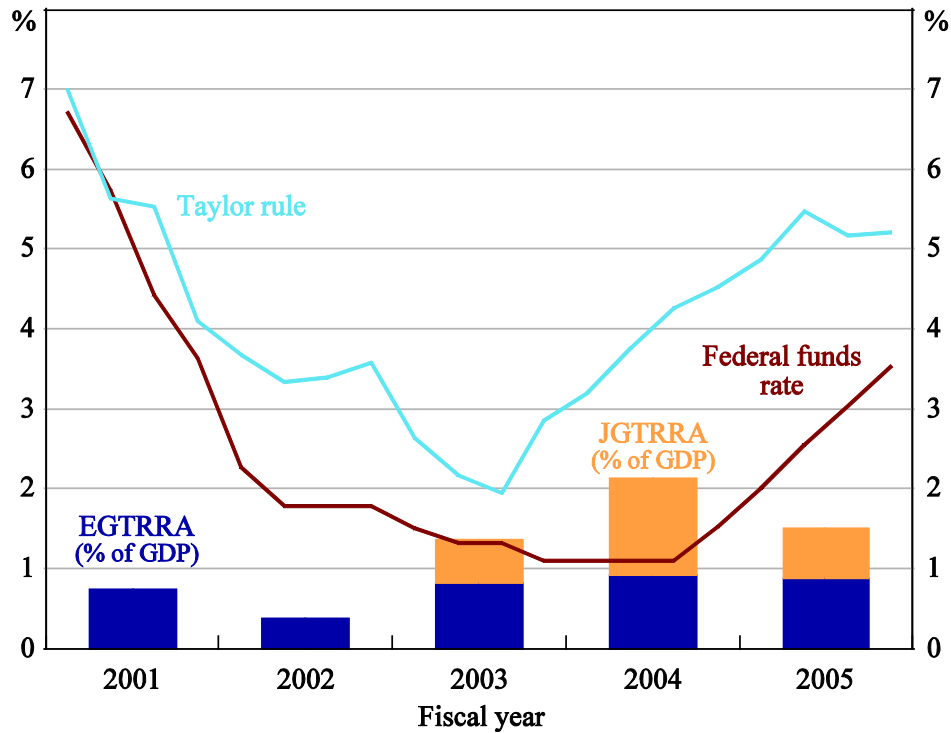
Similarly, this paper does not examine implications of recent innovations in monetary policy, such as asset purchases. The rationale for considering new developments in monetary policy is similar to that for considering new developments in fiscal policy, and the implications for the inflation target are qualitatively similar. I expect including asset purchases as an extra instrument of monetary policy would further allay concern about the zero bound, reinforcing one of my key results. But, at this stage, that conjecture remains to be verified.

2. The New Regime of Fiscal Activism

The United States has had two recent encounters with the zero bound on interest rates, in the early 2000s and following 2008. Both have been accompanied by large fiscal stimulus. This relationship is illustrated in Figures 1 and 2, which show interest rates and Congressional Budget Office (CBO) estimates of the budgetary costs of major legislation intended to boost aggregate demand. Figure 1 shows CBO estimates of the budgetary cost of the Economic Growth and Tax Relief Reconciliation Act, or EGTRRA, of 2001, and the Jobs and Growth Tax Relief Reconciliation Act, or JGTRRA, of 2003. Figure 2 shows CBO estimates of the budgetary cost of the stimulus Acts of 2008, 2009 and 2010 (formally, the Economic Stimulus Act of 2008; the American Recovery and Reinvestment Act, or ARRA, of 2009, and the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act, or TRUIRJA, of 2010). These comprise the main stimulus legislation enacted through mid 2011, with estimated effects shown through fiscal 2012. As discussed in Appendix B, I subtract the contribution of the alternative minimum tax from the CBO estimates. For comparison, the figures also show

estimates of a Taylor-type rule, described below, using estimates of the output gap from CBO (2011).

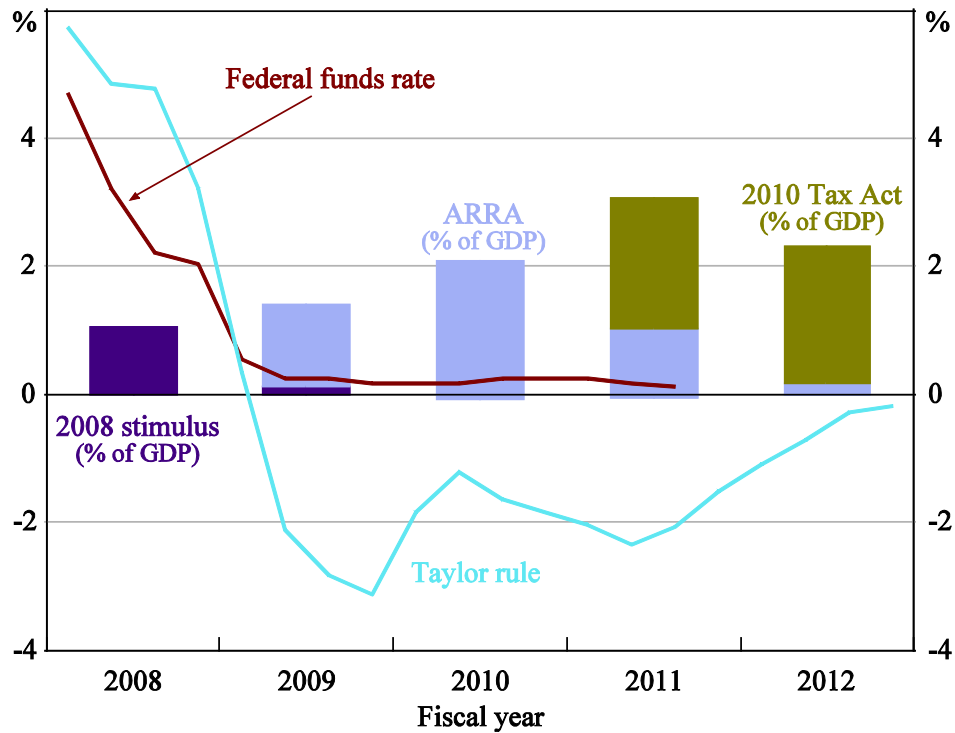
Figure 1: Fiscal Stimulus near the Zero Bound



Sources: Board of Governors of the Federal Reserve System; CBO (2001, 2003, 2011); author's calculations

Figures 1 and 2 also show that, in each episode, fiscal stimulus was delivered in a succession of distinct packages. So, although the number of observations is small, there has been a pattern of countercyclical activism. Furthermore, stimulus has been enacted during both Republican and Democratic administrations.

Discretionary fiscal policy has also been strongly countercyclical in other countries. The recent global recession was accompanied by discretionary fiscal measures in OECD economies averaging 3.4 per cent of annual GDP between 2008 and 2010 (OECD 2009, Table 3.1).

Figure 2: Fiscal Stimulus near the Zero Bound

Sources: Board of Governors of the Federal Reserve System; CBO (2008, 2009, 2011); JCT (2009); author's calculations

The turn to fiscal activism in the United States is new. In contrast to the two most recent business cycles, fiscal policy was neutral to contractionary in previous US recessions. Auerbach, Gale and Harris (2010) provide a narrative description of this shift, noting the explicit decisions of Congress to tighten fiscal policy in 1982 and 1990. A quantitative measure of the shift can be seen, for example, in Follette and Lutz's (2010, Table 6) estimates of fiscal impetus, an impact-weighted measure of the stance of fiscal policy. In the three years following the business cycle peaks of 1969, 1973, 1980, and 1990, federal fiscal impetus averaged 0.1 per cent of GDP, near its 'neutral' benchmark of about 0.2 per cent. In contrast, it averaged almost one per cent of GDP after the peaks of 2000 and 2007, using data through 2009.

