# Information Sets and Dynamic Scoring

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**Abstract**

Recent work by Schmitt-Grohe and Uribe[8] has explored the effect of anticipated shocks or news shocks to the US business cycle. I extend this analysis using US tax rates and investment incentives. I explore the period between 2008 and 2015 when US lawmakers were repeatedly extending or modifying an additional deduction for qualified property placed in service. Because I am able to vary the information sets of taxpayers inside of the DSGE model used for analysis, I can model the effect of extending a tax policy repeatedly against one single extension over the same period of time. I also explore the effects of phasing out a policy and timing the announcement under varied information sets. Finally, I discuss these results in the context of the varied information set assumptions used by the Joint Committee on Taxation for dynamic scoring.

Keywords: DSGE Models; Fiscal Policy; Dynamic Scoring

JEL Codes: C32; C51; C52

# 1 Introduction and Summary

In analyzing the macroeconomic effects of tax policy proposals, the Joint Committee staff uses several different models to account for the sensitivity of the analysis to different modeling assumptions. Two of these models, the Joint Committee macroeconomic equilibrium growth model (”MEG”), and the overlapping generations model (”OLG”) have been described in Joint Committee staff documents.[1]

The DSGE model outlined below provides two key additional analytic capabilities for macroeconomic analysis. (1) It has the ability to assume people make decisions under uncertain future tax rates, with more information about future policy than is assumed in the myopic MEG model and less information than is assumed in the perfect foresight OLG model. For example, in the DSGE model households will react differently to an anticipated change in taxes than an unanticipated change. In MEG every change is unanticipated, while in OLG every change is anticipated. (2) It has the ability to model the effects of expectations of future monetary policy, which is useful in scenarios where the Federal Reserve is constrained by a Federal funds rate that is near zero.

[1] Joint Committee on Taxation, *Summary of Economic Models and Estimating Practices of the Staff of the Joint Committee on Taxation* (JCX-46-11) September 19, 2011, and Joint Committee on Taxation, *Overview of Revenue Estimating Procedures and Methodologies Used by the Staff of the Joint Committee on Taxation*,(JCX-1-05), February 2, 2005.

## 2 Description Of The Dynamic Stochastic General Equilibrium Model

This model is a dynamic stochastic general equilibrium model which is consistent with microeconomic foundations. The model is based on the neoclassical growth framework[10] and incorporates new Keynesian price frictions and adjustment costs. Households in the model supply labor and capital to firms. Firms produce investment, consumption and housing goods. Because the firms exist in a monopolistically competitive market with sitcky price the model produces persistent price growth or inflation. This sticky price feature combined with adjustment costs on the investment good comprise a common set of rigidities for a new Keynesian DSGE model[2]. The real economy is closed in the model. Therefore, all goods produced by firms are consumed in the model and all goods consumed or invested are produced by firms in the model. Thus, model cannot consider include international flows of capital goods or services. A central monetary authority sets the nominal interest rate according to a prescribed rule which all other households and firms are aware of.

The term "dynamic" refers to the fact that decision makers in the model (households and firms) take the passage of time explicitly into account. For instance, households value consumption today slightly higher than they value planned consumption in the next period. Because each period in the model corresponds to one quarter of a year DSGE is a model of quarterly behavior of the U.S. economy.

The term "stochastic" means that any uncertain outcomes in the model can be assigned finite mathematical probabilities by the decision makers inside the model. This differs from the MEG model where decision makers are myopic and have an unchanging expectation of the future. This also differs from the OLG model where decision makers have perfect foresight or knowledge of all future outcomes and do not prepare for multiple outcomes. If we assume that decision makers inside the DSGE model construct expectations of the future using the probabilities of random variables embedded in the model and their calculated expectations match repeated simulated outcomes of the model then these decision makers have what macroeconomists refer to as rational expectations. In other words, the DSGE model assumes rational expectations and thus decision makers inside the model know the probability of all random variables in the model and calculate expectations based on those random variables correctly.

The model includes random variables in the processes describing Federal taxes, Federal government consumption, transfer payments and monetary policy. Decision makers in our model know the exact values of future Federal tax variables up to two and a half years into the future. Tax rates beyond two and a half years are assumed to persist at previous known levels following a stochastic process. That is, individuals and businesses think tax rates may be higher or lower than current tax rates, but they are uncertain which outcome will prevail. This is a less extreme information assumption than perfect foresight imposed by the Joint Committee's OLG model yet larger than the zero information assumption imposed by the Joint Committee's MEG model. Unlike the OLG or MEG models, the stochastic component of DSGE allows for the modeling of anticipated changes against unanticipated changes in the tax code.

Finally, the term "general equilibrium" refers to the fact that we intend to model all markets of the real U.S. economy. This means that all real variables of the model are constructed to be consistent with national income accounting and correspond to real, inflation adjusted, variables in the National Income and Product Accounts.

A medium scale new Keynesian DSGE model [6] typically contains five types of agents: a large number of identical households referred to as a representative agent, a large number of monopolistically competitive firms producing an intermediate good, a final good producing firm that has zero profit, a central monetary authority that sets nominal interest rates according to a simple rule, and a government that levies a lump sum tax against the representative agent. The dollar amount of the tax is determined by what the government needs to finance its spending. My model introduces several features to this framework to make the model more useful for tax policy analysis. It adds a second group of households, often referred to as non-Ricardians or rule-of-thumb agents in the literature; it incorporates a separate good and production sector for residential housing; it allows governments to levy taxes proportional to income earned in the economy and to issue debt to pay for tax cuts; and it allows agents to deduct depreciation of capital from their capital tax liability following a predetermined schedule.

