NBER WORKING PAPER SERIES

FORESIGHT AND INFORMATION FLOWS

Eric M. Leeper
Todd B. Walker
Shu-Chun Susan Yang

Working Paper 16951
http://www.nber.org/papers/w16951

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 2011

Walker acknowledges support from NSF grant SES-0962221. Yang thanks Academia Sinica for support in the early stages of this research. We also acknowledge comments by Troy Davig, Mike Dotsey, Dale Henderson, Beth Klee, Karel Mertens, Jim Nason, Ricardo Nunes, Morten Ravn, Chris Sims, and participants at many conferences and presentations. Joonyoung Hur provided excellent research assistance. We are particularly grateful to Harald Uhlig and four anonymous referees for helpful comments. The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, its management, or the National Bureau of Economic Research.

Foresight and Information Flows
Eric M. Leeper, Todd B. Walker, and Shu-Chun Susan Yang
NBER Working Paper No. 16951
April 2011
JEL No. C5,E62,H30

ABSTRACT

News--or foresight--about future economic fundamentals can create rational expectations equilibria with non-fundamental representations that pose substantial challenges to econometric efforts to recover the structural shocks to which economic agents react. Using tax policies as a leading example of foresight, simple theory makes transparent the economic behavior and information structures that generate non-fundamental equilibria. Econometric analyses that fail to model foresight will obtain biased estimates of output multipliers for taxes; biases are quantitatively important when two canonical theoretical models are taken as data generating processes. Both the nature of equilibria and the inferences about the effects of anticipated tax changes hinge critically on hypothesized tax information flows. Differential U.S. federal tax treatment of municipal and treasury bonds embeds news about future taxes in bond yield spreads. Including that measure of tax news in identified VARs produces substantially different inferences about the macroeconomic impacts of anticipated taxes.

Eric M. Leeper
Department of Economics
304 Wylie Hall
Indiana University
Bloomington, IN 47405
and Monash University, Australia
and also NBER
eleeper@indiana.edu

Todd B. Walker
Department of Economics
105 Wylie Hall
Indiana University
Bloomington, IN 47405
walkertb@indiana.edu

Shu-Chun Susan Yang
International Monetary Fund
700 19th Street, N.W.
Washington, D.C. 20431
ssyang@econ.sinica.edu.tw

Foresight and Information Flows*

Eric M. Leeper[†], Todd B. Walker[‡], and Shu-Chun Susan Yang[§]

1 Introduction

A venerable tradition, often traced to Pigou (1927), ascribes a significant role in aggregate fluctuations to economic decision makers' responses to expectations about not-yet-realized economic fundamentals. That tradition finds voice in a recent surge of interest in the economic consequences of *news*—or *foresight*. Recent work explores how news affects the predictions of standard theories, seeks evidence of the impacts of news in time series data, and estimates dynamic stochastic general equilibrium models to quantify the relative importance of anticipated and unanticipated "shocks" to fundamentals.

Existing work typically posits a particular stochastic process for news, grounded in neither theory nor empirics. That process determines the economy's information flows and, in a rational expectations equilibrium, agents' expectations. Given the prominent role of expectations in the news literature, it is remarkable that existing work does not systematically examine how the specification of information flows affects the nature of equilibrium and the connection of theory to data. This paper addresses that gap.

For several reasons we focus on how to identify and quantify the impacts of foreseen "shocks" to taxes. First, few economic phenomena provide economic agents with such clear signals about how important margins will change in the future: foresight is endemic to tax policy. Second, an institutional structure governs information flows about taxes: the process of changing taxes entails two kinds of lags—the inside lag, between when new tax law is initially proposed and when it is passed, and the outside lag, between when the legislation is signed into law and when it is implemented. That institutional structure informs the nature of tax information flows. Third, differential U.S. tax treatment of municipal and treasury bonds leads to a direct measure of tax news that offers a potential solution to modeling tax foresight. Such measures are scarce for news about nonpolicy fundamentals like total factor productivity. Despite the paper's focus on taxes, one of its key message—that hypothesized

*April 12, 2011. Walker acknowledges support from NSF grant SES-0962221. Yang thanks Academia Sinica for support in the early stages of this research. We also acknowledge comments by Troy Davig, Mike Dotsey, Dale Henderson, Beth Klee, Karel Mertens, Jim Nason, Ricardo Nunes, Morten Ravn, Chris Sims, and participants at many conferences and presentations. Joonyoung Hur provided excellent research assistance. We are particularly grateful to Harald Uhlig and four anonymous referees for helpful comments. The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management.

[†]Department of Economics, Indiana University, Monash University and NBER, eleeper@indiana.edu

[‡]Department of Economics, Indiana University, walkertb@indiana.edu

[§]International Monetary Fund, SYang@imf.org.

information flows are critical to determining the impacts of news—extends immediately to other contexts.[1]

Fiscal foresight poses a challenge to econometric analyses of fiscal policy because it generates an equilibrium with a non-fundamental moving average representation. Information sets of economic agents and the econometrician tend to be misaligned, with agents basing their choices on more information than the econometrician possesses. Structural shocks to tax policy, then, cannot be recovered from current and past fiscal data, a central assumption of conventional econometric methods. Instead, conventional methods can lead the econometrician to label as "tax shocks" objects that are linear combinations of all the exogenous disturbances at various leads and lags.[2]

This paper builds on and extends Hansen and Sargent's (1991b) general characterization of the implications of environments in which the history of innovations in a vector autoregression does not equal the history of information that agents observe. First, we go beyond treating invertibility as a 0–1 proposition by assessing the quantitative importance of failing to model foresight in two workhorse macroeconomic models. Second, we offer a compelling economic example—tax foresight—that makes clear that non-fundamentalness and its consequences affect answers to substantive macroeconomic questions. Most importantly, we ground non-fundamentalness in economic theory, which points toward an empirical line of attack that we pursue. Both Hansen and Sargent (1991b) and Fernández-Villaverde, Rubio-Ramírez, Sargent, and Watson (2007) have been read primarily as cautionary notes, in large part because they point to a serious problem but not to a way forward.

No consensus exists on how to handle tax foresight, a fact that is underscored by the diverse empirical findings in the literature. Research concludes that an anticipated cut in taxes may have little or no effect [Poterba (1988), Blanchard and Perotti (2002), Romer and Romer (2010)], may be mildly expansionary in the short run [Mountford and Uhlig (2009)], or may be strongly contractionary in the short run [House and Shapiro (2006), Mertens and Ravn (2011)]. By using different measures of tax news, these studies implicitly posit different tax information flows, which, as we show, can produce strikingly different inferences about the effects of anticipated tax changes.

The paper has three major parts:

1. A simple analytical example makes precise how foresight and optimizing behavior create equilibria with non-fundamental moving average representations. The example makes the source of non-fundamentalness transparent: it arises as a natural by-product of the fact that agents' optimal intertemporal decisions discount future tax obligations.

[1] In addition to taxes, studies have examined news about a wide range of fundamentals, including total factor and investment-specific productivity [Beaudry and Portier (2006), Christiano, Ilut, Motto, and Rostagno (2008), Jaimovich and Rebelo (2009), Schmitt-Grohé and Uribe (2008), Fujiwara, Hirose, and Shintani (2011)]; government military spending run ups [Fisher and Peters (2009), Ramey (2011)]; phased-in government infrastructure spending [Leeper, Walker, and Yang (2010)]; announcements of interest-rate paths by inflation-targeting central banks [Blattner, Catenaro, Ehrmann, Strauch, and Turunen (2008), Laséen and Svensson (2011)]. All of these applications lend themselves to the analysis that we conduct.

[2] Issues associated with non-fundamentalness were pointed out in the rational expectations econometrics literature by Hansen and Sargent (1980, 1991b) and Lippi and Reichlin (1993, 1994) and recently emphasized by Fernández-Villaverde, Rubio-Ramírez, Sargent, and Watson (2007). Leeper (1989) and Yang (2005) examine the issues in the context of tax foresight.

Although private agents discount tax *rates* in the usual way, they discount recent tax *news* more heavily than past news because with foresight the recent news informs about taxes in the more distant future. The econometrician, in contrast, discounts in the usual way, down weighting older news relative to recent news. Agents and the econometrician employ different discounting patterns because the econometrician's information set lags the agents'.

2. Simple analytics reveal the source of non-fundamentalness, but do not shed light on whether it matters in practice. Using two canonical dynamic stochastic general equilibrium models—Chari, Kehoe and McGrattan's (2008) real business cycle model and Smets and Wouters' (2003; 2007) new Keynesian model—as data generating processes, we quantify the inference errors an econometrician might make by failing to model foresight. We tie those errors to alternative, empirically motivated specifications of tax news processes—information flows that distinguish between the "inside" and "outside" lags associated with tax policies. Estimates of tax multipliers can be off by hundreds of percent and even be of the wrong sign. Biases can be positive or negative, but the econometrician tends to underestimate the effects of foresight over longer horizons.

3. We exploit a feature of the U.S. tax code that exempts municipal bonds from federal income tax to extract news about future tax changes from the spread between municipal and treasury bond yields. This is a flexible method to distinguish between anticipated and unanticipated shocks to taxes that does not require *a priori* assumptions about the period of foresight or the nature of information flows, assumptions that other empirical approaches to foresight are forced to make. Statistically, spreads are Granger-causally prior relative to the information sets in the fiscal VAR systems that Blanchard and Perotti (2002) and Mountford and Uhlig (2009) estimate. Employing exactly the identification schemes and data sets of Blanchard-Perotti and Mountford-Uhlig, we ask how augmenting the econometrician's information set with a direct measure of tax news affects inferences. For Blanchard-Perotti, results change dramatically: anticipated tax increases *raise* output substantially for about three years before output begins to decline. Differences also emerge for Mountford-Uhlig. Investment multipliers, which Mountford-Uhlig estimated to be zero, become significantly positive and evidence emerges against the zero restrictions that Mountford-Uhlig impose to identify tax foresight.

The body of the paper concentrates on empirical efforts to estimate the effects of foresight in loosely identified econometric models. In the concluding remarks we discuss two alternative strategies. The first estimates fully specified dynamic stochastic general equilibrium (DSGE) models, as Schmitt-Grohé and Uribe (2008) and Fujiwara, Hirose, and Shintani (2011) do, which is closely related to "root flipping" to obtain the non-invertible representation that foresight creates, as in Mertens and Ravn (2010) and Kriwoluzky (2010). A second strategy expands the econometrician's information set in an effort to ensure a fundamental representation [Forni and Gambetti (2010a,b)].

2 Analytical Example

This section introduces fiscal foresight into a simple economic environment where the econometric issues can be exposited analytically. Results and conclusions reached in the simple exposition extend to more general setups, as section 2.2 discusses.

Consider a standard growth model with a representative household that maximizes expected log utility, $E_0 \sum_{t=0}^{\infty} \beta^t \log(C_t)$, subject to $C_t + K_t + T_t \leq A_t K_{t-1}^{\alpha}$, where C_t, K_t, Y_t, and T_t denote time-t consumption, capital, output, and lump-sum taxes, respectively, and A_t is an exogenous technology shock. As usual, $0 < \alpha < 1$ and $0 < \beta < 1$. The government sets the tax rate according to a time-invariant rule and adjusts lump-sum transfers to satisfy the constraint, $T_t = \tau_t Y_t$. Government spending is identically zero. Labor is supplied inelastically which, as section 3.3 shows, understates the problems that foresight creates.

The equilibrium conditions are well known and given by

$$\frac{1}{C_t} = \alpha\beta E_t\left[(1-\tau_{t+1})\frac{1}{C_{t+1}}\frac{Y_{t+1}}{K_t}\right] \tag{1}$$

$$C_t + K_t = Y_t = A_t K_{t-1}^{\alpha}. \tag{2}$$

Let A and τ denote the steady state values of technology and the tax rate. The steady state capital stock is $K = [\alpha\beta(1-\tau)A]^{1/(1-\alpha)}$. Let lower case letters denote percentage deviations from steady state values, $k_t = \log(K_t) - \log(K)$, $a_t = \log(A_t) - \log(A)$, and $\hat{\tau}_t = \log(\tau_t) - \log(\tau)$. Log linearizing (1)–(2) yields an equilibrium that is characterized by a second-order difference equation in capital

$$E_t k_{t+1} - (\theta^{-1} + \alpha)k_t + \alpha\theta^{-1}k_{t-1} = E_t[a_{t+1} - \theta^{-1}a_t] + \left\{\theta^{-1}(1-\theta)\left(\frac{\tau}{1-\tau}\right)\right\}E_t\hat{\tau}_{t+1}, \tag{3}$$

where $\theta = \alpha\beta(1-\tau)$ is a particularly important constant in the analysis. Assuming an *i.i.d.* technology shock, the solution to (3) is

$$k_t = \alpha k_{t-1} + a_t - (1-\theta)\left(\frac{\tau}{1-\tau}\right)\sum_{i=0}^{\infty}\theta^i E_t\hat{\tau}_{t+i+1}. \tag{4}$$

Equilibrium investment depends negatively on the expected discounted present value of future tax rates, a well-known result [Lucas (1976), Abel (1982), Judd (1985), Auerbach (1989)]. Of course, more distant tax rates receive heavier discount than more recent rates.

To model foresight, we must specify how news about taxes signals future tax rates. For many of the points we wish to make, it suffices to assume that tax information flows take a particularly simple form: agents at t receive a signal that tells them exactly what tax rate they will face in period $t+q$. In later sections we will relax this assumption and posit more sophisticated rules for tax rates. The tax rule is $\tau_t = \bar{\tau}e^{\varepsilon_{\tau,t-q}}$, or in log-linearized form

$$\hat{\tau}_t = \varepsilon_{\tau,t-q} \tag{5}$$

Assume the technology and tax shocks are *i.i.d.* and the representative agent's information set at date t consists of variables dated t and earlier, including the shocks, $\{\varepsilon_{A,t}, \varepsilon_{\tau,t}\}$. Given the tax rule in (5), this implies that at t the agent has (perfect) knowledge of $\{\hat{\tau}_{t+q}, \hat{\tau}_{t+q-1}, \ldots\}$.

Using the information flows in the tax rule to solve for expected tax rates in (4) for various degrees of fiscal foresight yields the following equilibrium dynamics.

$q = 0$ implies:

$$k_t = \alpha k_{t-1} + \varepsilon_{A,t} \tag{6}$$

$q = 1$ implies:

$$k_t = \alpha k_{t-1} + \varepsilon_{A,t} - \kappa\varepsilon_{\tau,t} \tag{7}$$

$q = 2$ implies:

$$k_t = \alpha k_{t-1} + \varepsilon_{A,t} - \kappa\Big\{\varepsilon_{\tau,t-1} + \theta\varepsilon_{\tau,t}\Big\} \tag{8}$$

$q = 3$ implies:

$$k_t = \alpha k_{t-1} + \varepsilon_{A,t} - \kappa\Big\{\varepsilon_{\tau,t-2} + \theta\varepsilon_{\tau,t-1} + \theta^2\varepsilon_{\tau,t}\Big\} \tag{9}$$

where $\kappa = (1-\theta)(\tau/(1-\tau))$.

If there is no foresight, $q = 0$, we get the usual result that *i.i.d.* shocks to tax rates have no effect on capital accumulation. When there is some degree of tax foresight ($q > 0$), rational agents will adjust capital contemporaneously to yield the unusual result that even serially uncorrelated tax hikes reduce capital accumulation. Fiscal foresight manifests in the additional moving average terms present in the equilibrium representation. The number of moving average terms increases with the foresight horizon.

A striking, though seemingly perverse, implication of (8) and (9) is that more *recent* news is discounted (by $\theta = \alpha\beta(1-\tau) < 1$) relative to older news. This is because with two-quarter foresight, $\varepsilon_{\tau,t-1}$ affects $\hat{\tau}_{t+1}$, while $\varepsilon_{\tau,t}$ affects $\hat{\tau}_{t+2}$, so the news that affects tax rates farther into the future receives the heaviest discount. While tax *rates* are discounted in the usual way, tax *news* is discounted in reverse order. This difference in discounting between tax rates and tax news stems from optimizing behavior and underlies the econometric problems that foresight creates.

2.1 The Econometrics of Foresight

The moving average terms that foresight produces pose challenges for conducting econometric inference. Conventional econometric analyses, such as those using identified vector autoregressions (VARs), can draw erroneous conclusions. Errors arise because models with foresight may imply that the information set of private agents is larger than the econometrician's.

An econometrician who estimates an identified VAR aims to condition on the same information set as the economic agents to recover the structural shocks $\{\varepsilon_{\tau,t-j}\}_{j=0}^{\infty}$. Typically, this is achieved by conditioning the VAR estimates on current and past observable variables. Consider the univariate case of conditioning on current and past capital, $\{k_{t-j}\}_{j=0}^{\infty}$, and suppose that agents have two quarters of foresight. Using lag operators (*i.e.*, $L^s x_t = x_{t-s}$), (8) may be written as

$$(1-\alpha L)k_t = -\kappa(L+\theta)\varepsilon_{\tau,t}. \tag{10}$$

Will the econometrician's conditioning set, current and past capital, span the same space as the agents', current and past structural shocks?[3] The answer depends on whether $\{\varepsilon_{\tau,t-j}\}_{j=0}^{\infty}$ is *fundamental* for $\{k_{t-j}\}_{j=0}^{\infty}$, using the terminology of Rozanov (1967). Fundamentalness requires the equilibrium process to be invertible in current and past k_t, so that

$$\left[\frac{1-\alpha L}{1+\theta^{-1}L}\right]k_t$$

is a convergent sequence. If $|\theta|>1$ this condition holds and $\{k_{t-j}\}_{j=0}^{\infty}$ spans the same space as $\{\varepsilon_{\tau,t-j}\}_{j=0}^{\infty}$. But a unique saddlepath solution requires $|\theta|<1$. Therefore, $\{\varepsilon_{\tau,t-j}\}_{j=0}^{\infty}$ is *not fundamental* for $\{k_{t-j}\}_{j=0}^{\infty}$.