One reason for considering the new fiscal activism to be structural is that it has been accompanied by a parallel change in policy advice. Many economists have explained that whereas they used to be sceptical of fiscal intervention, they now view it as desirable at the zero bound. Examples include DeLong (2011) and Krugman (2011). Surveys of the state of academic thought, such as Blanchard *et al* (2010) or David Romer (2011) suggest this change is widespread. In the

words of Becker (2009), ‘there appears to have been a huge conversion of economists toward Keynesian deficit spenders’. The evolution in advice partly represents new circumstances rather than a change in opinion. According to Summers (2010), ‘[m]ost economists across a broad spectrum’ simultaneously believe that fiscal stimulus is effective at the lower bound but that it is not effective in normal circumstances.

Given these developments, it would now seem sensible to consider the likely effects of large fiscal stimulus when the economy next approaches the zero bound. That requires modifications to the models used to estimate the effect of the zero bound, which do not include active countercyclical fiscal policy.

3. Modelling Countercyclical Fiscal Policy

What kind of fiscal policy should be expected when interest rates approach the zero bound? A natural benchmark is the recent stimulus. Recent behaviour is important as a guide to what is likely to occur in the future, as an illustration of what is practical, and as a familiar reference point for discussions of whether fiscal policy should do more or less. For these purposes, it is useful to describe this behaviour with a reaction function, or rule. As noted above, it is desirable that the rule is roughly consistent with the size and timing of the recent stimulus, though precise estimation is not necessary.

The role of a policy reaction function (whether fiscal or monetary) is sometimes misunderstood. It does not mean that policymakers forsake discretion or perceive themselves to be constrained. Commitment is not necessary. Rather, it simply assumes that their response to the recent recession will be repeated in future, in proportion to the severity of economic conditions. Nor does it mean that the rule reflects a well-accepted or understood set of principles. It more likely reflects a compromise, with which only the median policymaker agrees. The motivating assumption is that similar compromises may occur in the future.

My objective is to specify a rule that approximately fits the recent data subject to constraints that it be simple and not be obviously poor policy. A fiscal rule that is both realistic and sensible adds interest, avoids distractions, and is more likely to be stable, as policymakers are less likely to adhere to obviously flawed rules. The

multiple objectives do, however, sometimes involve trade-offs. Furthermore, while I believe my judgements as to what constitutes sensible countercyclical policy are in line with mainstream economics, others would make different assumptions. I discuss these specification choices below.

Countercyclical fiscal policy is desirable when monetary policy is likely to be constrained by the lower bound. A simple indicator of that likelihood would be a low value of the actual federal funds rate. However, because the funds rate does not fall below zero, it provides no indication of the severity with which the constraint binds. Accordingly, I tie stimulus to low values of a monetary policy rule. (Though I acknowledge that the actual funds rate has been a better indicator of fiscal stimulus sometimes – see, for example, the 2004 observation in Figure 1).

My main determinant of fiscal stimulus is a variation of the Taylor rule (often called a ‘Taylor (1999)’ rule) that previous studies have used as a baseline:

$$i_t = r + \pi_t + 0.5(\pi_t - \pi^*) + x_t \quad (1)$$

where i_t denotes the prescription of the rule, r is the equilibrium real interest rate, assumed to be 2.5 per cent, π_t is the four-quarter percentage change in core PCE prices, π^* is the inflation target, and x_t is the output gap with a coefficient of 1. The rule’s inflation target, π^* , is exogenous. It is assumed to be 2 per cent for constructing Figures 1, 2, and 3. This rule has attractive normative and positive properties (see Taylor (1999); Williams (2009)). Reifschneider and Williams (2000), Elmendorf *et al* (2005), and Williams (2009) present sensitivity analysis for alternative monetary rules.

Using a Taylor-type rule in my fiscal reaction function makes fiscal policy place the same weights on inflation and resource utilisation as monetary policy, so the two arms of policy work in concert. In contrast, Feldstein (2007) suggests that countercyclical fiscal policy should react to three-month changes in payroll employment, whereas Orszag (2011) would tie it to the unemployment rate. Feldstein’s measure would help to explain recent stimulus and has been a successful predictor of future variations in the Taylor rule. However, a problem with both suggestions is that they do not take account of inflation. For example,

weakness in the labour market during the early 1980s, in 1989, or 2000 reflected a need to reduce inflationary pressure, not a call for macroeconomic stimulus.

I assume fiscal stimulus occurs when, but only when, i_t falls to low levels. So countercyclical fiscal policy is not called for when interest rates are unconstrained. This imparts a nonlinearity that does not exist in some other fiscal rules, such as Auerbach and Gale (2009) and makes computation of model-consistent expectations difficult. The reason for the nonlinearity is that, as Taylor (2000), Blinder (2006), DeLong and Summers (2012) and others discuss, discretionary countercyclical fiscal policy is not attractive when interest rates are free to adjust. In those conditions, fiscal measures are offset by the monetary policy rule and so have little medium-term effect on demand. In addition to being ineffective, discretionary countercyclical fiscal policy can be costly – it distracts scarce attention, it blurs accountability, and execution can be distortionary or otherwise imperfect – and these costs are often judged to be not worth incurring when the multiplier is low.

However, that is not to say that fiscal stimulus should wait until the zero bound actually binds (in contrast to the rule in Williams (2009)). As interest rates decline toward zero, there is an increasing probability of hitting the constraint. Moving after this became certain would be unnecessarily late, given the asymmetry of policy mistakes. As Krugman (2008) has argued, too much fiscal stimulus can be undone by tighter monetary policy, so does little damage. Too little fiscal stimulus is not immediately correctable if interest rates are low, so means lower income and employment. Accordingly, I assume stimulus is proportionate to the amount the Taylor-type rule falls below a positive threshold. I assume a threshold of 2 per cent, a level below which hitting the zero bound becomes a serious probability.² This interest rate gap, \hat{i}_t is defined as

$$\hat{i}_t = \max\{2 - i_t, 0\} \quad (2)$$

Choosing a threshold of 2 per cent involves some trade-offs. A higher threshold would help explain the tax cuts of 2001 and 2008. In July 2001, households started

² Assuming a threshold of zero would remove an inequality condition, making it easier to compute model-consistent expectations. However, for reasons noted above, this would be neither realistic nor sensible policy: the stimulus would come too late.

receiving tax cuts worth 0.3 per cent of GDP, when the outcome of the Taylor-type rule stood at 4 per cent. In April 2008, households started receiving tax rebates worth 0.8 per cent of annual GDP, though the outcome of the Taylor-type rule again was 4 per cent. However, it is not clear that a higher threshold would be justified in terms of stabilisation policy. In particular, the 2001 tax cut was originally motivated by other objectives, though the recession that preceded its passage may have convinced pivotal members of Congress to support it. A more complicated rule would probably be needed to describe these developments. However, because fiscal policy needs to be understood and supported by the political/legislative process, the stimulus rule should be simple.

I explain d_t , the deviation from baseline of the deficit as a proportion of GDP, as a function of the lagged four-quarter average of the interest rate gap.

$$d_t = \beta \sum_{k=1}^4 \hat{i}_{t-k} / 400 \quad (3)$$

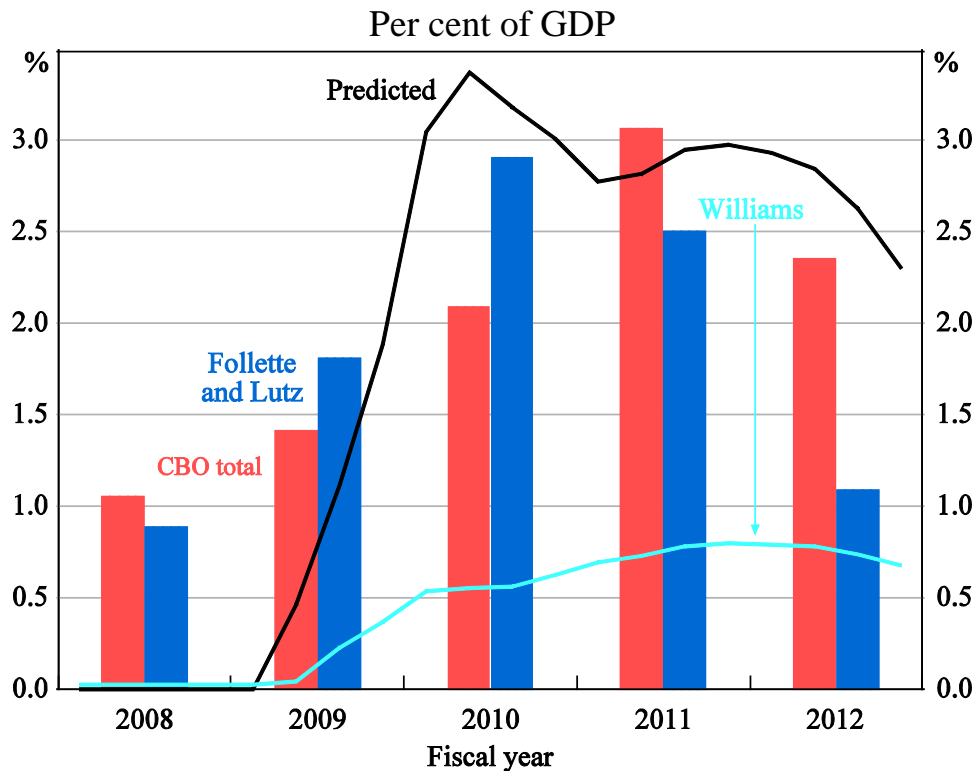
The lags help fit the data and reflect delays in policy implementation. The parameter β indexes the aggressiveness of fiscal policy. I show results for different values of β in Section 5.

Summers (2008) has argued that fiscal policy near the zero bound should be ‘timely, targeted and temporary’. As Johannes Wieland has pointed out in conference discussion, my rule follows Summers’ advice in principle, although perhaps not in detail. The rule is timely, in that stimulus begins before interest rates hit zero. It is targeted, in that stimulus responds endogenously to the depth and duration of the zero bound. And it is temporary, in that stimulus ends four quarters after interest rates rise above 2 per cent.

Figure 3 shows various estimates of recent stimulus, measured in terms of budget cost as a percentage of GDP. Predictions from Equation (3) are shown as the black line. These are constructed using projections of the output gap and inflation from CBO (2011). These predictions use a value of $\beta = 0.7$, which delivers a cumulative stimulus from 2009 to 2012 of 9½ per cent of annual GDP, which is close to estimates of the total legislated amount of stimulus. CBO-based estimates – that is, the sum of the three major acts shown in Figure 2 – are depicted by the red bars. These estimates imply a cumulative stimulus of 8.9 per cent (summing the 2009

and 2010 acts) or 9.9 per cent (if the Economic Stimulus Act of 2008 is included as well).

Figure 3: Alternative Measures of Fiscal Stimulus



Note: 'Follette and Lutz' updated for fiscal years and the 2010 Tax Act

Sources: CBO (2008, 2009, 2011); Follette and Lutz (2010); Williams (2009); author's calculations

The blue bars in Figure 3 show an alternative measure of fiscal stimulus by Follette and Lutz (2010), kindly updated for me by Glenn Follette, which I discuss in Appendix A. My rule also roughly approximates the Follette-Lutz estimates, which imply a total stimulus of 9.2 per cent of annual GDP from 2008 through 2012. A third alternative, by Blinder and Zandi (2010), which is not shown, estimates fiscal stimulus enacted through mid 2010 (not including the 2010 Tax Act) at about 7 per cent of annual GDP, marginally more than my estimates for the comparable period. Last, the light blue line in Figure 3 represents the fiscal rule modelled (before the

event) by Williams (2009), which implies a stimulus that is substantially smaller and later than the other estimates.³

For the 2001–2005 period, predictions of Equation (3) are zero, because the Taylor rule did not fall below 2 per cent. Nonetheless, that episode is relevant for establishing a pattern of fiscal activism at low interest rates. As noted above, I was unable to develop a stimulus rule that satisfactorily explained the fiscal expansion of the early 2000s. If the calibration were adjusted to place more weight on this episode, then my rule would imply bigger, earlier, stimulus going forward.

Having calibrated the total stimulus, I then distribute it over the federal fiscal equations of the model. I assume that stimulus d_t , is composed of 50 per cent reductions in personal taxes, 25 per cent increases in federal government consumption purchases, and 25 per cent increases in transfers to persons. This is a parsimonious approximation to recent behaviour, which avoids channels of influence where FRB/US modelling is not firmly guided by the available literature, such as changes in corporate taxes or in grants to states.^{4,5}

To illustrate, consider the equation for real transfers to persons, T_t .

$$T_t = \gamma z_t + s d_t GDP_{t-1} \quad (4)$$

z_t is a small vector of relevant model variables, which for this equation comprises the output gap, GDP, and a stochastic trend. γ is a vector of coefficients. s represents the share of the countercyclical stimulus d_t allocated to this instrument.

3 I interpret Williams' Equation (6) as describing the deviation of government consumption purchases (excluding employee compensation) from its trend, where the trend is 4 per cent of real GDP in 2010:Q4, then grows at 2.5 per cent. I use CBO estimates of the output gap and inflation, and the same Taylor-type rule I use elsewhere.

4 Updated estimates from Follette and Lutz suggest that federal fiscal stimulus from 2008 through 2012 comprised 31 per cent individual tax cuts, 24 per cent transfers, 18 per cent grants to state and local governments, 18 per cent corporate tax cuts, and 8 per cent 'other', largely federal government purchases. Largely reflecting their different baseline, Follette and Lutz's estimates include more transfers but smaller personal tax cuts than my CBO-based estimates.

5 Some readers have suggested the stimulus should comprise more spending and transfers, which have a higher 'bang-for-the-buck'. However, as discussed in Mankiw and Weinzierl (2011), that view is controversial.

So for federal taxes, transfers, and purchases, $s = 0.5$, 0.25 , and 0.25 respectively, while for other fiscal instruments, including those of state and local governments, $s = 0$. The variable GDP is self-explanatory.

The stimulus is added to equations for government spending and taxes in much the same way as in Equation (4), with slight modifications to prevent the endogenous persistence in these variables amplifying the stimulus. The modified fiscal equations of the model are presented, using FRB/US mnemonics, in Appendix B. I do not modify other equations in the model.

The γz_t terms in Equation (4) and corresponding equations for other fiscal variables capture the normal response of fiscal instruments to the output gap, inflation and other macroeconomic variables. Coefficients (including for state and local fiscal equations) are estimated from 1965 through 2007. Following previous researchers, I describe this response as ‘passive’ or ‘neutral’: reflecting automatic stabilisers but not discretionary fiscal policy. That terminology is not exactly accurate because the equations also capture variations that are systematic but require legislation. Indexation of the alternative minimum tax to inflation and extension of unemployment benefits in recessions are examples. However, even with these effects, overall cyclical variations in fiscal instruments tend to be small and offsetting. That result is consistent with the earlier absence of discretionary fiscal policy discussed above.