To determine the econometrician's information set, we derive the Wold representation for k_t from the one-step-ahead forecast errors associated with predicting k_t conditional only on its past values. This representation emerges from flipping the root of the moving average representation from inside the unit circle to outside the unit circle using the Blaschke factor, $[(L+\theta)/(1+\theta L)]$ [see Hansen and Sargent (1991b) or Lippi and Reichlin (1994)]. The Wold representation for capital is

$$\begin{aligned}(1-\alpha L)k_t &= \underbrace{-\kappa(L+\theta)\left[\frac{1+\theta L}{L+\theta}\right]}_{=\quad -\kappa(1+\theta L)}\underbrace{\left[\frac{L+\theta}{1+\theta L}\right]\varepsilon_{\tau,t}}_{\varepsilon^*_{\tau,t}}\\ &= -\kappa\left\{\theta\varepsilon^*_{\tau,t-1}+\varepsilon^*_{\tau,t}\right\}. \end{aligned} \tag{11}$$

By observing current and past capital, the econometrician recovers current and past ε^*_τ, rather than the news that private agents observe, current and past ε_τ. The econometrician's innovations are the statistical shocks associated with estimating the autoregressive representation; those shocks turn out to represent information that is mostly "old news" to the agents of the economy. Fundamental shocks map into the econometrician's shocks as

$$\begin{aligned}\varepsilon^*_{\tau,t} &= \left[\frac{L+\theta}{1+\theta L}\right]\varepsilon_{\tau,t} = (L+\theta)\sum_{j=0}^{\infty}-\theta^j\varepsilon_{\tau,t-j}\\ &= \theta\varepsilon_{\tau,t}+(1-\theta^2)\varepsilon_{\tau,t-1}-\theta(1-\theta^2)\varepsilon_{\tau,t-2}+\theta^2(1-\theta^2)\varepsilon_{\tau,t-3}+\cdots \end{aligned} \tag{12}$$

This mapping shows that what the econometrician recovers as the tax innovation at time t, $\varepsilon^*_{\tau,t}$, is actually a discounted sum of the tax news observed by the agents at date t and earlier.

An econometrician who ignores foresight will discount the innovations incorrectly. In the econometrician's representation, yesterday's innovation has less effect than today's innovation, as the terms $\theta\varepsilon^*_{\tau,t-1}+\varepsilon^*_{\tau,t}$ in (11) show. Agents with foresight, in contrast, discount news according to $\varepsilon_{\tau,t-1}+\theta\varepsilon_{\tau,t}$, as in (8), because yesterday's news has a larger effect on

[3]More specifically, the information sets are equivalent if the the Hilbert space generated by $\{k_{t-j}\}_{j=0}^{\infty}$ is equivalent (in mean-square norm) to the Hilbert space generated by $\{\varepsilon_{\tau,t-j}\}_{j=0}^{\infty}$.

capital accumulation than today's news. Differences in discounting patterns applied by the econometrician and the agents lead to a variety of econometric problems.

By employing VAR analysis and not modeling foresight, the econometrician has conditioned on a smaller information set. The extent to which private agents condition on information that is not captured by current and past variables in the econometrician's information set determines the error associated with the VAR. This error can be mapped directly into the θ parameter that governs the non-invertibility of the equilibrium moving-average representation. The variance of the one-step-ahead forecast error for the agent is

$$E[(k_{t+1} - E[k_{t+1}|\varepsilon^t)^2] = E\left[\left(\frac{-\kappa(L+\theta)}{1-\alpha L}\varepsilon_{\tau,t+1} - L^{-1}[-\frac{\kappa(L+\theta)}{1-\alpha L} + \kappa\theta]\varepsilon_{\tau,t}\right)^2\right]$$
$$= (\kappa\theta)^2\sigma_\tau^2 \tag{13}$$

where ε^t denotes current and past ε. For the econometrician's information set, the variance of the forecast error is

$$E[(k_{t+1} - E[k_{t+1}|k^t])^2] = E\left[\left(\frac{-\kappa(L+\theta)}{1-\alpha L}\varepsilon_{\tau,t+1} - L^{-1}[-\frac{\kappa(1+\theta L)}{1-\alpha L} + \kappa]\left[\frac{L+\theta}{1+\theta L}\right]\varepsilon_{\tau,t}\right)^2\right]$$
$$= \kappa^2\sigma_\tau^2 \tag{14}$$

The ratio of (13) to (14) is θ^2. As θ^2 approaches unity (zero), the difference between the agent and econometrician's information sets gets smaller (larger). If θ is greater than or equal to 1, the representation for capital becomes fundamental with respect to $\varepsilon_{\tau,t}$ and the variances of the forecast errors (13) and (14) coincide.

To examine the importance of the information discrepancies in this model, we plot impulse response functions conditioning on the agents' and econometrician's information sets. Impulse response functions are widely used to convey how *agents* respond to innovations, but response functions based on the econometrician's information set will not capture these responses. Consider the impulse response functions generated by (8) and (11). Figure 1a plots the responses of capital assuming two quarters of foresight (with $\alpha = 0.36, \beta = 0.99, \tau = 0.25, \sigma_\tau^2 = 1$). With foresight, agents know exactly when the innovation in fiscal policy translates into changes in the tax rate. This creates the sharp decline in capital one quarter after the news arrives and before the tax rate changes, as the dotted-dashed line indicates. The econometrician's VAR, though, discounts the innovations incorrectly and reports that the biggest decline in capital occurs on impact, suggesting that foresight does not exist (solid line). The difference between the response functions can be quite dramatic, especially at short horizons.

Figure 1a shows that the econometrician will infer that the tax shock is *unanticipated*. Of course, not all shocks that affect fiscal policy are known several quarters in advance. Consider a tax rate process, $\hat{\tau}_t = e^u_{\tau,t} + \varepsilon_{\tau,t-q}$, that allows for both anticipated (ε_τ) and unanticipated (e^u_τ) shocks at time t. If these shocks are orthogonal at all leads and lags, then the equilibrium dynamics of (3) will not change because *i.i.d.* tax shocks will not alter the dynamics of capital. An econometrician who does not account for foresight will attribute *all* of the dynamics associated with the anticipated component of the tax rate to the unanticipated component. This suggests that researchers interested in the dynamic

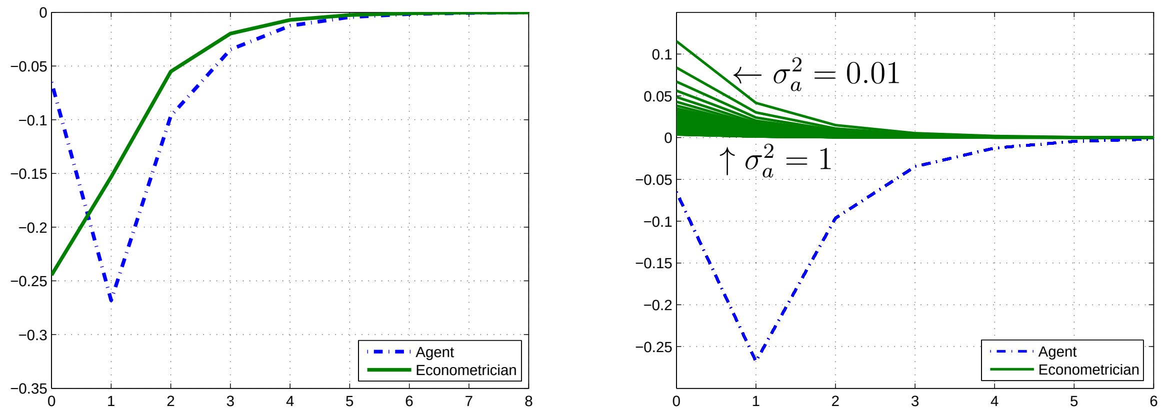

Figure 1: Responses of Capital to Tax Increase with $\alpha = 0.36, \beta = 0.99, \tau = 0.25$. Figure 1a plots the response of (13) and (14). Figure 1b plots the response to the VAR $(\tau_t, k_t)'$. Both figures assume two quarters of foresight.

effects of fiscal policy—whether the interest is in anticipated or unanticipated changes in policy—must explicitly account for foresight to avoid spurious conclusions.

Conditioning on more variables will not always lead to better inference. In the case of two-quarter foresight, suppose the econometrician estimates a VAR that includes the tax rate and the capital stock as observables

$$\begin{bmatrix} \hat{\tau}_t \\ k_t \end{bmatrix} = \begin{bmatrix} L^2 & 0 \\ \frac{-\kappa(L+\theta)}{1-\alpha L} & \frac{1}{1-\alpha L} \end{bmatrix} \begin{bmatrix} \varepsilon_{\tau,t} \\ \varepsilon_{A,t} \end{bmatrix}$$

$$\mathbf{x}_t = \mathcal{H}(L)\boldsymbol{\epsilon}_t. \tag{15}$$

A necessary condition for $\boldsymbol{\epsilon}_t$ to be a fundamental for $\mathbf{x}_t$ is that the determinant of $\mathcal{H}(z)$ be analytic with no zeros inside the unit circle. Foresight creates a zero inside the unit circle (at $z = 0$), implying that the information set generated by $\{\mathbf{x}_t, \mathbf{x}_{t-1}, \mathbf{x}_{t-2}, ...\}$ is smaller than the information set generated by $\{\boldsymbol{\epsilon}_t, \boldsymbol{\epsilon}_{t-1}, \boldsymbol{\epsilon}_{t-2}, ...\}$.

The Wold representation for (15) is obtained by finding Blaschke matrices $\mathcal{B}(L)$ and orthonormal matrices W, $\tilde{W}$ that do not alter the covariance generating function of $\mathbf{x}_t$, but "flip" the zeros outside of the unit circle. To do this we search for a $B(z)$ and W, $\tilde{W}$ that satisfy $\mathcal{B}(z)\mathcal{B}(z^{-1})' = I$ and $WW' = I$, $\tilde{W}\tilde{W}' = I$, and produces innovations that span the space generated by $\{\mathbf{x}_t, \mathbf{x}_{t-1}, \mathbf{x}_{t-2}, ...\}$. Following appendix A of Townsend (1983), the first step in the algorithm is to evaluate $\mathcal{H}(z)$ at $z = 0$, and postmultiply by W so as to put the zeros in the first column of the product matrix. The remaining columns of W can be constructed using a Gram-Schmidt orthogonalization procedure. The orthonormal W matrix ensures that the representation remains causal, preserving the assumption that the econometrician does not observe future values of the variables. Postmultiplying by $B(L)$ flips the zero outside of the unit circle. With two zeros inside the unit circle for (15), one must repeat this exercise (find an orthonormal matrix $\tilde{W}$ that aligns the zeros in the first column, etc.). Proceeding in this fashion delivers the representation

$$\underbrace{\begin{bmatrix}\hat{\tau}_t\\ k_t\end{bmatrix}}_{\mathbf{x}_t} = \underbrace{\begin{bmatrix} L^2 & 0 \\ \frac{-k(L+\theta)}{1-\alpha L} & \frac{1}{1-\alpha L}\end{bmatrix} W\mathcal{B}(L)\tilde{W}\mathcal{B}(L)}_{\mathcal{H}^*(L)}\,\underbrace{\mathcal{B}(L^{-1})\tilde{W}'\mathcal{B}(L^{-1})W'\begin{bmatrix}\varepsilon_{\tau,t}\\ \varepsilon_{A,t}\end{bmatrix}}_{\boldsymbol{\epsilon}_t^*} \tag{16}$$

where

$$W = \begin{bmatrix} \frac{1}{\sqrt{1+(\theta\kappa)^2}} & \frac{-\kappa\theta}{\sqrt{1+(\theta\kappa)^2}} \\ \frac{\kappa\theta}{\sqrt{1+(\theta\kappa)^2}} & \frac{1}{\sqrt{1+(\theta\kappa)^2}}\end{bmatrix}, \tilde{W} = \begin{bmatrix}\Delta(1+\kappa^2\theta^2) & -\Delta\kappa \\ \Delta\kappa & \Delta(1+\kappa^2\theta^2)\end{bmatrix}, \mathcal{B}(L) = \begin{bmatrix} L^{-1} & 0 \\ 0 & 1\end{bmatrix}$$

and $\Delta = [(1+\kappa^2\theta^2)^2 + \kappa^2]^{-1/2}$.

Now the econometric problems are more severe. First, the econometrician who proceeds with VAR analysis using (16) will likely obtain an impulse response function in which foresight does not appear to exist in the data. Figure 1b depicts the response of capital to a tax increase for the agent (dotted-dashed line) and econometrician as the variance of the technology shock decreases from 1 to 0.01. Conditioning on the econometrician's information set, the path of capital is flat when $\sigma_a^2 = \sigma_\tau^2 = 1$. In theory, unanticipated *i.i.d.* capital tax shocks have no effect on the economy, so based on the flat response of capital, an econometrician will infer that the effects of fiscal policy are limited to unanticipated components only. By not modeling foresight, this example achieves a "self-fulfilling prophesy" and wrongly concludes that foresight is not an issue.[4]

Second, as the variance of the tax shock increases relative to the technology shock, the errors associated with foresight become more pronounced. Figure 1b shows that the initial response of capital to a one-standard-deviation increase in the tax shock *increases* from 0 to 0.12 as σ_a^2 decreases from 1 to 0.01, so that an anticipated tax increase could be estimated to have no effect or a positive effect on capital and output.

Existing empirical work reports a diverse set of inferences about the effects of an anticipated tax increase on output. Figures 1a and 1b demonstrate that even this simple model can deliver diverse results that depend on the underlying information flows.

Finally, *all* conditional statistics reported by the econometrician will be misspecified. Consider the variance decompositions that Hansen and Sargent (1991b) emphasize. Let

$$E(\mathbf{x}_t - E^*_{t-j}\mathbf{x}_t)(\mathbf{x}_t - E^*_{t-j}\mathbf{x}_t)' = \sum_{k=0}^{j-1} \mathcal{H}^*_k\,\Sigma^*\,\mathcal{H}'^*_k$$

denote the j-step ahead prediction error variance associated with the econometrician's information set, where Σ^* is the variance-covariance matrix associated with $(\varepsilon^*_{\tau,t}, \varepsilon^*_{A,t})'$. Like impulse response functions, variance decompositions are derived using *conditional* expectations, so the discrepancy in the information sets implies the coefficients generated by $\mathcal{H}^*(L)$

[4] With this simple form of foresight, an econometrician who estimates a VAR in $(\hat{\tau}_{t+q}, k_t)$ will recover the true shocks. But more sophisticated information flows, as in later sections, or empirically plausible tax rules, as in Leeper, Plante, and Traum (2010), preclude that easy fix.

will misallocate the variance across the structural shocks.[5] Figure 1b suggests that the econometrician will treat the tax shock as nearly *i.i.d.* and infer that none of the variation in capital (and hence output) can be attributed to tax innovations; all of the variation will be attributed to the technology shock. This inference holds even if, in fact, the tax shock explained nearly all of the variation in capital (for example, when the variance of the technology shock, σ_A^2, is arbitrarily small).

We derive further implications of foresight in appendix A, where we show that Granger causality tests and tests of economic theory, such as tests of present value restrictions, will be misspecified in the presence of foresight. Errors associated with ignoring foresight can be quite large.

2.2 Generalizations The previous example assumes an *i.i.d.* tax shock, but the difficulties associated with foresight extend to more general setups. Suppose the stationary tax rate follows $\hat{\tau}_t = C(L)L^q\varepsilon_{\tau,t}$, where $C(L)$ is a polynomial in the lag operator L and q is the degree of foresight. The only restriction placed on $C(L)$ is that the corresponding coefficients are square summable, which allows for *any* serial correlation pattern. Agents guess that the law of motion for capital is given by a square summable linear combination of tax and technology shocks, $k_t = F(L)\varepsilon_{\tau,t} + G(L)\varepsilon_{a,t}$, as Whiteman (1983) shows. Focusing on tax shocks only and substituting this guess into the difference equation for capital in (3) yields

$$\theta L^{-1}[F(L) - F_0]\varepsilon_{\tau,t} - (1+\alpha\theta)F(L)\varepsilon_{\tau,t} + \alpha LF(L)\varepsilon_{\tau,t} = \left\{(1-\theta)\left(\frac{\tau}{1-\tau}\right)\right\}E_{t+1}\hat{\tau}_{t+1}$$

where the Weiner-Kolmogorov formula is used to take expectations (i.e., $E_t x_{t+1} = L^{-1}[D(L) - D_0]\varepsilon_{x,t}$), and $\theta = \alpha\beta(1-\tau)$. Uniqueness of the rational expectations equilibrium requires $|\theta| < 1$, where the equilibrium $F(L)\varepsilon_{\tau,t}$ for q degrees of foresight is given by

$$F(L)\varepsilon_{\tau,t} = -\left[\frac{\kappa[L^q C(L) - \theta^q C(\theta)]}{(1-\alpha L)(L-\theta)}\right]\varepsilon_{\tau,t}. \tag{17}$$

This equation makes plain how foresight impinges on optimal capital accumulation for any choice of $C(L)$. Whenever $q \geq 2$, the equilibrium contains moving average components even when $C(L)$ is purely autoregressive. This representation suggests that it is straightforward to construct impulse response functions that take a wide range of shapes (including hump-shaped), for which the dynamic equation for capital continues to be non-invertible in current and past k_t. For example, setting $C(L) = (1-\rho_1 L - \rho_2 L^2)^{-1}$ and assuming two quarters of foresight ($q = 2$) implies that the tax shocks $\varepsilon_{\tau t}$ are non-fundamental for k_t if $\theta < (1+\rho_1)^{-1}$. Because the condition for a non-fundamental moving average representation is independent of ρ_2, impulse response functions of non-fundamental moving average representations can adopt many forms.