An important feature of the standard FRB/US fiscal equations is that personal tax rates adjust so as to gradually stabilise the ratio of government debt to GDP. This effect means that simulated episodes of stimulus are followed by episodes of austerity. More precisely, while government spending returns to baseline as the need for stimulus dissipates, personal tax rates temporarily rise above baseline. After the results in this paper were finalised, fiscal stimulus in the United States was followed by a ‘sequester’ that sharply reduced growth in outlays. Although the model did not predict the form of this fiscal consolidation, it did predict a substantial fiscal tightening, though comparing that with actual policy requires difficult judgements about the counterfactual. One implication of the debt-stabilisation term is that the long-run average ratio of debt to GDP is not materially affected by repeated stimulus. Another implication is that the relevant ‘counterfactual’ – that is, policy in the absence of fiscal stimulus – is what might

be called ‘sustainable policy’ rather than existing policy. The relevant estimates of recent fiscal stimulus are somewhat larger than would be constructed using a baseline of existing policy.

A key assumption underpinning my calibration of the stimulus rule is that the standard FRB/US fiscal equations approximately reflect the CBO’s baseline of existing legislation. If that assumption is approximately valid, then adding a stimulus calibrated to the CBO estimates to the FRB/US equations can be interpreted as describing recent behaviour. I make allowances for indexation of the alternative minimum tax and unemployment benefits to improve this approximation. These issues are discussed in Appendix A.

The above approach is not the only way that countercyclical fiscal policy could be modelled. One alternative would be to re-estimate the fiscal equations of a macroeconomic model, such as FRB/US. That has advantages; for example, the counterfactual is precisely defined and complications of double-counting are avoided. But it also has substantial difficulties. One problem is distinguishing countercyclical fiscal policy from other variations in the budget (military operations, noise in tax receipts, the census). I do not want to model these temporary correlations as a systematic reaction to macroeconomic conditions. The scope for bias is large given that we have very few observations near the zero bound. Second, the estimates depend on equations that are specific to one particular model, which reduces their transparency, credibility, and comparability with other estimates.

4. The FRB/US Model

Estimates of the effect of fiscal stimulus require a macroeconomic model. I use the FRB/US model of the US economy, one of the main macroeconometric models used at the Federal Reserve Board of Governors. This model has been used in some key contributions on the setting of the inflation target (Reifschneider and Williams 2000; FOMC 2005; Williams 2009), though without countercyclical fiscal policy. It has also played a prominent role in assessing the consequences of fiscal stimulus (Romer and Bernstein 2009; CBO 2010; Coenen *et al* 2012), though not in a stochastic setting.

FRB/US differs from many models published in textbooks and academic journals in that it is not designed for expositional purposes. Rather, it is intended to provide a credible basis for policy advice.⁶ That, in turn, requires closely fitting the data and paying detailed attention to the various transmission mechanisms that policymakers regard as important. As a result, the model is large and detailed. It contains approximately 500 variables and 170 estimated equations. Unfortunately, that makes the model something of a black box to outsiders.

It is not possible to document the model here. Rather, interested readers are referred to descriptions published elsewhere. Brayton and Tinsley (1996) is the most detailed overview. Reifschneider and Williams (2000) provide a summary that focuses on the zero bound. Elmendorf and Reifschneider (2002) discuss fiscal multipliers. Coenen *et al* (2012) compare fiscal multipliers of FRB/US to those of other structural models used by policymaking institutions. The references in these papers provide further information.

In brief, the model is designed and revised with the intent of closely fitting the data. The main behavioural relationships are derived from explicit optimisation problems, under the assumption of costly adjustment. Most equations are estimated individually, with explicit expectational terms. When it is difficult to explain the data with optimising behaviour, further *ad hoc* terms are added. For example, the consumption equations include rule-of-thumb behaviour. For estimation, most operational work, and this paper, expectations are determined by small-scale vector autoregressions (VARs). However, in deterministic settings the model can also be solved under model-consistent expectations.

The channels through which monetary and fiscal policy work in FRB/US are summarised by intermediate macroeconomics textbooks (for example, Mankiw (2010, Chapter 10)). For more detail, consider as an illustration the consumption response to a reduction in taxes or an increase in transfers. Rule-of-thumb households (accounting for about one-quarter of total private consumption) are assumed to increase their consumption immediately. Other households raise their consumption, somewhat more gradually, to match the increase in perceived

⁶ For regular applications of FRB/US, see the alternative scenarios and confidence intervals typically published around page I-17 in each Greenbook presented to the FOMC, available at <http://www.federalreserve.gov/monetarypolicy/fomchistorical2005.htm>.

permanent income. Households are not assumed to have perfect foresight regarding the duration of the increased income. Rather, they regard their permanent income as the annuitised present value (calculated with a high discount rate) of the sum of expected wages, taxes, transfers and so on, with expectations being the predictions of small-scale VARs. So the contribution of transfers to perceived permanent income, for example, reflects the estimated persistence of transfers in the historical data. Normally, the monetary policy rule would increase interest rates in response to the increase in consumption, in turn raising longer-term rates and the exchange rate and lowering equity prices. However, at the zero bound, these offsetting effects are greatly muted. FRB/US does not include an effect of government debt on bond risk premia, explicit ‘Ricardian equivalence’ effects, or hysteresis in the labour market.

In deterministic settings, the model can be solved assuming that households know how long a zero bound episode, and hence the fiscal stimulus, will last. In stochastic settings, alternative assumptions are needed. In my simulations, households are assumed to expect historical correlations to persist, even though policy has changed. In principle, this assumption is susceptible to the Lucas critique and I discuss it in Section 7.

Any macroeconomic model rests on a large number of debatable assumptions. One way of assessing these assumptions is by examining the model’s multipliers. A wide range of FRB/US multipliers have been publicly documented; see, for example, Brayton and Tinsley (1996) or footnote 6. For this paper the fiscal multipliers are particularly relevant. Table 1 shows the estimated response of real GDP to sustained variations in key fiscal variables with nominal interest rates held fixed. As a guide to interpretation, estimates in the top row imply that were government purchases to deviate from baseline by 1 per cent of GDP for the duration of the experiment, then the level of GDP would be 0.99 per cent above baseline after four quarters and 1.22 per cent above baseline after twelve quarters.

Table 1: FRB/US Fiscal Multipliers at Fixed Nominal Funds Rate

Effect on level of GDP (per cent deviation from baseline) of a sustained change in fiscal variables by 1 per cent of GDP

	After four quarters	After twelve quarters
Government purchases	0.99	1.22
Reduction in personal tax receipts	0.31	0.56
Transfers	0.42	0.50

Source: author's calculations

Estimation of fiscal multipliers is controversial and subject to uncertainty. I do not wish to enter this debate here, beyond some brief comments as to why the estimates in Table 1 provide an interesting and relevant benchmark. The FRB/US multipliers are similar to many other estimates that assume constant nominal interest rates. For example, a survey by the OECD (2009) concluded ‘[a] review of the evidence ... typically suggests a first-year government spending multiplier of slightly greater than unity, with a tax cut multipliers of around half that’. Overviews of the literature by Christina Romer (2011), David Romer (2011) and DeLong and Summers (2012) conclude that fiscal multipliers are substantial. Coenen *et al* (2012) present a more detailed comparison of structural (mainly DSGE) models used by central banks, international organisations, and academics; they found FRB/US fiscal multipliers at fixed nominal interest rates to be similar to those of other models. As noted above, FRB/US multipliers have been one of the main sets of estimates relied upon by policymakers. The CBO (2010, Appendix) compares fiscal multipliers from models like FRB/US with other estimates in the literature and concludes that the FRB/US multipliers are a useful basis for policy in current conditions.⁷

Cogan *et al* (2010) have argued that FRB/US multipliers are too high. Part of their argument is that the FRB/US model is ‘Old Keynesian’ and out of step with modern modelling techniques. However, the extent to which FRB/US is ‘old-fashioned’ and whether or not this would be a problem is debatable. More important, Coenen *et al* (2012, Figure 7) find that FRB/US multipliers are similar

⁷ The estimates in Table 1 differ from FRB/US multipliers published elsewhere, given that my purposes and context are slightly different. My multipliers are higher than FRB/US multipliers that assume monetary policy follows a Taylor-type rule, for example, if the zero bound is explicitly expected to stop binding soon. My multipliers are lower than estimates that assume the zero bound is expected to last many years.

to those of recent DSGE models, including the model used by Cogan *et al.* As Woodford (2011) and Coenen *et al* discuss, the apparent disagreement occurs because Cogan *et al* compare multipliers like those in Table 1 with multipliers that assume government spending is expected to substantially outlast the zero bound. The possibility that stimulus measures may outlive their rationale is an important concern, but it is not the policy I am considering here.

5. The Effect of Fiscal Stimulus

To consider the effect of fiscal stimulus, I run repeated stochastic simulations of FRB/US about its long-run steady state. I follow the approach discussed by Reifschneider and Williams (2000) with a few variations. Whereas Reifschneider and Williams use a linearised version of the model with model-based expectations, I use the nonlinear form with VAR expectations. Assuming VAR expectations will strike many readers as unusual for an analysis of policy rules. However, as I discuss in Section 7, the differences between VAR-based and model-based expectations do not seem to be large for this particular exercise. And there are both practical and conceptual reasons for preferring VAR expectations.

I use the 2010 vintage of the model, in which most equations, including VAR-based expectations, are estimated through 2009. I randomly draw residuals from 65 key model equations from the period 1968 through 2009, then simulate the model over 120 years, discard the first 20 years, store, and repeat 500 times.⁸ I use a block bootstrap with block size of four quarters.⁹ That means that serially correlated surprises, such as the financial crisis of 2008–2009, are represented in the simulations. To avoid double-counting the recent stimulus, the fiscal equations of the model are only estimated through 2007 and bootstrapped residuals for fiscal variables are set at zero after 2008:Q1. The aim of this approach is to generate 50 000 years of artificial data with the same conditional correlations (across variables and across time), covariances, skewness, and kurtosis as the last 40-odd years of US history. Unusual events, such as the financial crisis of 2008–2009 or the oil price increase of 1973, are effectively assumed to be once-in-40-year

8 About 3 per cent of simulations of 120 years fail – that is, once every 4 000 years. Typically, this is because the model wanders off to an inadmissible region; for example, with a negative income or expenditure share. When this happens, I disregard the simulation.

9 Whereas a basic bootstrap draws one quarter of observations at a time, the block bootstrap draws blocks of consecutive quarters, so as to capture unmodelled leads and lags.

events. Alternatively, they can be considered to be representative of a larger class of less frequent events.

The simulations generate distributions of many key macroeconomic variables that are similar to those seen in recent US history. For example, the standard deviation of the unemployment rate is 1.3 percentage points in simulations with high inflation targets. This compares with an actual standard deviation of the gap between the unemployment rate and the model's effective NAIU of 1.4 percentage points from 1968 through 2009. Because the simulations are conditional on inflation targets that differ from those implicitly used in the past, the volatility of nominal variables is harder to compare with the data. However, the frequency of zero bound episodes in my simulations (Table 2, row 1) is about the same as that of Coibion *et al* (2012, Figure 1), which, they argue, matches US experience. With respect to the distribution of variables conditional on a given starting point, Reifschneider and Tulip (2007, Table 9) show that FRB/US stochastic simulations are similar to real-time errors from major US macroeconomic forecasters.

Panel A of Table 2 shows key summary statistics for simulations with no unusual fiscal stimulus; that is, β in Equation (3) equals zero. As the inflation target approaches the lower bound, monetary policy is constrained more often. For example, as shown in row 1, interest rates are zero 8 per cent of the time with an inflation target of 2 per cent, rising to 14 per cent of the time if the target is 1 per cent. And, as shown in the second and third rows, the severity of these episodes, as measured by their duration or the standard deviation of unemployment, also increases at low inflation rates. As reported by Reifschneider and Williams (2000, Table 1), the volatility of other variables, such as the inflation rate or interest rates, is not greatly affected by the inflation target.

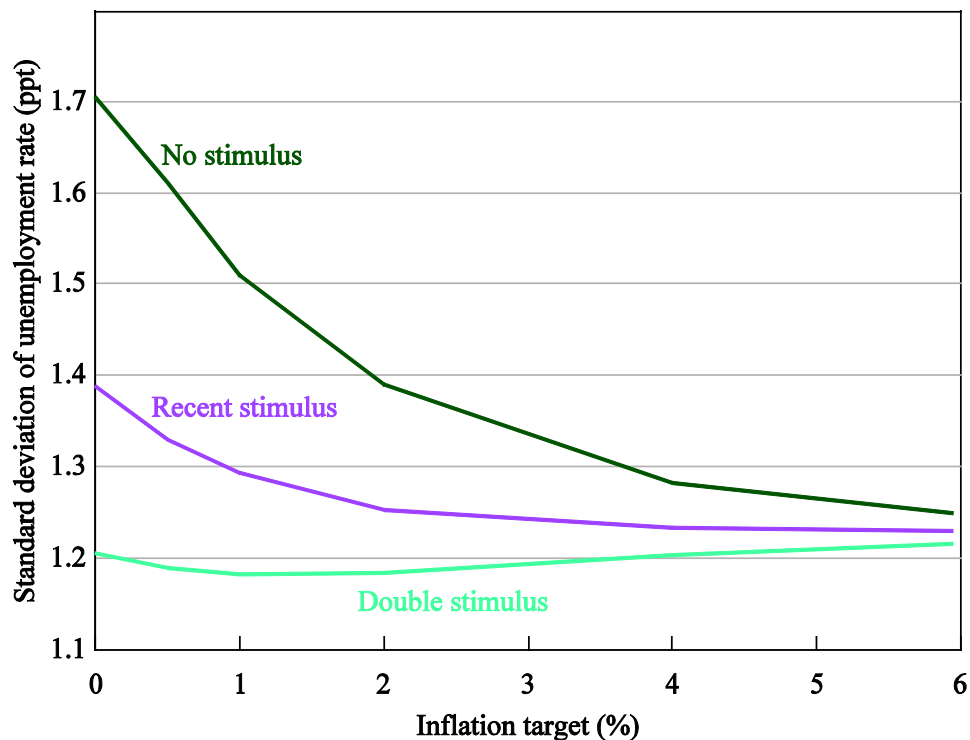
The simulations reported in Panel A of Table 2 are in line with previous research using FRB/US. The standard deviation of unemployment is higher than that reported by Reifschneider and Williams, but that is accounted for by the difference in sample period, which here includes the recent financial crisis. If this episode is excluded, the results are essentially the same, as discussed in Section 6.