The logic that leads foresight to produce equilibria with non-fundamental moving-average representations extends to a large class of models. Consider the generic multivariate rational

[5] This result holds even though the statistical shocks of the VAR remain uncorrelated. Orthogonality of the Blaschke and W matrices ($\mathcal{B}(L)\mathcal{B}(L^{-1}) = I$ and $WW' = \tilde{W}\tilde{W}' = I$) implies that the unconditional second moments of the VAR system remain the same, but the conditional moments will be different.

expectations model

$$\Gamma_0 y_t = \Gamma_1 y_{t-1} + \Psi z_t + \Pi \eta_t, \tag{18}$$

where y_t is an $n \times 1$ vector of endogenous variables, z_t is an $m \times 1$ vector of exogenous random shocks, η is a $k \times 1$ vector of expectation errors, which satisfy $E_t \eta_{t+1} = 0$ for all t. Γ_0 and Γ_1 are $n \times n$ coefficient matrices, along with Ψ $(n \times m)$ and Π $(n \times k)$. Klein (2000) and Sims (2002) use a generalized Schur decomposition of Γ_0 and Γ_1 to show that there exist matrices such that $Q'\Lambda Z' = \Gamma_0$, $Q'\Omega Z' = \Gamma_1$, $Q'Q = Z'Z = I_{n\times n}$, where Λ and Ω are upper-triangular. The ratios of the diagonal elements of Ω and Λ, ω_{ii}/λ_{ii}, are the generalized eigenvalues. Defining $w_t = Z' y_t$ and pre-multiplying (18) by Q, yields the decomposition

$$\begin{bmatrix} \Lambda_{11} & \Lambda_{12} \\ 0 & \Lambda_{22} \end{bmatrix} \begin{bmatrix} w_{1,t} \\ w_{2,t} \end{bmatrix} = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ 0 & \Omega_{22} \end{bmatrix} \begin{bmatrix} w_{1,t-1} \\ w_{2,t-1} \end{bmatrix} + \begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} (\Psi z_t + \Pi \eta_t) \tag{19}$$

The system is partitioned so that the generalized eigenvalues imply an explosive path for $w_{2,t}$. $\Omega_{22}^{-1}\Lambda_{22}$ is the multivariate analog to θ in the simple analytical example. Analogous to (4), $w_{2,t}$ must be solved forward to ensure stability of the system. Sims shows that the forward solution of (18) is

$$y_t = \Theta_1 y_{t-1} + \Theta_0 z_t + \Theta_y \sum_{s=1}^{\infty} \Theta_f^{s-1} \Theta_z E_t z_{t+s} \tag{20}$$

where $\Theta_f = \Omega_{22}^{-1}\Lambda_{22}$, $\Theta_z = \Omega_{22}^{-1} Q_2 \Psi$. If the structural shocks, z_t, are *i.i.d.* and agents do not have foresight, then the last term in (20) drops out of the solution and the equilibrium has a VAR representation. By conditioning on the control and state variables, y_t, an econometrician who estimates a VAR will be able to recover the structural shocks. But when agents have foresight, the equilibrium representation becomes a VARMA with the MA coefficients determined by the unstable generalized eigenvalues. Suppose the structural shocks are given by $z_t = \epsilon_{t-q}$, and agents have foresight—at date t they observe ϵ's dated t and earlier. The equilibrium is

$$y_t = \Theta_1 y_{t-1} + \Theta_0 \epsilon_{t-q} + \Theta_y [\Theta_z \epsilon_{t-q+1} + \Theta_f \Theta_z \epsilon_{t-q+2} + \cdots + \Theta_f^{q-1} \Theta_z \epsilon_t]. \tag{21}$$

As in the univariate case, the contemporaneous shocks are discounted the heaviest, which is precisely why models with foresight are more likely to deliver non-fundamental equilibrium representations.

The extent to which foresight leads to econometric errors depends on the underlying structure of the economy and the nature of information flows. The next section examines this issue in two canonical macro models.

3 Quantitative Importance of Foresight

The information flows specification in (5) was chosen for its analytical convenience, not for its plausibility. To assess the quantitative importance of foresight, this section generalizes those flows to capture actual news processes and embeds the generalized specification in two empirically motivated DSGE models. We show how the nature of information flows affects the inference errors an econometrician can make by not modeling foresight. Quantitative importance is summarized by dynamic tax multipliers, comparing those estimated by an econometrician who fits an identified VAR to the true tax multipliers.

3.1 Modeling Information Flows Rich information flows characterize the arrival and accumulation of news about tax changes, but generally fall into two periods: between initial proposal and final enactment—or rejection—of a new tax law ("inside lag") and between enactment and when the law takes effect ("outside lag").[6] During the inside lag, information and expectations are evolving about the likelihood and the precise form of proposed legislation. Sources of information that mark the beginning of the inside lag can be formal—a president's State of the Union speech—or informal—a politician's campaign pledges. And this early information may be confirmed or contravened by subsequent actions.[7] Outside lags arise whenever there is a delay between the legislation's passage and its implementation, as when tax changes are phased in. The two types of lags differ in important ways. During the inside lag, anticipated taxes are uncertain; news arrives regularly and induces agents to update their expectations. During the outside lag, the tax law has been adopted, no more news arrives, and agents have perfect foresight about future tax rates.

Examples clarify the nature of information flows. The Economic Recovery Tax Act of 1981, enacted in August 1981, phased in tax reductions through the beginning of 1984 to yield an outside lag of 10 quarters. In announcing his candidacy for president in November 1979, Ronald Reagan made clear that he intended to substantially lower taxes: "The key to restoring the health of the economy lies in cutting taxes" [Reagan (1979)]. News about future taxes, then, arrived throughout 1980, evolving with Reagan's prospects of winning office. An additional six months passed between President Reagan's formal call for tax relief in February 1981 and the legislation's enactment. The inside lag associated with this tax change is, arguably, five or more quarters, with the weights agents place on the bits of news changing over time. Taken together, the two lags imply a foresight period of about four years.

Adjustments to Social Security taxes can entail extraordinarily long lags. The National Commission on Social Security Reform was established in December 1981 to recommend solutions to the System's short- and long-term solvency problems. Its recommendations, reported in January 1983, formed the basis for the Social Security Amendments of 1983, which were enacted in April 1983. The Amendments phased in payroll tax increases beginning in 1984 and extending to 1990. Although their inside lag may have been only a few quarters, the Amendments' outside lag is over six years. Other changes in Social Security taxes had comparably long lags.

To model these intricacies, we generalize (5) with a specification of information flows about tax rates that is flexible enough to capture both inside and outside lags. For labor taxes, we posit

$$\hat{\tau}_t^L = \rho\hat{\tau}_{t-1}^L + \sum_{j=0}^{J} \phi_j \left[\sigma^L \varepsilon_{\tau,t-j}^L + \xi\sigma^K \varepsilon_{\tau,t-j}^K\right] \tag{22}$$

where $\hat{\tau}_t^L$ is the labor tax rate, ξ permits rates to be correlated, and the ε's are serially uncor-

[6] These labels date back to Friedman (1948), where we combine the "recognition" and "decision" lags to form inside lags and our outside lags refer to how long it takes legislation to change tax rates.

[7] Announcing their candidacies, both Ronald Reagan and George W. Bush made clear their intentions to cut taxes, well over a year before they took office and formally proposed tax cuts. George H. W. Bush, in contrast, pledged in his announcement speech, "I am not going to raise your taxes—period." That was two-and-a-half years before he called for a tax increase. See http://www.4president.org for these speeches.

related. To interpret the moving-average coefficients as weights, we impose that $\sum_j \phi_j = 1$. Exogenous tax processes are the best-case scenario for econometricians because identification is straightforward in the absence of foresight. This ensures that all errors arise solely from foresight.

Modeling information flows as moving average processes captures the idea that from quarter to quarter news about taxes evolves randomly. News might accumulate, with information improving and concentrating agents' probability distributions over future tax rates. Or news might disappoint, with agents' expectations frustrated by realizations of ε's that reverse earlier expectations. This randomness captures the vagaries of the political process that determines fiscal choices.

Specification (22) embeds many of the information flows that appear in theoretical studies of foresight, including Christiano, Ilut, Motto, and Rostagno (2008), Jaimovich and Rebelo (2009), and Fujiwara, Hirose, and Shintani (2011) in the context of technology news; Ramey (2007) for government spending news; Yang (2005) and Mertens and Ravn (2011) with regard to tax news, and Schmitt-Grohé and Uribe (2008) for news about a variety of variables. These studies set $\phi_j = 0$ for all j except for $\phi_q = 1$, where q is the period of foresight.[8] These specifications imply that once the news arrives, agents have q periods of *perfect foresight* about the object being modeled. This may be an adequate assumption about information flows that stem from outside lags, but they miss altogether the inside lags. Inside lags are periods when agents are learning about how the future may play out. Tax policies develop over time, from initial informal proposals to formal proposals, all the way through the legislative process. The ϕ_j coefficients in (22) reflect how agents update their views about taxes during the inside lags. Values of the ϕ_j's describe how information flows differ from period to period.

Existing work on foresight does not systematically distinguish between the information flows associated with inside and outside lags. Romer and Romer (2007, 2010) base their tax-shock series on narrative sources that report both enacted and proposed tax changes, but Mertens and Ravn (2011) treat all of the Romers' anticipated tax changes as stemming from outside lags. The Romers also limit themselves to actions that actually change tax liabilities, so their data series excludes proposals that do not reach fruition. Ramey's (2009; 2011) narrative analysis identifies a number of instances where the news about major military build ups arrived well before any explicit legislative actions were taken, which are clear examples of inside lags. But Ramey's (2007) theoretical specification posits the analog to (22) for military spending as an autoregressive process with a news shock lagged two periods, capturing only the outside lag.

3.2 Model Descriptions

We study a real business cycle model—closely related to Chari, Kehoe, and McGrattan (2008)—and a new Keynesian model—similar to those in Smets and Wouters (2003, 2007)—but add distorting tax rates on capital and labor income. These models are workhorses in the macroeconomics literature so we provide only brief descriptions here. Appendix B describes the models and our estimation strategies more

[8] Some studies allow the news shocks, ε_{t-j}, to be drawn from distinct distributions for each j, and set $\phi_j = 1$ for each relevant j [Schmitt-Grohé and Uribe (2008), Fujiwara, Hirose, and Shintani (2011), and Mertens and Ravn (2011)]. The $j = 0$ shock is unanticipated, while the $j > 0$ shocks are anticipated given information at time t.

thoroughly.

In the real business cycle (RBC) model, a representative agent maximizes time-separable discounted utility over consumption and leisure. The agent supplies labor and capital to a representative firm, which produces output according to a Cobb-Douglas technology. The government chooses a set of fiscal variables to satisfy the flow budget constraint, $G_t + Z_t = \tau_t^L w_t l_t + \tau_t^K r_t^K k_{t-1}$, where G_t is government consumption, and Z_t is transfers.

Tax legislation tends to adjust labor and capital taxes simultaneously, following (22), and its analog for capital tax rates. Yang (2005) estimates the correlation between tax rates at 0.5, implying the value of ξ. A a "typical" tax change, analogous to those studied in VARs, moves the tax rates together.

Log-linearized government consumption policy follows the process

$$\hat{G}_t = \rho_G \hat{G}_{t-1} + \sigma_G \varepsilon_t^G. \tag{23}$$

Lump-sum transfers adjust to balance the government budget constraint each period.

The new Keynesian (NK) model extends the RBC model to incorporate real and nominal rigidities that have been shown to help fit macroeconomic data. It also models fiscal financing by allowing spending to adjust to stabilize government debt. The NK model adds external habit formation, differentiated labor types, a monopolistically competitive intermediate goods sector, variable capital utilization, wage and price rigidities, and a monetary authority that follows a Taylor-type rule for setting nominal interest rates. Tax policies obey (22) and government spending policies follow the process

$$\hat{X}_t = \rho_X \hat{X}_{t-1} + \gamma_X \hat{s}_{t-1}^B + \sigma_X \varepsilon_t^X, \ \hat{X} \in \{\hat{G}, \hat{Z}\} \tag{24}$$

where $\hat{s}_{t-1}^B \equiv \frac{B_{t-1}}{Y_{t-1}}$ is the debt-output ratio and $\gamma_X < 0$.

We estimate the NK model using Bayesian methods and U.S. quarterly data from 1984 to 2007. To conduct simulations, we fix parameters at the mode of the posterior distributions (see table 4 in appendix B). For the RBC model, the structural parameters are calibrated to the values used in the literature and standard deviations of the shocks are set to the values estimated in the NK model (see Appendix B).

3.3 Information Flows and Estimation Bias The Romers' (2007; 2010) narrative analysis and Yang's (2009) timeline of outside lags associated with federal tax changes reveal two critical features of information flows about taxes. First, the foresight horizon varies considerably from one piece of tax legislation to the next. Second, most tax changes entail substantial inside and outside lags. The generalized specification (22) can model these features of information flows; simple specifications like (5) cannot.

We examine the implications of four alternative information flows in the two DSGE models. The alternatives reflect the diversity of information flows that previous authors have documented. With a maximum length of tax foresight of eight quarters, the four information processes we employ appear in table 1.

Processes I and II model inside lags that differ in the intensity of information flows. In I, the flows are smooth, so news over the previous six quarters receives equal weight. Tax laws that make steady progress through the legislature and get implemented with little delay create flows like I. Process II concentrates the news on lags four through six, with small

Process	Lags	Description	Coefficients
I	Inside	6 qtrs, smooth news	$\phi_j = \frac{1}{6}, j = 1, 2, \ldots, 6$ $\phi_0 = \phi_7 = \phi_8 = 0$
II	Inside	6 qtrs, concentrated news	$\phi_1 = \phi_2 = \phi_3 = 0.05, \phi_4 = 0.25$ $\phi_5 = \phi_6 = 0.3, \phi_0 = \phi_7 = \phi_8 = 0$
III	Outside	8-qtr phase-in	$\phi_j = 0\ j \neq 8$ $\phi_8 = 1$
IV	Outside	2-qtr phase-in	$\phi_j = 0,\ j \neq 2$ $\phi_2 = 1$

Table 1: Information Flow Processes. Coefficient settings in tax rule (22).

weight on recent news. Tax changes implemented with a lag of about one year, with only slight changes in details in the periods immediately before implementation, generate flows like II.

The outside lags in processes III and IV closely resemble the information flows that other authors posit [for example, Mertens and Ravn (2011), and Forni, Gambetti, and Sala (2011)]. These processes imply that agents have eight-quarter (III) or two-quarter (IV) perfect foresight about tax changes. Perfect foresight precludes any further changes in legislation, so these processes are exclusively about implementation delays or phased-in tax changes.[9]

Table 2 summarizes the actual and estimated output multipliers associated with a typical tax change in the RBC and NK models. In this exercise, the agent knows the information process and observes the actual ε_t's. The econometrician, on the other hand, bases inference on a set of observable variables. We construct the innovations representation based on the econometrician's conditioning set and use the Kalman filter to back out the econometrician's inferences about the responses of output and taxes to a shock to the tax rate. For the RBC model, the econometrician conditions on the labor tax rate, income tax revenue, output, and investment; the conditioning set for the NK model adds government consumption, private consumption, labor, government debt, inflation, and the nominal interest rate. Thus, the estimated VAR contains several "forward-looking" variables. As a robustness check, we examined many combinations of alternative conditioning variables and found results that are consistent with those in table 2. We report biases as estimated less actual multipliers and biases as a percentage of the actual multipliers. In the absence of foresight, the bias is always zero.

Several general findings emerge from the table. Biases can be very large—hundreds of percent—and can change sign over time across both models. In both models, the biggest errors arise from outside lags—information processes III and IV—which are the information flows most frequently posited in work on foresight. Inside lags with moving-average terms—processes I and II—produce smaller, though still sizeable errors. Information process III, in which agents have two years of perfect foresight about tax rates, generates the largest inference errors in both models. It also confounds dynamics: the econometrician estimates that the strongest effect is contemporaneous, while the largest impact actually occurs two

[9] Ideally, information flows would encompass both inside and outside lags, but such flows would take us outside of a linear structure. For example, one could posit the flows for the inside lag and then, conditional on legislation having been enacted, switch to the outside lag specification, a process that is inherently nonlinear.

or three years later, depending on the model.

In the RBC model, actual multipliers change *sign*—positive in the foresight period and negative later—but estimated multipliers are uniformly negative. Frictions in the NK model propagate errors, making short/long-run distinctions less pronounced.[10] In the frictionless RBC model, biases dissipate over time.