Table 2: Simulated Outcomes at Different Inflation Targets

	Inflation target			
	0 per cent	1 per cent	2 per cent	4 per cent
Panel A. Without stimulus				
1. Proportion of time at zero bound	0.25	0.14	0.08	0.03
2. Median length of zero bound episode (quarters)	8	6	5	4
3. Standard deviation of unemployment rate (percentage points)	1.71	1.51	1.38	1.28
4. Standard deviation of debt/GDP (percentage points)	3.7	3.4	3.2	2.9
Panel B. With recent stimulus				
5. Proportion of time at zero bound	0.20	0.11	0.06	0.02
6. Median length of zero bound episode (quarters)	6	5	4	3
7. Standard deviation of unemployment rate (percentage points)	1.39	1.29	1.26	1.23
8. Standard deviation of debt/GDP (percentage points)	5.1	4.3	3.7	3.1
Source: author's calculations				

Panel A assumes that fiscal policy behaves passively, in line with historical patterns and earlier research. In contrast, the lower panel shows the effect of countercyclical fiscal policy, that is with $\beta = 0.7$. I interpret this calibration as describing recent policy, and label it as such. As can be seen by comparing the upper and lower panels, countercyclical fiscal policy reduces the frequency and severity of zero bound episodes.

Figure 4 plots the standard deviation of the unemployment rate for different inflation targets. The lines labelled 'no stimulus' and 'recent stimulus' represent simulations with β equal to zero and 0.7 respectively. With active fiscal policy, the economy is more stable, especially at low inflation rates.

Figure 4: Unemployment Variability at Different Inflation Targets

Source: author's calculations

The difference between the lines labelled 'no stimulus' and 'recent stimulus' provides a measure of the benefits from countercyclical fiscal policy. If fiscal policy is passive, then an inflation target of 2 per cent is associated with a standard deviation of the unemployment rate of 1.39 percentage points. However, if fiscal policy behaves as it has recently, then the same variability of unemployment could be achieved with an inflation target of zero. Put another way, countercyclical fiscal policy is estimated to lower the standard deviation of the unemployment rate by 9 per cent at a 2 per cent inflation target or by 19 per cent at a zero inflation target.

As noted above, the personal tax rate equation in FRB/US adjusts taxes so as to stabilise the ratio of government debt to GDP around its assumed target, set at 55 per cent in the baseline. Active countercyclical fiscal policy does not change the average ratio of debt/GDP but it does increase its variability, as shown by comparing the last row in each panel of Table 2. It is not clear that a government that borrows in its own currency, such as the United States, should be especially concerned about these variations, and the model assumes they are costless. However, they may be a political constraint on active fiscal policy.

A third alternative, labelled ‘double stimulus’ in Figure 4, sets $\beta = 1.4$, twice the previous value. According to these estimates, this more aggressive fiscal policy almost eliminates economic variability arising from the zero bound. Such a policy may seem attractive; however, a discussion of optimal fiscal policy would also consider costs, and is beyond the scope of this paper. An interesting feature of the ‘double stimulus’ simulation is that unemployment is slightly more stable at low inflation (1 or 2 per cent) than at higher rates. Presumably this is because this particular fiscal rule – which only kicks in at low interest rates – is more stabilising than the baseline monetary policy rule.

From the perspective of monetary policy, it seems appropriate to take current fiscal policy as given. In that sense, a frontier such as the ‘recent stimulus’ line in Figure 4 can be considered as a possible menu from which central bankers might choose. This issue is explored in Section 6. From a broader perspective, society needs to choose between different combinations of fiscal policy and the associated inflation target. One option would be fiscal policy resembling that seen recently with a moderate inflation target; another option would be more aggressive fiscal policy with a lower inflation target.

The results in Figure 4 span a wide range of possible outcomes, which reduces the need for detailed sensitivity analysis. In qualitative terms, alternative modelling choices affect the results in fairly straightforward ways. For example, if fiscal policy multipliers were smaller than FRB/US estimates, or if the stimulus were smaller than my ‘recent stimulus’ simulations, those simulations would more closely resemble the ‘no stimulus’ experiment. Such an outcome would be likely if, for example, fiscal stimulus placed more weight on low-multiplier instruments, such as tax cuts, or if stimulus were expected to considerably outlast the zero bound, giving rise to offsetting increases in bond yields. Alternatively, if fiscal policy were more potent, timely, or aggressive than assumed in the ‘recent stimulus’ simulations, those results would move toward those depicted by the ‘double stimulus’ simulations. Such an outcome would be likely if the fiscal rule placed more weight on the 2001 and 2008 fiscal measures.

Perhaps a more important sensitivity is to the assumed volatility of economic shocks, addressed in the following section.

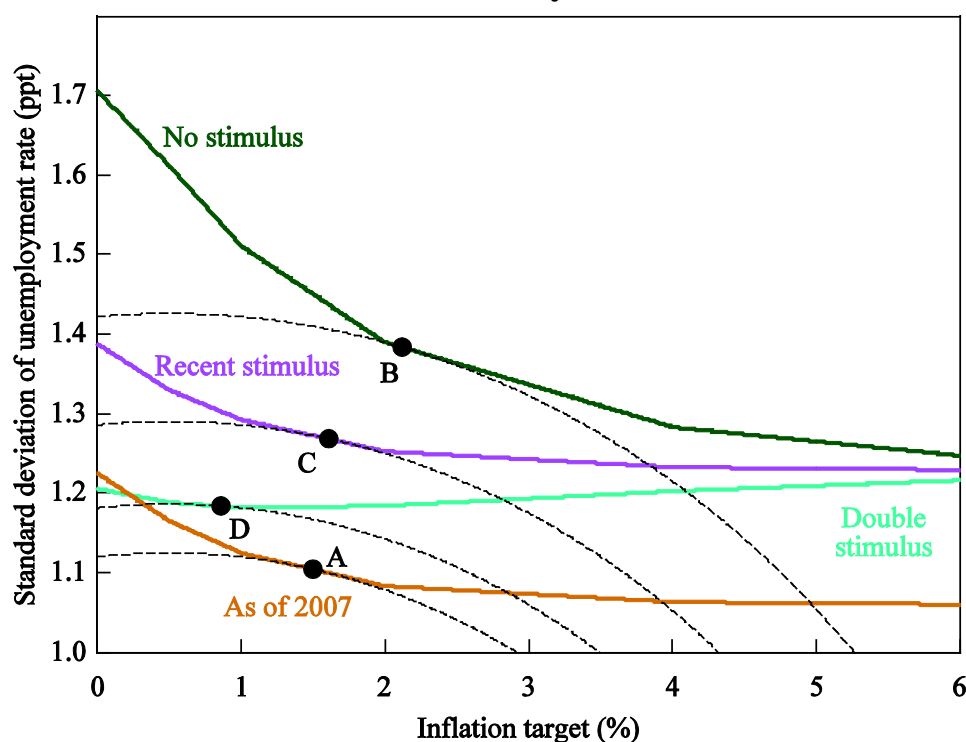
6. Lessons of the Crisis

The previous section suggested that researchers and policymakers may have overestimated the optimal inflation target by neglecting countercyclical fiscal policy. However, that is not the only lesson from the recent crisis. We have also learned, for example, that macroeconomic shocks are more volatile. Yellen (2009), Williams (2009), and Blanchard *et al* (2010) have discussed having a higher inflation target because of this increase in perceived volatility. This raises the question of how changes in fiscal activism and volatility should be balanced against each other. Put another way, suppose a policymaker regarded an inflation target of say 1.5 per cent as appropriate before the recent recession (as suggested by Elmendorf *et al* (2005) or Yellen (2006), among others). Given what has been learned since then, what might be his or her new target?

Figure 5 provides one possible answer. The blue and green lines represent the trade-offs between inflation and instability reproduced from Figure 4, labelled as before. To illustrate how a central banker in early 2007 might have perceived the trade-off, the line labelled 'as of 2007' is constructed assuming passive fiscal policy and drawing residuals from the period 1968 to 2006. That curve is essentially the same as the estimates of Reifschneider and Williams, adjusting for measurement differences.¹⁰ This is intended to be a simple approximation to the menu from which policymakers may have chosen a target of 1.5 per cent.

¹⁰ See their presentation to the FOMC on 29 January 2002 (FOMC 2002). My estimates are about the same as those in row 2 of the middle panel on page 161 if the inflation rate is shifted by half a percentage point, the average difference between CPI inflation and PCE inflation.

Figure 5: Different Trade-offs between Inflation and Unemployment Instability



Source: author's calculations

The curve drawn through point A reflects a hypothetical indifference curve. The preferences that might give rise to a choice like A can be represented by the loss function:

$$L = (\pi^* - 0.5)^2 + 22\sigma^2 \quad (5)$$

where π^* is the inflation target (not deviations from the target, as often appears in discussion of stabilisation policy), the parameter 0.5 is Elmendorf *et al's* (2005) estimate of the measurement bias in the PCE price series, σ is the standard deviation of the unemployment rate, and the coefficient 22 is chosen so as to minimise the loss at point A. For simplicity, I assume that other factors that affect preferences over inflation objectives, such as tax distortions or downward nominal wage rigidity, are roughly offsetting. At point A, the central banker has an inflation target of 1.5 per cent, which implies a standard deviation of the unemployment rate of 1.10 percentage points. Such a choice implies that an extra percentage point of steady-state inflation is worth 0.04 percentage points extra standard deviation of

unemployment. Indifference curves through points B, C, and D represent the same preferences.

Under these assumptions, a central banker who perceives that volatility has increased, but that fiscal policy will remain passive, might choose a point such as B, with an inflation target of 2 per cent. The difference between points A and B illustrates the sensitivity of this approach to changes in estimates of volatility.

Were the central banker also to believe that recent fiscal stimulus is likely to be repeated, he or she may choose a point like C, also with a target of 1½ per cent. According to the model's estimates, the inflation target is about the same as the pre-recession choice, because the change in fiscal policy offsets the increase in perceived volatility. Thus, although changes in volatility are important for the choice of inflation target, whether fiscal policy is active or passive is of similar importance.

If fiscal policy were even more aggressive, the inflation target could be lower still. For example, a fiscal policy that is twice as aggressive as recently would imply point D, with an inflation target of 0.9 per cent. For such an aggressive fiscal policy, the trade-off between steady-state inflation and instability is very flat. In these conditions, the inflation target is essentially decided by considerations other than the zero bound, such as estimates of measurement bias.

The examples above are illustrative and omit some other important lessons from the recent crisis. For example, we have also learned that central banks are likely to purchase long-term securities so as to reduce bond premiums. Furthermore, point A may not be the best starting point, as suggested by Billi (2011) or Coibion *et al* (2012). But notwithstanding these caveats, the simulations shown in Figure 5 suggest that the inflation target should not increase simply because perceived volatility has increased.

7. Expectations

An unusual feature of my simulations is the treatment of expectations. I have assumed that agents base their expectations on small-scale VARs rather than on the full model. Although this assumption is usually inappropriate for analysis of policy

rules, it seems a reasonable approximation given the unusual characteristics of this particular question.

As I discuss below, it is not obviously feasible or desirable to conduct the relevant simulations with model-consistent expectations. But even if it were, it is not clear that they would be significantly different. One reason for this is that the inflation-variability frontier does not seem to be noticeably affected by different assumptions about expectations. As noted in footnote 10, frontiers calculated using VAR expectations are very similar to estimates Reifchneider and Williams calculate using model-based expectations, when put on a consistent basis. A more important reason is that fiscal multipliers are likely to be similar. This can be seen in Table 3, which compares FRB/US fiscal multipliers calculated using VAR expectations and calculated using the nonlinear model-consistent version of FRB/US (called ‘PFVER’).¹¹ The table shows effects on GDP after four quarters. Under VAR expectations, agents implicitly assume that shocks persist as long as similar shocks in the past (though for purposes of constructing Table 3, all that needs to be assumed is that they last at least as long as the multiplier horizon, four quarters). For model-consistent expectations, agents are assumed to know how long a shock will last, so this needs to be specified: I assume that both shocks and zero bound episodes are expected to last eight quarters, the same experiment as Coenen *et al* (2012, Figure 3, lower left panel). Eight quarters is a bit longer than most zero bound episodes in my simulations (Table 2), but may be representative, given that the positive threshold makes stimulus last slightly longer than time at the zero bound, and that most stimulus occurs in longer-lasting recessions. For the experiments shown in Table 3, multipliers with model-consistent expectations are slightly smaller than those with VAR expectations, but the difference is small. These comparisons suggest that the overall impact of fiscal policy at the zero bound may not be significantly different once expectations become model-consistent.

¹¹ To conduct stochastic simulations, it would be necessary to linearise the model. The approximation errors involved would further change the multipliers, but not in an economically interpretable manner.

Table 3: FRB/US Fiscal Multipliers, with Different Assumptions about Expectations

Effect on level of real GDP (per cent deviation from baseline) after four quarters of a change in fiscal variables by 1 per cent of GDP expected to last eight quarters

	VAR expectations	Model-consistent expectations
Government purchases	0.99	0.94
Reduction in personal tax receipts	0.31	0.27
Transfers	0.42	0.28

Source: author's calculations

The reason multipliers are similar is that these experiments are not historically unusual. Under VAR expectations, the household expects a tax cut (for example) to persist for as long as unusual variations in disposable income have persisted in the past, which is a few years. So there is a moderate increase in permanent income and hence consumption. Under model-consistent expectations, the household expects the tax cut to persist as long as the model predicts the funds rate will remain near zero, which is assumed to be two years in Table 3. That is, model-consistent expectations give households information that is not very surprising. So household behaviour is similar.

Similarity in results, in itself, is not a reason for preferring VAR expectations. That preference reflects both practical and conceptual considerations.

Stochastic simulations of nonlinear models under model-consistent expectations are computationally difficult. Accordingly, previous researchers have used linearised versions of their models. Linearisation can change model properties in unattractive ways (Braun, Körber and Waki 2012). Whereas the nonlinear version of FRB/US with VAR-based expectations has been tested, documented, scrutinised, and successfully used in a wide variety of applications, the properties of the linearised version are less well-established, reducing the confidence that can be placed in them.

It is not even clear that linearisation is feasible for this study given that the fiscal rule is nonlinear. Reifschneider and Williams (2000) include one nonlinear constraint in an otherwise linear model. Coibion *et al* (2012) have two nonlinear constraints in a smaller model. I am not aware that multiple nonlinear constraints have been successfully included in a large-scale model. In both the Reifschneider

and Williams and the Coibion *et al* exercises the introduction of nonlinear constraints involves a large cost in computational complexity. Moreover, the expectations are not actually ‘model-consistent,’ but ‘model-based’. They represent the model’s deterministic solution, not the mean of the stochastic solution. Because the zero bound is asymmetric, these will differ.

In terms of principle, it is ordinarily appropriate to model policy rules using model-consistent expectations. As people gain experience of a rule, their behaviour will adapt to be consistent with it and systematic errors should disappear. However, modelling newly-introduced rules under the assumption of model-based expectations can be misleading. Economic agents have limited information processing capabilities. It is implausible to assume that they quickly learn the structure of the model, when most professional economists do not know it. In particular, new policies may not have perfect credibility. Empirical observation suggests that people often do not perceive a change in policy regime simply because it is announced. For example, changes in monetary policy rules in the early 1980s in the United States and United Kingdom seem to have led to recessions rather than changes in inflation expectations. Similarly, households respond to tax cuts when the policy change is implemented, not when it is enacted or credibly announced (see the numerous references listed in footnote 3 of Auerbach *et al* (2010)). Accordingly, the use of VAR-based expectations may be more appropriate to describe behaviour until households have had experience of a change in structure.