A consistent finding across the two models is that for horizons of eight quarters and beyond, the econometrician *underestimates* the multiplier. The lone exception being the new Keynesian model under information process I. The discounting of the tax innovations that appears in (4) and (20) explains this result. An agent with q quarters of foresight discounts the innovations so that the $\varepsilon_{\tau,t-q}$ shock receives little discount relative to shocks dated t through $t-q-1$. As in the analytical model, this perverse discounting occurs because $\varepsilon_{\tau,t-q}$ informs about the contemporaneous tax rate, τ_t, while shocks dated t through $t-q-1$ inform about future tax rates. An econometrician, who does not observe the true innovations, applies the conventional discounting to the innovations in her information set, as in (11). This makes the econometrician's impulse response functions die out faster than the true impulse response functions, yielding the underestimates.

These findings establish two key points. First, failure to model fiscal foresight can produce quantitatively important errors of inference in the canonical models used for macroeconomic policy analysis. Second, the precise nature of information flows about news matters for the pattern of inference errors. Getting the information flows "right" poses a substantial challenge to DSGE modelers. We turn now to an empirical approach to extract the tax news from data that does not require specifying the nature of information flows.

4 Attacking the Problem

Fiscal foresight can imply that private agents' information sets include news about tax changes that is difficult to embed into a VAR. We exploit a feature of the U.S. tax code that exempts interest earnings on municipal bonds from federal income taxation to extract news about future tax changes from yield spreads between municipal and treasury bonds. We augment two standard fiscal VARs with bond spreads to re-examine the macroeconomic effects of anticipated taxes. Before launching into the empirical work, we connect two kinds of non-uniqueness of moving average representations to existing efforts to identify VARs, with and without foresight.

4.1 Two Kinds of Non-Uniqueness Moving average representations are not unique for two distinct reasons that Hansen and Sargent (1991a) emphasize. Consider the Wold representation for the $n \times 1$ vector stochastic process $\mathbf{x}_t$

$$\mathbf{x}_t = \sum_{j=0}^{\infty} H_j^* \boldsymbol{\epsilon}_{t-j}^* \tag{25}$$

where $\sum_{j=0}^{\infty} \text{tr } H_j^* H_j^{*'} < \infty$ and $\boldsymbol{\epsilon}_t^*$ is an n-dimensional white noise process defined as the innovation in predicting $\mathbf{x}_t$ linearly from its semi-infinite past ($\boldsymbol{\epsilon}_t^* \equiv \mathbf{x}_t - P[\mathbf{x}_t|\mathbf{x}^{t-1}]$).

[10] This echoes Leeper and Walker's (2011) results for foresight about technology.

Real Business Cycle Model							
Info Process		0 qtr	4 qtrs	8 qtrs	12 qtrs	20 qtrs	peak (qtr)
I	actual	0.19	−1.14	−1.48	−1.11	−0.65	−1.71 (6)
	estimated	−0.31	−1.35	−1.27	−0.97	−0.59	−1.57 (5)
	bias	−0.50	−0.21	0.20	0.14	0.06	
	% bias	−263%	−19%	14%	12%	8%	
II	actual	0.15	−0.54	−1.40	−1.05	−0.61	−1.62 (6)
	estimated	−0.56	−1.46	−1.19	−0.91	−0.55	−1.48 (2)
	bias	−0.71	−0.92	0.21	0.14	0.06	
	% bias	−473%	−169%	15%	13%	9%	
III	actual	0.09	0.16	−1.51	−1.12	−0.64	−1.51 (8)
	estimated	−1.44	−1.09	−0.82	−0.64	−0.39	−1.44 (0)
	bias	−1.54	−1.24	0.69	0.49	0.25	
	% bias	−1641%	−784%	46%	43%	39%	
IV	actual	0.16	−1.34	−1.00	−0.76	−0.45	−1.56 (2)
	estimated	−1.41	−1.06	−0.81	−0.62	−0.38	−1.41 (0)
	bias	−1.57	0.28	0.20	0.14	0.07	
	% bias	−962%	21%	20%	18%	16%	
New Keynesian Model							
Info Process		0 qrt	4 qtrs	8 qtrs	12 qtrs	20 qtrs	peak (qtr)
I	actual	−0.08	−0.36	−0.48	−0.43	−0.24	−0.48 (8)
	estimated	−0.07	−0.44	−0.57	−0.51	−0.28	−0.57 (8)
	bias	0.01	−0.09	−0.09	−0.08	−0.04	
	% bias	11%	−24%	−20%	−18%	−18%	
II	actual	−0.06	−0.27	−0.43	−0.40	−0.23	−0.43 (9)
	estimated	−0.09	−0.37	−0.42	−0.37	−0.19	−0.42 (7)
	bias	−0.03	−0.10	0.00	0.04	0.04	
	% bias	−51%	−37%	1%	9%	19%	
III	actual	−0.03	−0.12	−0.32	−0.37	−0.26	−0.37 (12)
	estimated	−0.14	−0.10	−0.08	−0.06	−0.01	−0.14 (0)
	bias	−0.11	0.01	0.24	0.32	0.25	
	% bias	−340%	13%	76%	85%	95%	
IV	actual	−0.06	−0.30	−0.33	−0.28	−0.14	−0.33 (7)
	estimated	−0.15	−0.24	−0.26	−0.22	−0.11	−0.26 (7)
	bias	−0.08	0.07	0.07	0.06	0.04	
	% bias	−128%	22%	22%	22%	25%	

Table 2: Output Multipliers for a Labor Tax Change, Correlated with a Capital Tax Change. Multipliers are output responses scaled by the peak response of revenues, converted to dollars, as in Blanchard and Perotti (2002). Agent knows the information process and observes the actual ϵ_t's. Econometrician bases inference on a set of observable variables, as described in text. Biases equal estimated less actual multipliers.

There are two transformations that are observationally equivalent to (25). The first comes from multiplying by a nonsingular matrix U,

$$\mathbf{x}_t = \sum_{j=0}^{\infty}(H_j^* U^{-1})(U\boldsymbol{\epsilon}_{t-j}^*) \tag{26}$$

where the innovation is now defined as $U\boldsymbol{\epsilon}_t^*$ and $H_j^* U^{-1}$ represents the altered impulse responses. If U is nonsingular, then the new innovations process spans the same space as $\mathbf{x}^t$ and the information content of $U\boldsymbol{\epsilon}_t^*$ is identical to that $\boldsymbol{\epsilon}_t^*$. This is the type of non-uniqueness that Sims (1980) describes. Researchers confront this non-uniqueness with different orthogonalization schemes that rotate the covariance matrix through recursive orderings [Sims (1980)], short-run restrictions [Bernanke (1986), Sims (1986)], long-run restrictions [Blanchard and Quah (1989)], a combination of short and long-run restrictions [Gali (1999)], or sign restrictions [Faust (1998), Canova (2000), Uhlig (2005)].

A second type of non-uniqueness that is observationally equivalent to (25) is generated by foresight and is described by the non-fundamental representation[11]

$$\mathbf{x}_t = \sum_{j=0}^{\infty} H_j \boldsymbol{\epsilon}_{t-j} \tag{27}$$

where now $\{\boldsymbol{\epsilon}_{t-j}\}_{j=0}^{\infty}$ spans a larger space than $\{\mathbf{x}_{t-j}\}_{j=0}^{\infty}$, and $H(L)$ satisfies

$$H^*(z)E\boldsymbol{\epsilon}_t^*\boldsymbol{\epsilon}_t^{*'}H^*(z^{-1})' = H(z)E\boldsymbol{\epsilon}_t\boldsymbol{\epsilon}_t'H(z^{-1})'.$$

Under the typical assumption that agents observe the structural shocks $\boldsymbol{\epsilon}_t$ directly while the econometrician observes only $\mathbf{x}_t$, models with sufficient foresight belong to this class of non-fundamental representations. The covariance generating functions of $H(L)\boldsymbol{\epsilon}_t$ and $H^*(L)\boldsymbol{\epsilon}_t^*$ are identical, but only $H^*(L)$ possesses an invertible representation in $\mathbf{x}_t$. Let $A(L) = H^*(L)^{-1}$. The typical VAR methodology delivers

$$\mathbf{x}_t = A_0^{-1}[A_1\mathbf{x}_{t-1} + A_2\mathbf{x}_{t-2} + \cdots + \boldsymbol{\epsilon}_t^*]. \tag{28}$$

Identifying A_0^{-1} in the usual way recovers the shocks $\boldsymbol{\epsilon}_t^*$, but not the structural shocks, $\boldsymbol{\epsilon}_t$, that agents see.

Hansen and Sargent's non-uniqueness point sends a clear message: to identify structural shocks in a vector autoregression, *both* types of non-uniqueness must be confronted. Confronting the non-uniqueness in (26) does *not* solve the non-uniqueness of representation (27), and vice versa. Although a large literature focuses on the non-uniqueness associated with (26), identifying (27) requires the econometrician to condition on the same information set as the agents they are modeling.

Casting the problem as resolving the two distinct forms of non-uniqueness sheds light on approaches that appear in the empirical macro literature. One line of attack estimates conventional VARs, identified in a variety of creative ways to isolate anticipated effects, and then examines the impacts of foresight [Sims (1988), Blanchard and Perotti (2002), Yang (2007), Mountford and Uhlig (2009), Beaudry and Portier (2006), Fisher and Peters (2009),Barsky and Sims (2011)]. For example, Beaudry and Portier (2006) and Fisher and Peters (2009) condition on stock prices to capture news about expected changes in technology and government spending, respectively. Barsky and Sims (2011) identify news about productivity as the shock that is orthogonal to current utilization-adjusted productivity that best explains future variations in adjusted productivity. A second line of attack rejects VAR identification schemes, arguing that VARs cannot adequately measure the impacts of foreseen changes in fiscal policy, and takes a narrative approach to bring fresh data to bear on the identification problem [Ramey and Shapiro (1998), Edelberg, Eichenbaum, and Fisher (1999), Burnside, Eichenbaum, and Fisher (2004), Ramey (2007), Romer and Romer (2010)]. A third approach uses standard methods, such as An and Schorfheide (2007), to estimate a model with foresight. To pursue this approach, Schmitt-Grohé and Uribe (2008) make very particular assumptions about the information flows that give rise to foresight about technology and

[11] Foresight is not the only way to generate this type of non-uniqueness. Any structural VAR in which the econometrician conditions on less *or more* information is subject to this form of non-uniqueness.

government spending. The tradeoff is that the modeler must be explicit about the role of information in the economy.

Each approach has its strengths and weaknesses.[12] A unifying theme underlying each approach, though, is the need to specify an information structure that is consistent with agents that have foresight. Although most papers do not explicitly cast the problem as resolving the non-uniqueness of (27) by specifying information flows, this is precisely what each paper aims to do in its own way. We have seen in table 2 that different assumptions about information flows can dramatically alter the dynamics of the model and the associated econometric inferences. Careful modeling of the information available to agents is of first-order importance.

4.2 Municipal Bonds and Fiscal Foresight

We now offer a new method to capture the information flows associated with news about future tax changes in an estimated VAR that builds on Poterba (1989). Identification takes two steps. First, we condition on the spread between municipal and treasury bonds to solve the non-uniqueness associated with (27). Then we apply two well-known identification schemes to identify the moving-average representation in (26).

In the United States, municipal bonds are exempt from federal taxes.[13] If $\mathcal{Y}_T^M$ is the yield on a municipal bond with maturity T and $\mathcal{Y}_T$ is the yield on a taxable bond with the same maturity, then if the bonds have the same callability, market risk, credit risk, and so forth, an implicit tax rate is given by $\tau_T^I = 1 - \mathcal{Y}_T^M/\mathcal{Y}_T$. This is the tax rate at which the investor is indifferent between the tax-exempt and taxable bond. If participants in the municipal bond market are forward looking, the implicit tax rate should predict subsequent movements in individual tax rates. This tactic follows the advice of Sims (1977), who shows that durable goods prices that are determined in spot markets, and financial prices in particular, should be nearly Granger-causally prior to any time series that market participants observe. This observation motivates and restricts the kinds of information that might be useful for capturing foresight in VARs, and explains why merely augmenting VARs with "forward-looking" variables, especially slow-moving ones, is unlikely to be helpful.

Several papers document that municipal bonds respond to changes in tax policy [Poterba (1989), Fortune (1996), Park (1997), and Ang, Bhansali, and Xing (2010)]. Leeper, Richter, and Walker (2010) update Poterba (1989) and find that municipal bonds are reliable predictors of future tax changes. Many of these papers conclude that the short end of the municipal bond yield curve predicts pending fiscal policy changes much more accurately than the long end of the yield curve—the municipal bond puzzle [Chalmers (1998)]. In light of this puzzle, our analysis uses municipal and treasury bond data with maturity lengths of one and five years only.

A newly issued tax-exempt bond with maturity T, a par value of \$1, and per-period

[12] We discuss the strengths and weaknesses of several approaches in more detail in Leeper, Walker, and Yang (2008) (an earlier working-paper version of the current paper) and in Leeper, Walker, and Yang (2011).

[13] Depending on the type of bond, municipal bonds can also be exempt from the Alternative Minimum Tax, state, and local taxes.

coupon payments C_M, will sell at par if

$$1 = \frac{C^M}{\sum_{t=1}^{T}(1+R_t^\tau)^t} + \frac{1}{(1+R_T^\tau)^T}, \tag{29}$$

where R_t^τ is the *after-tax* nominal interest rate for payments made in period t. No-arbitrage conditions imply that an identical taxable bond paying coupon C, and selling at par satisfies

$$1 = \frac{\sum_{t=1}^{T} C(1-\tau_t^e)}{\sum_{t=1}^{T}(1+R_t^\tau)^t} + \frac{1}{(1+R_T^\tau)^T}, \tag{30}$$

where τ_t^e is the future tax rate expected to hold in period t.

Bonds that sell at par have a yield-to-maturity that equals the coupon payments, so the implicit tax rate is $\tau_T^I = 1 - C_M/C$. Subtracting (30) from (29) and solving for C_M/C gives

$$\tau_T^I = \sum_{t=1}^{T} \omega_t \tau_t^e, \tag{31}$$

where $\omega_t = \delta_t / \sum_{t=1}^{T} \delta_t$ and $\delta_t = (1+R_t^\tau)^{-t}$. The current implicit tax rate is a weighted average of discounted expected future tax rates from $t = 1$ to T and should respond immediately to news about anticipated *future* tax changes.

Equation (31) makes plain the advantages of using municipal bond spreads to capture information flows about pending tax changes. First, there is no need to specify *a priori* the period of foresight. Assuming market efficiency, the implicit tax rate reveals the extent to which agents do or do not have foresight. Second, there is no need to specify a functional form for information flows. In the previous section, we modeled information flows as coming from one of several possible information processes. We would have to conduct a similar sensitivity analysis if we were estimating a DSGE model. Using the implicit tax rate avoids taking an *a priori* stand on the nature of information flows. Finally, as we emphasize below, conditioning on the implicit tax rate resolves the non-uniqueness associated with moving-average representation (27), which allows us to examine identification schemes designed to handle the non-uniqueness of representation (26).

We turn to two prominent identification strategies that have acknowledged foresight in the fiscal VAR literature—Blanchard and Perotti (2002) (BP) and Mountford and Uhlig (2009) (MU). We derive conditions under which these identification schemes capture the true information flows. We then augment each identification strategy by conditioning on implicit tax rates and argue that this additional step alleviates the problems associated with foresight.

4.2.1 Blanchard and Perotti (2002)

BP estimate a quarterly VAR in output, y, government revenues net of transfers (including interest payments), τ, and government spending (government consumption plus government investment), g. The data are logarithms of real, per capita variables. We allow for both a deterministic trend (quadratic in logs) and a stochastic trend (unit root with drift), as BP do.

Tests overwhelmingly support the causal priority of the implicit tax rate series in BP's VAR system. A test of whether lags of other variables help to predict spreads, given past information on spreads, yields χ^2 statistics with significance levels of 0.23 (deterministic detrending) and 0.34 (stochastic detrending).[14]

Write the reduced-form residuals from this VAR as

$$\begin{aligned} u_t^\tau &= a_{\tau y} u_t^y + b_{\tau g} e_t^{*g} + e_t^{*\tau} \\ u_t^g &= a_{gy} u_t^y + b_{g\tau} e_t^{*\tau} + e_t^{*g} \\ u_t^y &= c_{y\tau} u_t^\tau + c_{yg} u_t^g + e_t^{*y} \end{aligned} \tag{32}$$

If agents have sufficient foresight, as BP themselves note and section 3 above documents, the BP VAR will be misspecified and will result in biased inference. To account for such bias, we let e_t^{*g}, $e_t^{*\tau}$, and e_t^{*y} denote the shocks associated with representation (28). We differentiate these shocks from the structural shocks available to the agents of the economy (which we denote e_t^g, e_t^τ, and e_t^y).[15]

Section VIII of BP derives a mapping from the e_t^* shocks to the shocks observed by the agents, e_t, that follows from augmenting the VAR as

$$\tau_t = a_1 y_t + A_{11}(L)\tau_{t-1} + A_{12}(L) y_{t-1} + e_t^{*\tau} \tag{33}$$

$$y_t = c_0 E_t(\tau_{t+1}) + c_1 \tau_t + A_{21}(L)\tau_{t-1} + A_{22}(L) y_{t-1} + e_t^{*y} \tag{34}$$

where now output at date t responds to *expected* taxes at $t+1$. When agents have foresight, it is likely that output will depend not only on current and lagged taxes but also on expected taxes. BP show how the innovation in (33) led one quarter, $e_{t+1}^{*\tau}$, can be used to instrument for the expectational effects in (34). For this instrumental variables approach to be valid, two stringent assumptions must hold. First, agents must have *exactly* one quarter of foresight—no more, no less. Second, the innovation, $e_t^{*\tau}$, in (33) cannot be correlated with other shocks in the VAR.