The use of fiscal stimulus at the zero bound falls in between the extremes of a ‘one-off’ shock and a change to which everyone has adjusted. The difficulty in assuming quick learning is that we are discussing a policy that is applied infrequently. Interest rates only occasionally hit the zero bound and the constraint seriously binds only once every decade or so. To be precise, in simulations with $\beta = 0.7$ and a 2 per cent inflation target, a stimulus exceeding 2 per cent of GDP occurs once every 12 years, on average. And the size and duration of stimulus have large variances. So learning from experience of the change in structure seems likely to take a long time, perhaps decades. In the meantime, it seems plausible to assume that households will continue to behave in line with historical correlations. This is a ‘short-run’ solution, but it is long enough to matter. Permanent effects

will be different (in character, if not in size), and would be interesting to model, but that is not a reason for neglecting the effects that will occur within our lifetime.

8. Directions for Future Research

The simulations shown in Figure 4 imply that countercyclical fiscal policy, such as we have just seen, can be expected to stabilise the economy, substituting for a higher inflation target.

This result could be developed and refined in several directions. One variation would be to assume model-consistent expectations. However, as discussed in Section 7, it is not clear that this would affect the results. A second useful extension would be to incorporate non-conventional monetary policy, as discussed by Chung *et al* (2012). This should be included for essentially the same reasons as those I gave for including fiscal activism. A third important challenge is to determine how large will be the shocks hitting the economy. As discussed in reference to Figure 5, the inflation target is sensitive to this assumption unless fiscal policy is very aggressive. Related to this point, interest rates have remained at the zero bound for longer than was expected when my results were finalised. That does not pose problems for the fiscal rule, as extra stimulus measures were also introduced. However, it does highlight the sensitivity of assessments of economic volatility to the sample period from which shocks are drawn.

My simulations quantify substantial benefits from systematic countercyclical fiscal policy. However, in order to make fiscal policy recommendations, it would need to be argued that these benefits exceed the costs. The current version of FRB/US is not specified so as to address this question, because the costs of countercyclical fiscal policy in FRB/US are simply assumed to be unimportant. For example, perceptions of default probabilities do not depend on debt levels, labour supply does not respond to variations in tax rates, and my stimulus rule did not include measurement or other errors. Although these assumptions may be appropriate for many purposes, a more general model would be able to more persuasively address the issue of optimal fiscal policy.

Appendix A: Measurement of Recent Stimulus

For reasons given in Section 3, it is desirable to calibrate my stimulus rule, Equation (3), to recent behaviour. Estimates of recent stimulus legislation by the CBO, by Follette and Lutz and by Blinder and Zandi (2010) (through mid 2010) are similar. Notwithstanding this agreement, some issues of measurement and definition may be worth noting.

To avoid double-counting, I want to exclude measures that the standard FRB/US equations predict would have occurred anyway. The main component of the CBO estimates to which this applies is indexation of the alternative minimum tax (AMT), which I subtract from the published CBO totals to give the series plotted in Figures 2 and 3. Follette-Lutz and Blinder-Zandi make similar adjustments.

Although the FRB/US equations for transfers have a substantial cyclical effect, they do not explain all the recent increase, the shortfall being about 1½ per cent of GDP. Fortuitously, that roughly corresponds to increases in transfers that have been legislated in the three large bills. So restricting estimates of stimulus to the three large bills is a crude but simple approximation to the increase in transfers that is additional to the FRB/US equations.

The biggest difference between the CBO estimates and Follette-Lutz is the extension of ‘middle-class tax cuts’ that were scheduled to expire at the end of 2010. They are included within the CBO estimates, which are relative to a counterfactual of ‘existing legislation’, but excluded from Follette-Lutz, which is relative to a counterfactual of ‘existing policy’. In contrast, my implicit counterfactual is ‘predictions of FRB/US equations’, or what might be called ‘sustainable policy’, which calls for a large increase in taxes around this time in order to stabilise the debt. So the CBO estimates happen to provide a measure of stimulus in 2011 and 2012 that is closer to my purposes.

Less important, but high profile, are asset purchases such as the Troubled Asset Relief Program or TARP. I do not include this as systematic countercyclical policy largely because the net present value of asset purchases is highly uncertain and their multiplier is widely assumed to be quite low. So repetition of future TARP-like programs would have little effect on the cyclical behaviour of the economy.

There are other recent programs that might be considered to be countercyclical fiscal policy, including Cash for Clunkers, the homebuyers tax credit, and so on. But the total budgetary cost of these measures was small (Blinder and Zandi 2010, Table 10).

Appendix B: FRB/US Fiscal Equations

This appendix presents key equations in the fiscal block of FRB/US, modified to include the effects of countercyclical stimulus, d_t as defined in Equation (3). The model's full equation list is available at www.petertulip.com.

Real transfers (GFT) equal the trend share ($GFTRT$) of transfers in potential output ($XGDPT$) plus deviations from that trend ($GFTRD$) plus a quarter of the stimulus, $d_t * XGDP$, where $XGDP$ is real GDP.

$$GFT = (GFTRD + GFTRT) * XGDPT + .25 * d_t * XGDP(-1) \quad (B1)$$

Real government consumption purchases before the stimulus, excluding employee compensation, ($EGFOBASE$) is a function of own lags, a stochastic time trend, $EGFOT$, and the output gap, $GDPGAP$.

$$\begin{aligned} D(\text{LOG}(EGFOBASE)) = & -.0026 - .17 \\ & * \text{LOG}(EGFOBASE(-1) / EGFOT(-1)) \\ & -.24 * D(\text{LOG}(EGFOBASE(-1))) \\ & -.11 * D(\text{LOG}(EGFOBASE(-2))) \quad (B2) \\ & + 1.78 * D(\text{LOG}(EGFOT)) \\ & -.00039 * GDPGAP(-1) \\ & + .0012 * GDPGAP(-2) \end{aligned}$$

$EGFO$ is $EGFOBASE$ plus a quarter of the total stimulus, in real dollars. The separation of $EGFO$ and $EGFOBASE$ ensures that the endogenous persistence in $EGFOBASE$ does not amplify the stimulus.

$$EGFO = EGFOBASE + .25 * d_t * XGDP(-1) \quad (B3)$$

Nominal personal tax receipts ($TFPN$) equal the tax rate ($TRFP$) times taxable income ($YPNADJ$) minus half the stimulus in nominal dollars.

$$TFPN = TRFP * YPNADJ - .5 * d_t * XGDPN(-1) \quad (B4)$$

The tax rate ($TRFP$) is a function of the trend tax rate ($TRFPT$), own lags and the output gap ($GDPGAP$). I shock $TFPN$ rather than $TRFP$ so that the endogenous persistence in $TRFP$ does not amplify the stimulus.

$$\begin{aligned} TRFP = TRFPT + .57 * (TRFP(-1) - TRFPT(-1)) \\ + .35 * (TRFP(-2) - TRFPT(-2)) + .00034 * GDPGAP(-1) \end{aligned} \quad (B5)$$

The trend tax rate ($TRFPT$) adjusts to stabilise debt ($GFDBTN$) at 55 per cent of nominal GDP ($XGDPN$)

$$\begin{aligned} TRFPT = TRFPT_{t-1} + 0.05 * (GFDBTN_{t-1} / XGDPN_{t-1} - .55) \\ + 0.5 * D(GFDBTN_{t-1} / XGDPN_{t-1} - .55) \end{aligned} \quad (B6)$$

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