Neither assumption is likely to hold in practice. As the previous section argues, the length of foresight is likely to be much longer than one quarter and it varies substantially over time. The BP identification scheme cannot handle more than one quarter of foresight because that would require an implausible lag in the discretionary response of fiscal policy. With one quarter of foresight, the BP identification requires no discretionary response of fiscal policy to output realizations both this quarter *and* last quarter. Amending (34) with $E_t \tau_{t+2}$, which allows for two quarters of foresight, requires that there is no discretionary response of fiscal policy to output for three quarters, and so on. If agents have more than one quarter of foresight, it is also very likely that the innovation $e_t^{*\tau}$ in (33) will be correlated

[14]Forni and Gambetti (2010b) and its references contain detailed discussion of tests for "informational sufficiency" of a VAR. According to their criteria, our test satisfies a necessary but not sufficient condition for fundamentalness. Sufficiency requires testing the null of no Granger causality against the principal components from a factor model that contains a large set of macroeconomic data. For reasons discussed in the conclusion we avoid using a factor model framework.

[15]To confront the non-uniqueness associated with representation (26), BP identify the e_t shocks by arguing that legislative lags ensure that there can be no within-quarter adjustment of fiscal policy to unexpected changes in GDP, other than "automatic effects of activity on taxes and spending under existing fiscal policy rules." Automatic effects operate through parameters $a_{\tau y}$ and a_{gy}, which are elasticities of tax revenues and government purchases with respect to output. BP then show that once $a_{\tau y}$ and a_{gy} are calibrated to 2.08 and 0, respectively, $u_t^\tau - a_{\tau y} u_t^y$ and $u_t^g - a_{gy} u_t^y$ can be used as instruments in estimating $c_{y\tau}$ and c_{yg}. The final two parameters are set to either $b_{\tau g} = 0$ and $b_{g\tau} \neq 0$ or vice versa to triangularize the fiscal sector.

with other shocks in the VAR. This is shown explicitly in moving-average representation (16) of section 2.1. The innovation from the VAR in that example is a convolution of the tax and technology shocks. This suggests that the instrument used by BP to account for foresight will be only weakly correlated with the explanatory variable.

Now augment BP's VAR system with data on the spread, s, between municipal bonds and treasury bonds (the implicit tax rate)

$$\begin{aligned} u_t^\tau &= a_{\tau y} u_t^y + a_{\tau s} u_t^s + b_{\tau g} e_t^g + e_t^\tau \\ u_t^g &= a_{gy} u_t^y + a_{gs} u_t^s + b_{g\tau} e_t^\tau + e_t^g \\ u_t^y &= c_{y\tau} u_t^\tau + c_{yg} u_t^g + e_t^y \\ u_t^s &= c_{s\tau} u_t^\tau + c_{sg} u_t^g + c_{sy} u_t^y + e_t^s \end{aligned} \tag{35}$$

By conditioning on the implicit tax rate, the econometrician no longer needs to use the innovation $e_t^{*\tau}$ as an instrument for the expectation in (34). An efficient municipal bond market makes the implicit tax rate equivalent to the expectation in (34), as (31) makes clear. This relaxes the stringent assumptions that BP's identification of foresight requires; conditioning on the municipal bond spread posits that the innovations in (35) are the true structural shocks (i.e., that the observables augmented with the implicit tax rate spans the space of the shocks observed by the agents), and all that is left to achieve identification is a rotation of the covariance matrix. We make the reasonable assumption that news contained in interest-rate spreads has no direct impact on current output, tax revenues, and spending. This assumption sets both $a_{\tau s}$ and a_{gs} to zero and implies that the relationship between the reduced-form and structural innovations for the tax and spending shocks of (35) are identical to those of (32). We can now apply BP's identification of these shocks. We also identify the "news" shock, e_t^s, (again following the lead of BP) by using the reduced-form shocks and parameters as instruments to estimate $c_{s\tau}, c_{sg}$, and c_{sy}.[16] To facilitate comparison, we use the same data and follow the same detrending procedures as BP. We refer the reader to Section III of BP for a more detailed discussion of the data and empirical approach.

Figure 2 plots the estimated mean responses to an unanticipated tax revenue shock (panels C and D) and to a shock to the implicit tax rate (panels A and B), with one-standard deviation bands computed by Monte Carlo simulations based on 500 replications. Solid lines represent the deterministic-trend model and dashed lines the stochastic-trend VAR. Following BP, we transform the original impulse responses to report the dollar response of each variable to a dollar shock in the fiscal variables. We use the tax revenue data to transform the implicit tax rate so that the impulse response is interpreted as a dollar shock to *anticipated* tax revenue. Panels B and D of the figure condition on a five-year implicit tax rate, implying that agents have a maximum of five years of foresight, but results are robust to implicit tax rates with maturity less than five years.

Panel C is identical to BP's figure III and shows that the response of output to a surprise tax increase is negative and significant. The heavy solid line in panel C is BP's instrumental-variable estimate of the effect of foresight (figure VI in BP). That solid line represents the "upper bound" on the anticipatory effects of foresight, according to BP. As the figure shows,

[16]More specifically, $u_t^\tau - a_{ty} u_t^y$, $u_t^g - a_{gy} u_t^y$, and $u_t^y - c_{y\tau} u_t^\tau - c_{yg} u_t^g$ are used as instruments for $c_{s\tau}, c_{sg}$ and c_{sy}, respectively.

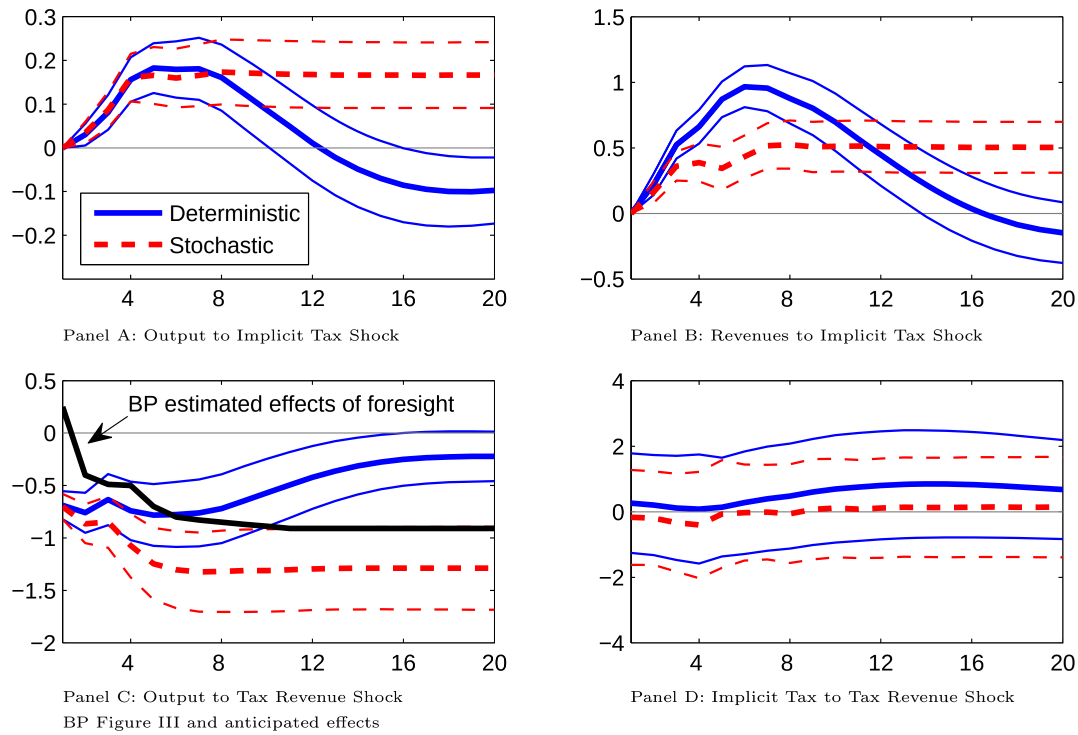

Figure 2: Estimated mean responses for deterministic trend (solid lines) and stochastic trend (dashed lines) to a positive tax revenue shock (panels C, D) and positive implicit tax rate shock (panels A, B) with one-standard-deviation bands.

identifying foresight using their approach generates a positive response on impact, in contrast to the negative response from the VAR that ignores foresight altogether. Beyond the impact period, BP's methodology does not, however, deliver responses that are statistically different from the VAR that ignores foresight. This result leads BP to conclude, "there is not much evidence of an effect of anticipated tax changes on output [p. 1353]."

Panel A contrasts sharply with BP's findings: output rises substantially and significantly after an increase in the implicit tax rate. The anticipatory effects of fiscal foresight last well beyond the initial quarter and, in the short run, anticipated increases in tax rates are *expansionary*.

Our approach generates markedly different results from BP primarily because the implicit tax rate provides flexible information about the degree of foresight. BP's identification permits only one quarter of foresight, while ours allows a maximum of five years. This is an example of the kind of *a priori* restriction on information flows that can drive inferences about foresight. Panels B and D of the figure corroborate the plausibility of our identification by showing that tax revenues respond positively and significantly to a positive innovation in the implicit tax rate, as theory suggests. Further corroboration of the identification comes from the fact that the implicit tax rate does not respond significantly to innovations in taxes, which theory also predicts (panel D).

	0 qtr	4 qtrs	8 qtrs	12 qtrs	20 qtrs
Panel A: Blanchard-Perotti, Deterministic Trend					
GDP (BP)	−0.69*	−0.74*	−0.72*	−0.42*	−0.22
GDP (U)	−0.84*	−1.15*	−0.95*	−0.36	−0.06
GDP (A)	0.03	0.19*	0.13*	−0.02	−0.10*
Panel B: Blanchard-Perotti, Stochastic Trend					
GDP (BP)	−0.70*	−1.07*	−1.32*	−1.30*	−1.29*
GDP (U)	−0.71*	−1.15*	−1.39*	−1.34*	−1.33*
GDP (A)	0.04	0.17*	0.18*	0.18*	0.17*
Panel C: Mountford-Uhlig, Output Multipliers					
GDP (MU)	−0.29*	−0.79*	−1.23*	−1.61*	−0.60
GDP (U)	−0.27	−1.04*	−1.64*	−1.81*	−1.05
GDP (A)	−0.10*	0.04*	0.09	0.02	0.03
Panel D: Mountford-Uhlig, Investment Multipliers					
INV (MU)	−0.19	−0.27*	−0.38	−0.46	−0.14
INV (U)	−0.23	−0.31*	−0.50*	−0.42	−0.27
INV (A)	0.03	0.12*	0.14*	0.10	0.09

Table 3: Output and Investment Multipliers for an Implicit Tax Shock (A) and Tax Revenue Shock (U). An asterisk indicates zero is outside of the region between the two one-standard deviation bands. BP denotes the numbers from the VAR without municipal bonds.

Panels A and B of table 3 report estimated output multipliers for the estimated VAR. The table also records results from BP's table III for comparison. The primary difference between the BP multipliers and ours is that we allow for the anticipatory effect that arises from foresight—the inside and outside lags. The row labeled GDP (A) is the multiplier associated with an innovation in the implicit tax rate arising from an anticipated increase in tax rates. The row labeled GDP (U) is the multiplier associated with an innovation in the tax revenue shock, identified as the effect of an unanticipated tax cut.

Several features stand out. First, for the majority of the horizon and both detrending methods, the output multiplier for the implicit tax rate is *positive*, so higher anticipated taxes *raise* output in the short run. With the lone exception of the 1- and 12-quarter multipliers, all multipliers in the anticipatory horizon have one-standard deviation error bands that do not cross zero. The peak positive responses are 0.19 at 4 quarters (deterministic trend model) and 0.18 (stochastic trend model). Second, the multipliers associated with the implicit tax rate are much smaller in absolute value than those from the tax revenue shock. This suggests that agents probably do not have *perfect* foresight, on average. Perfect foresight would imply movements in macro aggregates that are about the same magnitude as for unanticipated shocks (assuming identical variances). The relatively muted response of output to a shock in the implicit tax rate suggests that more intricate information flows than perfect foresight (e.g., moving-average processes for news) are probably at work. Implicit tax rates capture this kind of subtlety. Finally, unanticipated tax hikes have substantially larger effects in the VAR that includes the implicit tax rate than in the BP specification, particularly for the deterministic trend. For example, the one-standard deviation error bands on the 4-quarter multiplier are -1.64 and -0.65, which nearly exclude the BP estimate of -0.74. This is consistent with the numerical evidence presented in section 3.3, where the econometrician consistently underestimates the multiplier.

Our finding that news of higher taxes increases economic activity over much of the anticipation period, as figure 2 depicts, echoes results from two very different methodologies. In a case study, House and Shapiro (2006) argue that the phased-in tax reductions enacted by the 2001 Economic Growth and Tax Relief Reconciliation Act played a significant role in creating the unusually slow recovery from the 2001 recession. By feeding the legislated paths of marginal tax rates on labor and capital into an RBC model, the authors generate a path of equilibrium GDP that shares qualitative features with panel A of figure 2.

Mertens and Ravn (2011) augment a VAR with Romer and Romer's (2010) anticipated tax liabilities series, which they treat as strictly exogenous in the VAR. Mertens and Ravn append to each equation of the VAR a distributed lag of q periods in *future* tax liabilities. They estimate that an anticipated tax increase induces a boom in output whose amplitude and duration increase with the period of foresight q. In contrast to our approach with muni-treasury spreads, Mertens and Ravn must specify *a priori* the period of foresight and maintain that anticipated taxes are exogenous—assumptions that are critical to the quantitative effects they obtain. Nonetheless, the qualitative effects closely resemble those in panel A of our figure.

Despite their different methodologies, House-Shapiro and Mertens-Ravn share a common economic explanation for their findings, which also applies to the RBC model in section 3.3. Anticipated tax changes generate wealth effects that kick in immediately—upon arrival of the news—but the substitution effects, which operate on critical economic margins, do not affect behavior until the tax rates have changed. In a conventional model, expected tax increases reduce wealth, which induces agents to work harder, increasing employment and output immediately.

Anticipated tax changes have sharply different macroeconomic impacts in our model, which includes a direct measure of tax news and a flexible specification of foresight, than in the instrumental variables, tightly circumscribed approach that BP take. These differences underscore the importance of modeling information flows.

4.2.2 Mountford and Uhlig (2009)

Mountford and Uhlig (2009) impose restrictions directly on the shape of the impulse responses of the VAR to identify economic shocks, following the work of Faust (1998), Canova and Pina (2000), Uhlig (2005), and Canova and Pappa (2007). Like BP, MU identify two fiscal policy shocks—a government spending shock and a government revenue shock. They define a fiscal shock as a positive reaction of the respective fiscal variable for four consecutive periods, including the impact response. This is to ensure that only substantial movements in fiscal variables are counted as "shocks." Fiscal shocks are required to be orthogonal to business cycle shocks and monetary policy shocks. Business cycle shocks are defined as a shock which jointly moves output, consumption, nonresidential investment and government revenue in the same direction for four quarters following the shock.[17] A monetary policy shock is defined as a shock that moves interest rates up and reserves and prices down for four quarters after the shock.

Like with most identification schemes, this one intends to identify rotations of the covariance matrix associated with representation (26). Caldara and Kamps (2010) and Caldara (2010) show that the sign restriction approach of MU can be reinterpreted as pinning down the elasticities associated with the BP system (32). And like BP, MU acknowledge the importance of foresight and impose *additional* restrictions to account for it. These restrictions are meant to solve the non-uniqueness associated with (27). MU argue that anticipated fiscal policy changes can be identified by imposing zero restrictions on the responses of fiscal variables over the period of fiscal foresight, reflecting the idea that the isolated policy shock is news about a change in future, but not current, policy variables.

Under what conditions will the MU identification scheme deliver correct inference? As the analytical section shows, fiscal foresight does not imply a zero response of all fiscal variables over the foresight period. The various fiscal rules considered in the previous section suggest that this is an exceptional situation. In the special case where the tax rate is exogenous and follows the simple rule

$$\hat{\tau}_t = e^u_{\tau,t} + \varepsilon_{\tau,t-q} \tag{36}$$

when news arrives in period t, the tax rate does not change until period $t+q$. MU's zero restriction, if it were applied to the tax *rate*, would work in this case. But MU impose the zero restriction on tax *revenues*. They find that higher anticipated revenues reduce output—and, therefore, the tax base—over the period of foresight. Lower output, coupled with the restriction that revenues are fixed, delivers the eccentric implication that a particular sequence of *unanticipated* tax-rate increases, $\{e^u_{\tau,t}\}$, is imposed to identify an anticipated tax hike. Considering that in most countries automatic stabilizers in the tax code would lower rates when output falls, MU's identification scheme may have difficulty isolating the effects of fiscal foresight.

[17] To select among the many rotations consistent with this definition of the business cycle shock, MU impose the criterion that substantial movements in output, consumption, nonresidential investment and government revenue must be attributed to business cycle shocks.

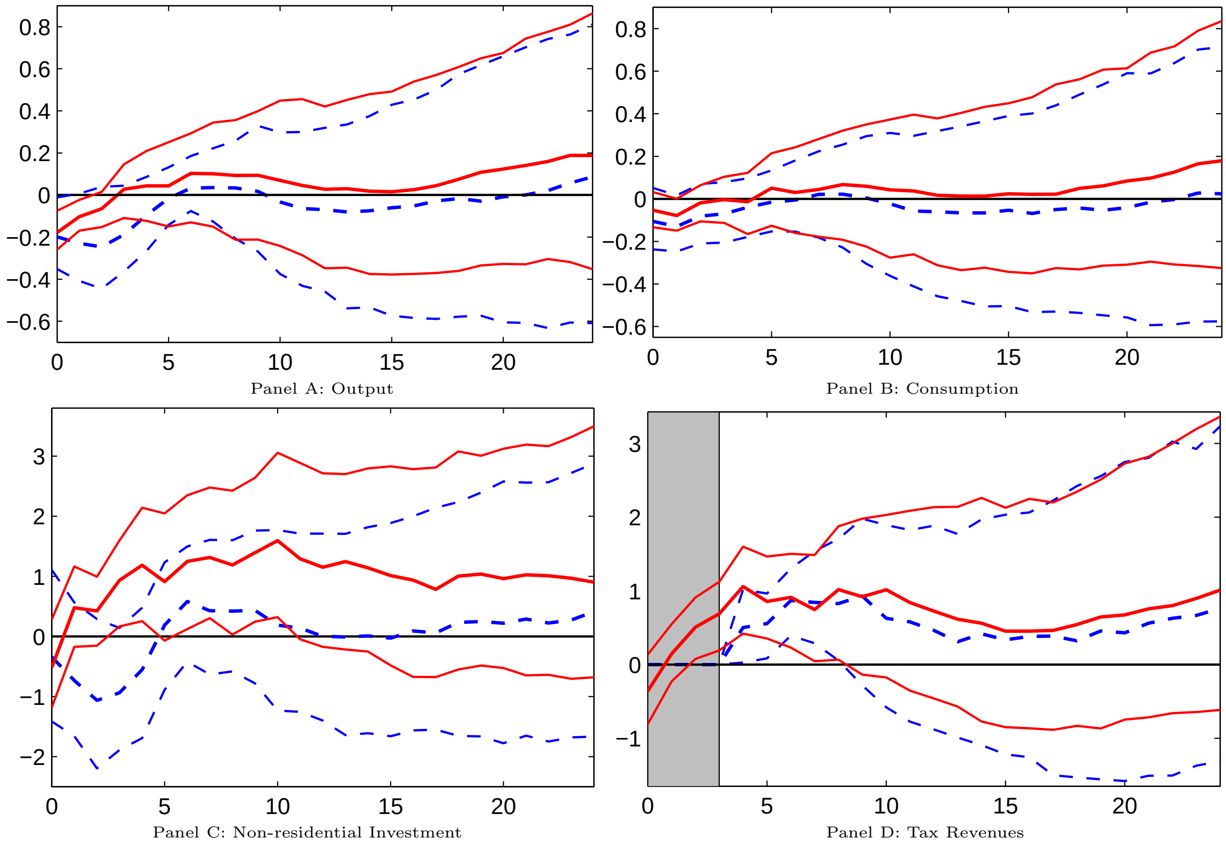

Figure 3: Estimated median responses with 16th and 84th percentile bands for MU VAR specification to a positive tax revenue shock (dashed lines) and MU VAR with muni spread to a positive implicit tax rate shock (solid lines).

We revisit the MU estimation but, instead of zero restrictions on fiscal variables, we condition on the municipal bond spread to account for fiscal foresight. To facilitate direct comparisons, we use the same data and estimation procedure as MU. We estimate a VAR in GDP, private consumption, total government expenditure, total government revenue, real wages, private non-residential investment, interest rate, adjusted reserves, the producer price index for crude materials, and the GDP deflator. Fiscal variables are defined as in MU, who follow BP; the remaining variables are quarterly observations from 1955 to 2000, and are logarithms except the interest rate, which is in levels. The VAR has six lags and no deterministic terms. Detailed descriptions of the data and estimation can be found in Appendixes A and B of Mountford and Uhlig (2009). To the MU variables we add the municipal bond spread (implicit tax rate). We identify a shock to the implicit tax rate as a positive response to the municipal bond spread for four quarters, and impose that it is orthogonal to the other shocks in the system.[18]

Figure 3 plots the median impulse response functions along with the 16th and 84th percentile bands for the MU zero restriction approach to foresight and the VAR specification

[18]MU's model expands BP's system of variables, but the test for Granger-causal priority of spreads still yields a χ^2 statistic with significance level of 0.74.

conditioning on the implicit tax rate. The solid lines show the responses to a positive innovation in the implicit tax rate. The dashed lines show the response to a tax revenue shock imposing zero restrictions on the first four quarters (shaded area of panel D). Conditioning on the municipal bond spread suggests that tax revenues are not zero over the foresight horizon, contradicting the restriction imposed by MU. In response to a shock in the implicit tax rate, tax revenues are negative on impact and then follow a hump-shaped pattern similar to panel B of figure 2. We interpret the short-run response of tax revenues to an innovation in the implicit tax rate as evidence that automatic stabilizers lower rates as output falls. This, again, demonstrates the flexibility of the muni spread in capturing information flows. In lieu of imposing a rigid four-quarter foresight assumption, the shock to the implicit tax rate reports how agents respond to news about future tax changes.

Responses of many aggregate variables to a shock in the implicit tax rate are not very different from the responses when imposing MU's zero restrictions. The consumption path is nearly identical, with zero within the error bands for both identification approaches. This suggests that consumption does not respond significantly to anticipated changes in future tax rates, which is consistent with the evidence in the public finance literature [Poterba (1988), Parker (1999), Souleles (1999, 2002)]. However, unlike the conclusions reached in those papers, we do not take this as evidence of the lack of foresight. Many of the aggregate variables respond in significant ways to the news in implicit tax rates. For example, the path of non-residential fixed investment mimics the hump-shaped response of tax revenues. An anticipated increase in tax rates produces a positive and significant response of investment for several quarters, which contrasts to the negative or zero response generated by imposing MU's zero restrictions.

Effects of anticipated taxes in figure 3 are consistent with economic theory. Mertens and Ravn (2011) emphasize the distinction between consumption of durables and nondurables in understanding the impacts of anticipated tax changes. In their empirical and theoretical analyses, Mertens and Ravn find that, while foresight can have a significant effect on durable consumption, nondurables are less likely to move in response to anticipated changes in tax rates.[19] Auerbach (1989) emphasizes the role of investment adjustment costs when examining the dynamic effects of anticipated taxes on investment. That investment responds positively and significantly over many quarters suggests that investment adjustment costs may be low: if adjustment costs were high, firms would begin to *decrease* investment immediately in response to an anticipated tax increase. Finally, counter to the results found in the BP specification, panel A shows that output responds negatively to an anticipated tax increase in both identification schemes. One explanation for the differences across BP and MU can be attributed to the particular rotation of the covariance matrix implemented by MU. Caldara and Kamps (2008) map the elasticities estimated by BP in (32) into the implied elasticities from imposing the MU sign restrictions. They find that MU impose a much higher within-quarter elasticity of net taxes with respect to output. The higher elasticity will drive down the response of output to an implicit tax rate shock.

Panels C and D of table 3 report estimates of the output and investment impact multipliers to an innovation in the tax revenue shock (U), the implicit tax rate (A) and the tax

[19] They reconcile this empirical finding with theory by assuming habit formation in consumption and complementarity in consumption goods, which smooth out the wealth effects during the period of foresight.

revenue shock in the original MU specification. As was the case with the BP identification, the estimated effects of an anticipated tax decline are smaller than the effects of unanticipated shocks. Also similar, the MU identification underestimates the size of the multipliers. For example, at the eight-quarter horizon, the MU estimate of the median output multiplier falls around the 20th percentile of the posterior for the tax revenue shock estimated from the expanded VAR. Table 3 makes clear that accounting for foresight changes the estimated output and investment multipliers associated with tax shocks.

5 Concluding Remarks

We have shown how foresight introduces econometric difficulties that complicate the interpretation of conventional econometric analyses. Foresight, of *any* type, can introduce non-fundamental moving average terms into the linear equilibrium process, changing the mapping between the true news that agents observe and the "shocks" that the econometrician identifies. Many of the econometric techniques in macroeconomists' toolboxes can be distorted by empirical methods that do not adequately estimate the non-invertible moving average components of equilibrium time series. Section 3 demonstrates that failing to model foresight can produce quantitatively important inference errors in data generated by models now in wide use for macro policy analysis. Section 4 employs municipal bond spreads to capture information flows about anticipated changes in tax rates. Incorporating this spread into VARs and imposing well-known identification schemes can drastically alter conclusions about the dynamic effects of anticipated tax changes.

Estimating the impacts of foresight requires either modeling the information flows about future economic fundamentals or finding direct and interpretable measures of news. In the former camp are efforts to estimate DSGE models with news and the closely related approach that "flips" the roots of the invertible process to obtain the non-invertible representation that foresight creates. These efforts resolve the econometric problems that foresight presents by making strong assumptions about information flows. Of course, the solutions are *conditional on the specified information flows*, aspects of the economic structure about which economists rarely have well developed prior beliefs or direct empirical evidence.[20]

Some authors, rather than seeking direct measures of news, rely on adding variables to try to align the econometrician's and the agents' information sets. Forni and Gambetti (2010b) estimate large empirical models that boil all relevant information down to a few critical factors and test whether a model's information content is "sufficient" to ensure fundamentalness. Their sufficient condition, however, will never be satisfied by the small-to-medium-sized VARs that have been heavily used to extract economically interpretable shocks. Because the estimated factors do not have clear economic interpretations, it is impossible to discern precisely what information is being tested for.[21] In contrast, our approach to tax foresight or Ramey's (2011) method for measuring news about government defense spending focus narrowly on a particular, economically unambiguous, type of news.

[20] That the assumptions about information flows matter to inferences from estimated DSGE models is shown in two versions of the same paper that differ in information flow specifications and yield very different inferences [Schmitt-Grohé and Uribe (2008) and Schmitt-Grohé and Uribe (2010)].

[21] Tests for invertibility harken back to the $0-1$ treatment of invertibility from which this paper advocates moving beyond.

Foresight poses a challenging mix of structural and measurement problems. Hypothesized information flows that are uninformed by observations and information sets that are unrestricted by theory are unlikely to resolve the foresight problem. Answers lie in blending theory with measurement.

A Testing Economic Theory

A.1 Testing Present-Value Constraints An extension of the econometric implications is that tests of economic theory will also be misspecified. One important example pertaining to fiscal policy is the testing of the government's present-value constraint, which links the value of government debt to the expected discounted value of future primary surpluses. A widely-used approach to test present-value restrictions estimates a VAR with debt and surpluses and then tests for the cross-equation restrictions that the present-value condition imposes on the model [Campbell and Shiller (1987)]. As we have shown, fiscal foresight implies the VAR obtained by the econometrician will not yield the true dynamics and hence will not impose the correct cross-equation restrictions in testing the present value condition.

To see how foresight will lead to type I error in present-value tests, consider an endowment economy with lump sum taxes, a constant equilibrium real interest rate, and one-quarter foresight with respect to innovations in surpluses (receipts less expenditures net of interest payments on the government's debt). Taking expectations conditional on information at time $t-1$ of the government's flow budget constraint yields

$$E(b_t|\Omega_{t-1}) = \beta^{-1}b_{t-1} - E(s_t|\Omega_{t-1}), \tag{A.1}$$

where s_t is the primary surplus, b_t is one-period debt outstanding, and $\beta^{-1} = (1+r)$ is the constant gross rate of return between time t and $t+1$. Fiscal sustainability is ensured by a policy rule that makes future surpluses rise with debt. Two exogenous disturbances—for revenues and spending—drive surpluses and agents have one period of foresight over both components of the surpluses. The policy rule is

$$s_t = \gamma b_{t-1} + \frac{\varepsilon_{1,t-1}}{1-\rho_1 L} + \frac{\varepsilon_{2,t-1}}{1-\rho_2 L} \tag{A.2}$$

where γ is set to ensure that the agent's transversality condition for debt is satisfied and $0 < \rho_1, \rho_2 < 1$ determine the serial correlation properties of the driving processes. The expectations are taken with respect to the agents' information set, which is assumed to be, $\Omega_{t-1} = \{\varepsilon_{1,t-j}, \varepsilon_{2,t-j}\}_{j=1}^{\infty}$. If this process holds for $t = 0, 1, ...T$, then imposing the transversality condition on government debt,

$$\lim_{N\to\infty} \beta^N E(b_{t+N}|\Omega_{t-1}) = 0$$

implies the present-value restriction that the current value of outstanding debt equals future discounted surpluses,

$$b_t = \sum_{j=1}^{\infty} \beta^j E(s_{t+j}|\Omega_{t-1}) \tag{A.3}$$

Following Hansen, Roberds, and Sargent (1991) and Roberds (1991), the cross-equation restrictions that satisfy (A.3) are given by

$$\begin{bmatrix} s_t \\ b_t \end{bmatrix} = \begin{bmatrix} LA(L) & LC(L) \\ \frac{\beta[L^2A(L)-\beta^2A(\beta)]}{L-\beta} & \frac{\beta[L^2C(L)-\beta^2C(\beta)]}{L-\beta} \end{bmatrix} \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix}$$

$$\mathbf{y}_t = \mathcal{P}(L)\mathbf{v}_t \tag{A.4}$$

where $A(L) = \frac{\beta^{-1}-\gamma}{(1-\rho_1 L)(1-\gamma L)}$, and $C(L) = \frac{\beta^{-1}-\gamma}{(1-\rho_2 L)(1-\gamma L)}$. Two observations spring from (A.4). First, foresight implies that (A.4) is not an invertible representation (due to the zero at $L = 0$). Second, the cross-equation restrictions imposed on the moving-average representation are nonlinear.

In light of the second observation, Campbell and Shiller (1987) derive the present-value restrictions on the VAR representation instead of the moving-average representation. This simplification makes the present-value constraint easy to test, as it amounts to restrictions on the coefficients of the VAR. Denote the invertible representation of (A.4) by $\mathcal{P}^*(L)$ and write the corresponding VAR of (A.4) as[22]

$$\begin{aligned}\begin{bmatrix} s_t \\ b_t \end{bmatrix} &= \mathcal{A}_0^{*-1}\mathcal{A}_1^*(L)\begin{bmatrix} s_{t-1} \\ b_{t-1} \end{bmatrix} + \mathcal{A}_0^{*-1}\begin{bmatrix} \varepsilon_{1t}^* \\ \varepsilon_{2t}^* \end{bmatrix} \\ &= \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}\begin{bmatrix} s_{t-1} \\ b_{t-1} \end{bmatrix} + \begin{bmatrix} w_{1t} \\ w_{2t} \end{bmatrix} \\ \mathbf{y}_t &= A^*\mathbf{y}_{t-1} + \mathbf{w}_t \end{aligned} \tag{A.5}$$

Note that $\mathcal{A}^*(L) = \mathcal{P}(L)^{*-1}$, implying that the coefficients of the VAR will *not* yield the correct cross-equation restrictions implied by (A.4) when there is foresight. Campbell and Shiller (1987) show that the restrictions on the VAR coefficients implied by the present-value constraint are given by

$$a_{11} + a_{21} = 0, \qquad a_{22} + a_{12} = \beta^{-1} \tag{A.6}$$

With foresight, however, the restrictions given by (A.6) will not hold even though the present-value constraint is satisfied. The VAR estimates give

$$a_{11} + a_{21} = \frac{\eta\rho_1\rho_2\beta A(\beta)C(\beta)}{\rho_2 C(\beta) - \rho_1 A(\beta)}, \qquad a_{22} + a_{12} = \frac{A(\beta)\eta\rho_2\rho_1(C(\beta) - A(\beta))}{\beta(\rho_2 C(\beta) - \rho_1 A(\beta))}$$

where $\eta = (1 + [A(\beta)C(\beta)]^2)^{-1/2}$. Therefore, the econometrician will incorrectly reject the null hypothesis that the present-value constraint holds.

A.2 Tests of Granger Causality Sargent (1981) calls for Granger (1969)-Sims (1972) causality tests to play a key role in helping the econometrician determine which variables properly belong in agents' information sets. For example, causality tests are commonly used to justify treating variables as exogenous for purposes of inference. Causality tests, however, are misspecified if agents have fiscal foresight.[23] To see this more clearly, return to the analytical model of section 2 with one quarter of foresight and an *i.i.d.* tax rule. The (true) moving-average representation, on the left, and the (econometrician's) fundamental representation, on the right, in the variables $(\hat{\tau}_t, k_t)'$ are given by

$$\begin{aligned}\begin{bmatrix} \hat{\tau}_t \\ k_t \end{bmatrix} &= \begin{bmatrix} L & 0 \\ -\frac{\kappa}{1-\alpha L} & \frac{1}{1-\alpha L} \end{bmatrix}\begin{bmatrix} \varepsilon_{\tau,t} \\ \varepsilon_{A,t} \end{bmatrix} \qquad &= \begin{bmatrix} \delta & -\kappa\delta L \\ 0 & [\delta(1-\alpha L)]^{-1} \end{bmatrix}\begin{bmatrix} \delta(\varepsilon_{\tau,t-1} + \kappa\varepsilon_{A,t-1}) \\ \delta(-\varepsilon_{\tau,t} + \kappa\varepsilon_{A,t}) \end{bmatrix} \\ \mathbf{x}_t &= \mathcal{D}(L)\boldsymbol{\epsilon}_t \qquad &= \mathcal{D}^*(L)\boldsymbol{\epsilon}_t^* \end{aligned} \tag{A.7}$$

[22]Given the structure of the non-invertibility, the invertible representation is obtained as in (16).

[23]Leeper (1990) shows that fiscal foresight can imply that money growth Granger-causes deficits in an equilibrium in which deficits are systematically monetized.

where $\delta = (1+\kappa^2)^{-1/2}$. Note that the zero appearing in the true MA will appear in the opposite off-diagonal in the econometrician's representation. By theorem 1 of Sims (1972), the econometrician's representation implies that $\hat{\tau}$ fails to Granger-cause k; in fact, $\hat{\tau}$ lies in a proper subspace of k, and hence k fails to Granger-cause $\hat{\tau}$. By not modeling foresight, the econometrician effectively reverses the Granger-causal ordering of the true dynamics.

B Simulations Details

B.1 Specifications of Models For the quantitative results reported in section 3.3, we augment a prototype RBC model (similar to the one in Chari, Kehoe, and McGrattan (2008)) and a standard New Keynesian model (similar to those in Smets and Wouters (2003, 2007)) with distorting taxes levied on capital and labor income. Agents in the models have foresight over tax policy changes. This appendix describes the models and the calibration/estimation strategy. Except for the parameters that characterize the information flow processes in the tax rules, the parameters in the RBC model are calibrated to the values commonly used in the literature, and the NK model is calibrated to the posterior mode of an estimated New Keynesian model, fit to U.S. quarterly data from 1984 to 2007.

B.1.1 RBC Model The representative agent maximizes utility

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\log c_t + \phi \log(1-l_t)\right]$$

over consumption c_t and labor l_t, where β is the discount factor and ϕ is the preference weight on leisure. The agent's budget constraint is $c_t + k_t - (1-\delta)\,k_{t-1} = \left(1-\tau_t^L\right) w_t l_t + \left(1-\tau_t^K\right) r_t^K k_{t-1} + z_t$, where k_t is capital, w_t is the wage rate, r_t^K is the real rate of return on capital, z_t is government transfers, and δ is the capital depreciation rate.

The representative firm produces output using the technology $y_t = u_t^a k_{t-1}^{\alpha} l_t^{1-\alpha}$, where y_t is output and u_t^a is total factor productivity, which follows the exogenous process $\ln u_t^a = \rho_a \ln u_{t-1}^a + \sigma_a \varepsilon_t^a$ and $\varepsilon_t^a \sim N(0,1)$. The firm chooses capital and labor to maximize profit: $y_t - r_t^K k_{t-1} - w_t l_t$.

Let capital letters denote aggregate quantities. Each period the government chooses a set of fiscal variables to satisfy its budget constraint, $G_t + Z_t = \tau_t^L w_t L_t + \tau_t^K r_t^K K_{t-1}$, where G_t is government consumption. The goods market clearing condition is $Y_t = C_t + I_t + G_t$, where $I_t = K_t - (1-\delta)\,K_{t-1}$ is investment.

Capital and labor tax rates follow the policy rules described by (22) and its capital tax analog. Government consumption policy follows (23), and lump-sum transfers adjust to balance the budget each period.

B.1.2 New Keynesian Model The NK model expands the RBC model to incorporate a variety of real and nominal frictions. The economy is populated by a continuum of households, indexed by $j \in [0,1]$. Each household maximizes expected utility,

$$E_t \sum_{t=0}^{\infty} \beta^t u_t^b \left[\frac{\left(c_t(j) - hC_{t-1}\right)^{1-\gamma} - 1}{1-\gamma} - \frac{l_t(j)^{1+\kappa}}{1+\kappa}\right]$$

where u_t^b is a general preference shock that follows the process $\ln(u_t^b) = \rho_b \ln(u_{t-1}^b) + \sigma_b \varepsilon_t^b$. We assume external habits that depend on aggregate consumption last period, C_{t-1}. As in Erceg, Henderson, and Levin (2000), each household supplies unique labor inputs. A state-contingent claim x_t sold at a price of q_t exists to eliminate the income differentials due to differentiated labor. The household's flow budget constraint (dropping index j) in units of goods is

$$(1-\tau_t^L)\frac{W_t}{P_t}l_t + (1-\tau_t^K)\frac{R_t^K v_t k_{t-1}}{P_t} + \frac{R_{t-1}b_{t-1} + x_{t-1}}{\pi_t} + z_t + d_t = c_t + i_t + b_t + q_t x_t + \Psi(v_t)\, k_{t-1}$$

where W_t is the nominal wage rate, P_t is the general price level, and $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is the inflation rate. The model has variable capital utilization with the utilization rate v_t; in the steady state, $v = 1$. Varying the utilization rate involves a cost $\Psi(v_t)\, k_{t-1}$, where Ψ is an increasing, convex function with $\Psi(1) = 0$. We define the utilization cost parameter ψ such that $\frac{1-\psi}{\psi} = \frac{\Psi''(1)}{\Psi'(1)}$. The nominal rental rate for effective capital, $v_t k_{t-1}$, is R_t^K. i_t is investment inclusive of adjustment costs. Capital evolves as $k_t = (1-\delta)k_{t-1} + \left[1 - s\left(\frac{u_t^i i_t}{i_{t-1}}\right)\right] \times i_t$, where $s(\cdot)$ is the adjustment cost function for investment; in the steady state, $s(1) = s'(1) = 0$, and $s''(1) \equiv s > 0$. Adjustment costs are subject to an investment shock, u_t^i, which follows the process $\ln(u_t^i) = \rho_i \ln(u_{t-1}^i) + \sigma_i \varepsilon_t^i$. Finally, each household owns an equal share of all intermediate goods producing firms and receives dividends, d_t.

Wages are rigid. A perfectly competitive labor packer purchases the differentiated labor inputs and assembles them to form composite labor service, L_t, using the technology $L_t = \left[\int_0^1 l_t(j)^{\frac{1}{1+\eta_t^w}} dj\right]^{1+\eta_t^w}$, where η_t^w denotes wage markups and is assumed to follow the process $\ln(\eta_t^w) = \rho_w \ln(\eta_{t-1}^w) + \sigma_w \varepsilon_t^w$. The aggregate wage is $W_t = \left[\int_0^1 W_t(j)^{\frac{1}{\eta_t^w}} dj\right]^{\eta_t^w}$. Each period household j receives a signal to reset its nominal wage with a probability $1-\omega_w$. Those who cannot reoptimize instead index their wages to past inflation according to $W_t(j) = W_{t-1}(j)\, \pi_{t-1}^{\chi^w}$.

Prices are rigid. A perfectly competitive final goods producer uses a continuum of intermediate goods $(y_t(i), i \in [0,1])$ to produce the final good, Y_t, using the technology $\left[\int_0^1 y_t(i)^{\frac{1}{1+\eta_t^p}} di\right]^{1+\eta_t^p} \geq Y_t$. η_t^p is the price markup for intermediate goods and follows the process $\ln(\eta_t^p) = \rho_p \ln(\eta_{t-1}^p) + \sigma_p \varepsilon_t^p$. Intermediate goods producers are monopolistic competitors in the product market. Firm i produces with the technology $y_t = u_t^a (v_t k_{t-1})^\alpha (l_t)^{1-\alpha}$, where u_t^a is the total factor productivity, following the process $\ln(u_t^a) = \rho_a \ln(u_{t-1}^a) + \sigma_a \varepsilon_t^a$. Analogous to households' wage decisions, a monopolistically competitive intermediate firm faces a probability $1-\omega_p$ that is will be able to reset its optimal price. Firms that cannot reoptimize index their prices to past inflation according to $p_t(i) = p_{t-1}(i)\pi_{t-1}^{\chi^p}$. The goods market clearing condition is $Y_t = C_t + I_t + G_t + \Psi(v_t)\, K_{t-1}$.

The monetary authority obeys a rule that sets the nominal interest rate

$$\hat{R}_t = \rho_r \hat{R}_{t-1} + (1-\rho_r)\left(\phi_\pi \hat{\pi}_t + \phi_y \hat{Y}_t\right) + \phi_{dy}\left(\hat{Y}_t - \hat{Y}_{t-1}\right) + \sigma^m \varepsilon_t^m$$

Fiscal policy evolves according to the rules in (22) and (24). The flow budget constraint of the government is $B_t + \tau_t^K \frac{R_t^K}{P_t} v_t K_{t-1} + \tau_t^L \frac{W_t}{P_t} L_t = \frac{R_{t-1}B_{t-1}}{\pi_t} + G_t + Z_t$.

B.2 Calibration and Estimation The RBC model is calibrated to values in the literature (largely following those in Chari, Kehoe, and McGrattan (2008)): $\beta = 0.99$, $\phi = 1.6$ implying a steady-state labor share of 0.32, $\alpha = 0.36$, $\frac{G}{Y} = 0.2$, and $\delta = 0.025$. The steady-state capital and labor tax rates are set at their sample means in the U.S. data from 1984 to 2007. The standard deviations of the technology, transfer, and capital and labor tax shocks are calibrated to the estimated posterior modes for the same shocks in the NK model to be described next (see table 4).

We estimate most of the parameters in the NK model using Bayesian methods, assuming agents have no foresight over taxes. In the exercises, the model parameters are fixed at the posterior modes that table 4 reports.

The NK model is log-linearized and solved by Sims's (2002) method. Models have no growth; data are detrended with a linear trend, as in Smets and Wouters (2003). The sample period, 1984-2007, is selected because monetary policy is widely believed to follow a Taylor rule [Taylor (1993)]. The estimation uses ten observables: real consumption, investment, labor, wage rate, the nominal interest rate, inflation, capital tax revenues, labor tax revenues, the sum of real government consumption and investment, and government transfers. Government data include all federal, state, and local levels. Section B.3 below describes the data.

Several parameters, which are known to be difficult to estimate from the data, are calibrated. The discount factor β is set to 0.99, implying an annual steady-state real interest rate of 4 percent. The capital income share in output is $\alpha = 0.36$. The quarterly depreciation rate $\delta = 0.025$. The steady-state elasticity of substitution in the goods and labor markets ($\frac{1+\eta^p}{\eta^p}$, $\frac{1+\eta^w}{\eta^w}$) are assumed to be 8, which implies the steady-state markups in the product and labor markets are approximately 14 percent, consistent with evidence that the average price markup of U.S. firms is between 5-15 percent [Basu and Fernald (1995)]. Steady state (gross) inflation is assumed to be 1. Other calibrated parameters are steady-state fiscal variables, which are set to their sample means. Steady-state ratios of government spending and debt to output come from their sample means: $\frac{G}{Y} = 0.17$ and $s^b = 1.58$ (debt to quarterly output), where output is the sum of consumption, investment, and government spending. The steady-state capital and labor income tax rates are computed based on Jones's (2002) definition: $\tau^K = 0.36$ and $\tau^L = 0.24$. When estimating the model, the correlation parameter of capital and labor tax shocks ξ is assumed to be zero. The simulation results in table 2 assumes $\xi = 0.26$, implying a correlation of 0.5 between capital and labor tax shocks as estimated by Yang (2005).

We assume that parameters are drawn independently and restrict the parameter space to deliver a unique rational expectations equilibrium. Our priors follow closely the priors used in Smets and Wouters (2007) for most of the shared parameters (see table 4). Priors for the debt financing parameters (γ_g and γ_z) are guided by their implied dynamics. When γ_g and γ_z are too high, macro variables oscillate because the government overreacts to stabilize debt. On the other hand, when the parameters are too small, a solution does not exist when monetary policy is active (in the sense of Leeper (1991)). Priors for γ_g and γ_z have independent normal distributions with means of 0.15 and standard deviations of 0.05.

To search for the posterior mode, the log-posterior function is minimized by Christopher Sims's minimization routine, `csminwel`. We initiate the mode search from different points, and multiple modes do not appear to be a concern. Table 4 summarizes our estimation results and compares them with the estimates by Smets and Wouters (2007) over a similar sample period. For structural and monetary policy parameters, most of our estimates are comparable to theirs.

B.3 Data Description

This section describes the data for estimating the NK model and the municipal and treasury bonds data used in section 4.

B.3.1 Data for Estimating the New Keynesian Model

Unless otherwise noted, data are from the National Income and Product Accounts Tables released by the Bureau of Economic Analysis.[24] All data in levels are nominal values. To convert nominal values to real per capita values, we deflate by the deflator for personal consumption expenditures (Table 1.1.9, line 2) and a population index (described below).

Consumption. Consumption, C, is defined as total personal consumption expenditures (Table 1.1.5, line 2).

Investment. Investment, I, is defined as gross private domestic investment (Table 1.1.5, line 7).

Capital and Labor Tax Revenues. Following Jones (2002), the average personal income tax rate is

$$\tau^p = \frac{IT}{W + PRI/2 + CI}$$

where IT is personal current tax revenues (Table 3.1, line 3), W is wage and salary accruals (Table 1.12 line 3), PRI is proprietors' income (Table 1.12, line 9), and CI is capital income. Capital income is defined as rental income (Table 1.12, line 12), corporate profits (Table 1.12, line 13), interest income (Table 1.12 line 18), and PRI/2.

Labor income tax revenue, T^l, is

$$\tau^p(W + PRI/2) + CSI$$

where CSI is contributions for government social insurance (Table 3.1, line 7). Capital income tax revenue, T^k is

$$\tau^p CI + CT$$

where CT is taxes on corporate income (Table 3.1, line 5) and PT is property taxes (Table 3.3, line 8).

Government Consumption and Investment. Government consumption is defined as government consumption expenditure (Table 3.1, line 16), government investment for defense (Table 3.9.5, line 13), and government net purchases of non-produced assets (Table 3.1, line 37), minus government consumption of fixed capital (Table 3.1, line 38). Government investment is defined as government investment for non-defense (Table 3.9.5, line 18).

Transfers. Transfers, Z, are defined as net current transfers, net capital transfers, and subsidies (Table 3.1, line 25), minus the tax residual. Net current transfers are defined as current transfer payments (Table 3.1, line 17) minus current transfer receipts (Table 3.1, line 11). Net capital transfers are defined as capital transfer payments (Table 3.1, line 36) minus capital transfer receipts (Table 3.1, line 32). The tax residual is defined as current

[24] Further information on data construction appears in Traum and Yang (2010).

Parameters	**Prior**			**Posterior mode**	
	func.	mean	std.	our estimation	S&W (2007)
Structural					
γ, risk aversion	G	1.75	0.5	1.54	1.47
θ, inverse Frisch labor elasticity	G	2	0.5	2.19	2.30
h, habit formation	B	0.5	0.15	0.31	0.68
ψ, capital utilization	B	0.5	0.15	0.45	0.69
s, investment adjustment cost	N	4	1.5	4.61	6.23
ω^w, wage stickiness	B	0.5	0.1	0.69	0.74
ω^p, price stickiness	B	0.5	0.1	0.79	0.73
χ^w, wage indexation	B	0.5	0.15	0.45	0.46
χ^p, price indexation	B	0.5	0.15	0.23	0.21
Monetary and fiscal policy					
ϕ_π, interest rate response to inflation	N	1.5	0.25	2.22	1.73
ϕ_y, interest rate response to output	N	0.12	0.05	0.04	0.08
ϕ_{yd}, interest rate response to output	N	0.12	0.05	0.17	0.16
γ_g, government spending response to debt	N	0.15	0.05	0.20	N.A.
γ_z, transfers response to debt	N	0.15	0.05	0.13	N.A.
AR(1) coefficients					
ρ_a, technology	B	0.5	0.2	0.93	0.94
ρ_b, preference	B	0.5	0.2	0.89	N.A.
ρ_i, investment	B	0.5	0.2	0.56	0.64
ρ_w, wage markup	B	0.5	0.2	0.31	0.82
ρ_p, price markup	B	0.5	0.2	0.49	0.74
ρ_r, interest rate	B	0.5	0.2	0.86	0.29
ρ_g, government spending	B	0.5	0.2	0.94	0.96
$\rho_{\tau,k}$, capital tax	B	0.5	0.2	0.92	N.A.
$\rho_{\tau,l}$, labor tax	B	0.5	0.2	0.88	N.A.
ρ_z, transfers	B	0.5	0.2	0.86	N.A.
Std. of shocks					
σ_a, technology	IG	0.1	2	0.55	0.35
σ_b, preference	IG	0.1	2	1.29	N.A.
σ_i, investment	IG	0.1	2	2.06	0.39
σ_w, wage markup	IG	0.1	2	0.27	0.21
σ_p, price markup	IG	0.1	2	0.16	0.11
σ_r, interest rate	IG	0.1	2	0.15	0.12
σ_g, government spending	IG	0.1	2	1.04	0.41
$\sigma_{\tau,k}$, capital tax	IG	0.1	2	2.65	N.A.
$\sigma_{\tau,l}$, labor tax	IG	0.1	2	2.46	N.A.
σ_z, transfers	IG	0.1	2	3.66	N.A.

Table 4: Prior and posterior distributions of the estimated parameters for the New Keynesian model. Functions G, B, N, IG denote Gamma, Beta, normal and inverse Gamma distributions.

tax receipts (Table 3.1, line 2), contributions for government social insurance (Table 3.1, line 7), income receipts on assets (Table 3.1, line 8), and the current surplus of government enterprises (Table 3.1, line 14), minus total tax revenues (the sum of labor, capital, and consumption tax revenues, where consumption tax revenues are taxes on production and imports (Table 3.1, line 4) less property taxes (Table 3.3, line 8).

Hours Worked. Hours worked are constructed from the following variables:

H the index for nonfarm business, all persons, average weekly hours duration, 1992 = 100, seasonally adjusted (from the Department of Labor).

Emp civilian employment for sixteen years and over, measured in thousands, seasonally adjusted (from the Department of Labor, Bureau of Labor Statistics, CE16OV). The series is transformed into an index where 1992Q3 = 100.

Hours worked are defined as

$$N = \frac{H * Emp}{100}$$

Wage Rate. The wage rate is defined as the index for hourly compensation for nonfarm business, all persons, 1992 = 100, seasonally adjusted (from the U.S. Department of Labor).

Inflation. The gross inflation rate is defined using the GDP deflator for personal consumption expenditures (Table 1.1.4, line 2).

Interest Rate. The nominal interest rate is defined as the average of daily figures of the Federal Funds Rate (from the Board of Governors of the Federal Reserve System).

Definitions of Observable Variables The observable per capita variable X is defined from the real level data x

$$X = \ln\left(\frac{x}{Popindex}\right) * 100$$

where

Popindex index of *Pop*, constructed such that 1992Q3 = 1;

Pop Civilian noninstitutional population in thousands, ages 16 years and over, seasonally adjusted (from the Bureau of Labor Statistics).

x = consumption, investment, hours worked, the sum of government consumption and investment, capital tax revenues, labor tax revenues, and transfers. The real wage rate is defined in the same way, except that it is not divided by the total population.

B.3.2 Municipal and Treasury Bonds Data.

Yields to maturity from 1954M1 to 1994M12 on tax-exempt prime-grade general obligation municipal bonds come from Salomon Brothers, Analytical Record of Yields and Yield Spreads. Salomon Brothers' municipal data are collected on bonds of various maturity lengths on the first of each month and based on estimates of the yields of new issues sold at face value. Yields on similarly rated (AAA) municipal bonds from 1994-2006 are obtained from Bloomberg's Municipal Fair Market Bond Index. Market yields on constant-maturity-adjusted, non-inflation-indexed U.S. Treasury securities from 1955-2006 come from the Federal Reserve's Statistical Release on Selected Interest Rates. These yields reflect the average of the weekly values within each month, which are interpolated from the daily yield curve.

References

Abel, A. B. (1982): "Dynamic Effects of Permanent and Temporary Tax Policies in a q Model of Investment," *Journal of Monetary Economics*, 9(3), 353–373.

An, S., and F. Schorfheide (2007): "Bayesian Analysis of DSGE Models," *Econometric Reviews*, 26(2), 113–172.

Ang, A., V. Bhansali, and Y. Xing (2010): "Taxes on Tax-Exempt Bonds," *The Journal of Finance*, 65(2), 565–601.

Auerbach, A. J. (1989): "Tax Reform and Adjustment Costs: The Impact on Investment and Market Value," *International Economic Review*, 30(4), 939–962.

Barsky, R., and E. Sims (2011): "News Shocks and Business Cycles," Forthcoming *Journal of Monetary Economics*.

Basu, S., and J. G. Fernald (1995): "Are Apparent Productive Spillovers a Figment of Specification Error?," *Journal of Monetary Economics*, 36(1), 165–188.

Beaudry, P., and F. Portier (2006): "Stock Prices, News, and Economic Fluctuations," *American Economic Review*, 96(4), 1293–1307.

Bernanke, B. S. (1986): "Alternative Explanations of the Money-Income Correlation," *Carneige-Rochester Conference Series on Public Policy*, 25, 49–99.

Blanchard, O. J., and R. Perotti (2002): "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output," *Quarterly Journal of Economics*, 117(4), 1329–1368.

Blanchard, O. J., and D. Quah (1989): "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *American Economic Review*, 79(4), 655–673.

Blattner, T., M. Catenaro, M. Ehrmann, R. Strauch, and J. Turunen (2008): "The Predictability of Monetary Policy," European Central Bank Occasional Paper No. 83.

Burnside, C., M. Eichenbaum, and J. D. M. Fisher (2004): "Assessing the Effects of Fiscal Shocks," *Journal of Economic Theory*, 115(1), 89–117.

Caldara, D. (2010): "The Analytics of SVARs: A Unified Framework to Measure Fiscal Multipliers," Manuscript, Stockholm University, November.

Caldara, D., and C. Kamps (2008): "What Are the Effects of Fiscal Policy Shocks? A VAR-Based Comparative Analysis," European Central Bank Working Paper Series No 877.

——— (2010): "The Analytics of the Sign Restriction Approach to Shock Identification: A Framework for Understanding the Empirical Macro Puzzles," Manuscript, European Central Bank, March.

Campbell, J. Y., and R. J. Shiller (1987): "Cointegration and Tests of Present Value Models," *Journal of Political Economy*, 95(5), 1062–1088.

Canova, F. (2000): "Validating Monetary DSGE Models Through VARs," Manuscript, Universitat Pompeu Fabra.

Canova, F., and E. Pappa (2007): "Price Differentials in Monetary Unions: The Role of Fiscal Shocks," *Economic Journal*, 117(520), 713–737.

Canova, F., and J. P. Pina (2000): "Monetary Policy Misspecification in VAR Models," Manuscript, Universitat Pompeu Fabra.

Chalmers, J. M. R. (1998): "Default Risk Cannot Explain the Muni Puzzle: Evidence from Municipal Bonds that are Secured by U.S. Treasury Obligations," *The Review of Financial Studies*, 11, 281–308.

Chari, V. V., P. J. Kehoe, and E. R. McGrattan (2008): "Are Structural VARs with Long-Run Restrictions Useful in Developing Business Cycle Theory?," *Journal of Monetary Economics*, 55(8), 1337–1352.

Christiano, L. J., C. Ilut, R. Motto, and M. Rostagno (2008): "Monetary Policy and Stock Market Boom-Bust Cycles," Working Paper No. 955, European Central Bank.

Edelberg, W., M. Eichenbaum, and J. D. M. Fisher (1999): "Understanding the Effects of a Shock to Government Purchases," *Review of Economic Dynamics*, 2(1), 166–206.

Erceg, C. J., D. W. Henderson, and A. T. Levin (2000): "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics*, 46(2), 281–313.

Faust, J. (1998): "The Robustness of Identified VAR Conclusions About Money," *Carneige-Rochester Conference Series on Public Policy*, 49, 207–244.

Fernández-Villaverde, J., J. F. Rubio-Ramírez, T. J. Sargent, and M. W. Watson (2007): "ABCs (and Ds) of Understanding VARs," *American Economic Review*, 97(3), 1021–1026.

Fisher, J. D. M., and R. Peters (2009): "Using Stock Returns to Identify Government Spending Shocks," Federal Reserve Bank of Chicago WP 2009-03.

Forni, M., and L. Gambetti (2010a): "Fiscal Foresight and the Effects of Government Spending," RECent Working Paper No. 49, June.

——— (2010b): "Testing for Sufficient Information in Structural VARs," Manuscript, Università di Modena e Reggio Emilia, December.

Forni, M., L. Gambetti, and L. Sala (2011): "No News in Business Cycles," *CEPR Discussion Paper No. 8274*, February.

Fortune, P. (1996): "Do Municipal Bond Yields Forecast Tax Policy?," *New England Economic Review*, (September/October), 29–48.

Friedman, M. (1948): "A Monetary and Fiscal Framework for Economic Stability," *American Economic Review*, 38(2), 245–264.

Fujiwara, I., Y. Hirose, and M. Shintani (2011): "Can News Be a Major Source of Aggregate Fluctuations? A Bayesian DSGE Approach," *Journal of Money, Credit and Banking*, 43(1), 1–29.

Gali, J. (1999): "Technology, Employment and the Business Cycle: Do Technology Shocks Explain Aggergate Fluctuations?," *American Economic Review*, 89(1), 249–271.

Granger, C. W. J. (1969): "Investigating Causal Relations by Econometric Models and Cross-spectral Methods," *Econometrica*, 37(3), 424–438.

Hansen, L. P., W. Roberds, and T. J. Sargent (1991): "Time Series Implications of Present Value Budget Balance and of Martingale Models of Consumption and Taxes," in *Rational Expectations Econometrics*, ed. by L. P. Hansen, and T. J. Sargent, pp. 121–161. Westview Press, Boulder, CO.

Hansen, L. P., and T. J. Sargent (1980): "Formulating and Estimating Dynamic Linear Rational Expectations Models," *Journal of Economic Dynamics and Control*, 2, 7–46.

——— (1991a): "Introduction," in *Rational Expectations Econometrics*, ed. by L. P. Hansen, and T. J. Sargent, pp. 1–12. Westview Press, Boulder, CO.

——— (1991b): "Two Difficulties in Interpreting Vector Autoregressions," in *Rational Expectations Econometrics*, ed. by L. P. Hansen, and T. J. Sargent, pp. 77–119. Westview Press, Boulder, CO.

House, C. L., and M. D. Shapiro (2006): "Phased-in Tax Cuts and Economic Activity," *American Economic Review*, 96(5), 1835–1849.

Jaimovich, N., and S. Rebelo (2009): "Can News about the Future Drive the Business Cycle?," *American Economic Review*, 99(4), 1097–1118.

Jones, J. B. (2002): "Has Fiscal Policy Helped Stabilize the Postwar U.S. Economy?," *Journal of Monetary Economics*, 49(4), 709–746.

Judd, K. L. (1985): "Short-Run Analysis of Fiscal Policy in a Simple Perfect Foresight Model," *Journal of Political Economy*, 93(2), 298–319.

Klein, P. (2000): "Using the Generalized Schur Form to Solve a Multivariate Linear Rational Expectations Model," *Journal of Economic Dynamics and Control*, 24(10), 1405–1423.

Kriwoluzky, A. (2010): "Pre-announcement and Timing—The Effects of a Government Expenditure Shock," Manuscript, University of Bonn, December.

Laséen, S., and L. Svensson (2011): "Anticipated Alternative Policy-Rate Paths in Policy Simulations," Sveriges Riksbank Working Paper No. 248.

Leeper, E., T. B. Walker, and S.-C. S. Yang (2011): "Approaches to Identifying Foresight," Manuscript, Indiana University.

Leeper, E. M. (1989): "Policy Rules, Information, and Fiscal Effects in a 'Ricardian' Model," Federal Reserve Board, International Finance Discussion Paper No. 360.

——— (1990): "The Dynamics of Interest Rate and Tax Rules in a Stochastic Model," Federal Reserve Board, International Finance Discussion Paper No. 375.

——— (1991): "Equilibria Under 'Active' and 'Passive' Monetary and Fiscal Policies," *Journal of Monetary Economics*, 27(1), 129–147.

Leeper, E. M., M. Plante, and N. Traum (2010): "Dynamics of Fiscal Financing in the United States," *Journal of Econometrics*, 156(2), 304–321.

Leeper, E. M., A. W. Richter, and T. B. Walker (2010): "Quantitative Effects of Fiscal Foresight," NBER Working Paper No. 16363, September.

Leeper, E. M., and T. B. Walker (2011): "Information Flows and News Driven Business Cycles," *Review of Economic Dynamics*, 14(1), 55–71.

Leeper, E. M., T. B. Walker, and S.-C. S. Yang (2008): "Fiscal Foresight: Analytics and Econometrics," NBER Working Paper No. 14028.

——— (2010): "Government Investment and Fiscal Stimulus," *Journal of Monetary Economics*, 57(8), 1000–1012.

Lippi, M., and L. Reichlin (1993): "The Dynamic Effects of Aggregate Demand and Supply Disturbances: Comment," *American Economic Review*, 83(3), 644–652.

——— (1994): "VAR Analysis, Nonfundamental Representations, Blaschke Matrices," *Journal of Econometrics*, 63(1), 307–325.

Lucas, J. R. E. (1976): "Econometric Policy Evaluation: A Critique," *Carneige-Rochester Conference Series on Public Policy*, 1, 104–130.

Mertens, K., and M. O. Ravn (2010): "Measuring the Impact of Fiscal Policy in the Face of Anticipation: A Structural VAR Approach," *The Economc Journal*, 120(544), 393–413.

——— (2011): "Understanding the Aggregate Effects of Anticipated and Unanticipated Tax Policy Shocks," *Review of Economic Dynamics*, 14(1), 27–54.

Mountford, A., and H. Uhlig (2009): "What are the Effects of Fiscal Policy Shocks?," *Journal of Applied Econometrics*, 24(6), 960–992.

Park, S. (1997): "The Relationship Between Government Financial Condition and Expected Tax Rates Reflected in Municipal Bond Yields," *National Tax Journal*, 50(1), 23–38.

Parker, J. A. (1999): "The Reaction of Household Consumption to Predictable Changes in Social Security Taxes," *American Economic Review*, 89(4), 959–973.

Pigou, A. C. (1927): *Industrial Fluctuations*. London: Macmillan, London, second edn.

Poterba, J. M. (1988): "Are Consumer Forward Looking? Evidence from Fiscal Experiments," *American Economic Review, Papers and Proceedings*, 78(2), 413–418.

——— (1989): "Tax Reform and the Market for Tax-Exempt Debt," *Regional Science and Urban Economics*, 19(3), 537–562.

Ramey, V. A. (2007): "Identifying Government Spending Shocks: It's All in the Timing," Manuscript, University of California, San Diego.

——— (2009): "Defense News Shocks, 1939-2008: Estimates Based on News Sources," Manuscript, University of California, San Diego, October.

——— (2011): "Identifying Government Spending Shocks: It's All in the Timing," *Quarterly Journal of Economics*, 126(1), 1–50.

Ramey, V. A., and M. D. Shapiro (1998): "Costly Capital Reallocation and the Effects of Government Spending," *Carneige-Rochester Conference Series on Public Policy*, 48, 145–194.

Reagan, R. (1979): "Official Announcement," New York Hilton, New York, November 13, http://www.4president.org/speeches/1980/reagan1980announcement.htm.

Roberds, W. (1991): "Implications of Expected Present Value Budget Balance: Application to Postwar U.S. Data," in *Rational Expectations Econometrics*, ed. by L. P. Hansen, and T. J. Sargent, pp. 163–175. Westview Press, Inc., Boulder, CO.

Romer, C. D., and D. H. Romer (2007): "A Narrative Analysis of Postwar Tax Changes," Manuscript, University of California, Berkeley.

Romer, C. D., and D. H. Romer (2010): "The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks," *American Economic Review*, 100(3), 763–801.

Rozanov, Y. A. (1967): *Stationary Random Processes*. Holden-Day, San Francisco.

Sargent, T. J. (1981): "Interpreting Economic Time Series," *Journal of Political Economy*, 89(2), 213–248.

Schmitt-Grohé, S., and M. Uribe (2008): "What's 'News' in Business Cycles?," *NBER Working Paper No. 14215*, August.

——— (2010): "What's 'News' in Business Cycles?," Manuscript, Columbia University, April.

Sims, C. A. (1972): "Money, Income, and Causality," *American Economic Review*, 62(September), 540–552.

——— (1977): "Exogeneity and Causal Orderings in Macroeconomic Models," in *New Methods in Business Cycle Research*, ed. by C. A. Sims, pp. 23–43. Federal Reserve Bank of Minneapolis, Minneapolis.

——— (1980): "Macroeconomics and Reality," *Econometrica*, 48(1), 1–48.

——— (1986): "Are Forecasting Models Usable for Policy Analysis?," *Federal Reserve Bank of Minneapolis Quarterly Review*, 10(Winter), 1–16.

——— (1988): "Identifying Policy Effects," in *Empirical Macroeconomics for Interdependent Economics*, ed. by R. C. et al Bryant, pp. 308–321. The Brookings Institution, Washington, DC.

——— (2002): "Solving Linear Rational Expectations Models," *Computational Economics*, 20(1), 1–20.

Smets, F., and R. Wouters (2003): "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association*, 1(5), 1123–1175.

——— (2007): "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 97(3), 586–606.

Souleles, N. S. (1999): "The Response of Household Consumption to Income Tax Refunds," *American Economic Review*, 89(4), 947–958.

——— (2002): "Consumer Response to the Reagan Tax Cuts," *Journal of Public Economics*, 85(1), 99–120.

Taylor, J. B. (1993): "Discretion versus Policy Rules in Practice," *Carneige-Rochester Conference Series on Public Policy*, 39, 195–214.

Townsend, R. M. (1983): "Forecasting the Forecasts of Others," *Journal of Political Economy*, 91(4), 546–588.

Traum, N., and S.-C. S. Yang (2010): "When Does Government Debt Crowd Out Investment?," *Center for Applied Economics and Policy Reserch Working Paper No. 2010-006*, May.

Uhlig, H. (2005): "What Are the Effects of Monetary Policy? Results From an Agnostic Identification Procedure," *Journal of Monetary Economics*, 52(2), 381–419.

Whiteman, C. (1983): *Linear Rational Expectations Models: A User's Guide*. University of Minnesota Press, Minneapolis.

Yang, S.-C. S. (2005): "Quantifying Tax Effects Under Policy Foresight," *Journal of Monetary Economics*, 52(8), 1557–1568.

——— (2007): "Tentative Evidence of Tax Foresight," *Economics Letters*, 96(1), 30–37.

——— (2009): "A Chronology of Federal Income Tax Policy: 1947–2009," *Center for Applied Economics and Policy Research Working Paper No. 2007-021*, October.