The model distinguishes between two types of households: those who save and those who do not. Savers, or Ricardians, have access to capital markets and can invest in the production of housing or the production of all other goods. Ricardians can also invest in a risk free government bond which is used to fund temporary government deficits. Households that do not save, or non-Ricardians, do not have access to capital markets or bond markets. Both types of households are able to purchase the housing good which is not consumed entirely each period but depreciates slowly over time. Non-Ricardians and Ricardians therefore face different intertemporal optimization problems. Each period non-Ricardians must choose the amount of labor they supply and the amount of goods they consume along with the amount of housing they purchase and hold for later periods. Ricardians face the same intertemporal tradeoffs but also have the choices of investing in capital or bonds. The fraction of Ricardians in the model population is chosen to be consistent with the empirical literature[11][3]. Ricardians are chosen to represent the top 41 percent of the income distribution.

Government in the model can sustain permanently higher levels of debt resulting from temporary deficits as long as fiscal solvency is maintained. Fiscal solvency means that the expected value of government debt cannot grow faster than the output of the economy for an infinite period of time. In order to insure fiscal solvency in the model Federal government consumption and the Federal government transfer payment are reduced in response to heightened levels of debt that persist for five years. Government consumption is part of GDP but is not valued by households and does not act as an input to production.

The model is calibrated such that the consumption share of output and investment share of output match U.S. data from 2010. The ratios of non-Ricardian housing to Ricardian housing and non-Ricardian income to Ricardian income are set to match averages from the Internal Revenue Service Statistics of Income and the Federal Reserve Survey of Consumer Finances. Table 1 summarizes the values of some structural parameters and some policy variables for the calibrated economy.

The model allows for a certain fraction of new capital purchases to be deducted immediately from the household capital tax liability. This feature gives the DSGE model the ability to explicitly model the investment incentives of proposals to alter bonus depreciation similar to Edge et al. (2011)[5]. The remaining fraction is then deducted according to a fixed, constant schedule.

Changes in tax rates on labor income influence a household's willingness to work both by affecting their marginal return to labor (the substitution effect) and by affecting their disposable income (the income effect). After a tax change has been implemented in the short run the substitution effect typically dominates the income effect. In the long run, once wealth has been significantly impacted by the change in after-tax income, the income effect will dominate the substitution effect. For instance, if reduced tax rates on labor income lead to an increased supply of labor, higher disposable labor income, and therefore to increased saving and increased wealth over time, households eventually choose to enjoy more leisure and begin to reduce labor. If households become aware of a future labor income tax change they will adjust to the change in future income by changing labor now. In such a case the income effect can play a larger role in the short run and households will make smaller adjustments in the long run.

Changes in taxes on capital income have a direct impact on Ricardians 'investment decisions. Reductions in tax rates on capital income increase the return to investment. Ricardians sacrifice consumption initially in order to invest more. Lower consumption makes Ricardians work harder as the marginal benefit for supplying additional hours of labor is higher. The wage rate falls initially because Ricardians are willing to work more hours, thus creating an excess supply of labor. Because non-Ricardians do not own capital, the short-run fall in the wage rate reduces incentives for them to work in early periods. In the longer run, as the increase in investment results in a build-up of capital, the marginal product of labor increases, firms demand more labor, and the wage rate increases. The increased wage rate leads non-Ricardians to supply more labor to the economy. Conversely, in the long run, the buildup in the capital stock leads to more capital income accruing to Ricardians, which reduces Ricardians'incentive to work, causing their supply of labor to decrease.

Temporary changes to the fraction of new capital which can be deducted from Ricardian households'tax liabilities temporarily alter the cost of capital and lead to short lived investment responses. In the case of a permanent change to this fraction households will change investment instantly and permanently with little change from short run to long run.

A formal description of the basic model structure is provided in the appendix.

| Parameter | Description | Value |
| --- | --- | --- |
| | Structural Parameters | |
| $\alpha$ | Production income share of capital | 36% |
| $\mu$ | fraction of non-Ricardians | 59% |
| $\gamma_\pi$ | Monetary authority response to inflation | 1.75 |
| | Fiscal Policy Parameters | |
| $gc_{ss}$ | Government consumption share of output | 27.2% |
| $tr_{ss}$ | Government transfer to output ratio | 28.5% |

Table 1: Selected parameters from the DSGE Model.

# A Appendix:Introduction

The model is a medium scale new Keynesian model similar to Fernandez-Villaverde and Rubio-Ramirez (2008) [6], Traum and Yang (2011) [11] and Rudd and Edge (2010) [5]. The model contains households, firms, a central monetary authority and a government or fiscal authority that purchases goods and services, makes a transfer payment, and imposes taxes.

# B Appendix:Households

There exists a continuum of infinitely lived households indexed by $j \in [0,1]$. Households in the interval $[\mu, 1]$ are able to access capital markets and purchase government bonds. Households in the interval $[0, \mu]$ are not able to access capital markets or hold bonds. All households have constant relative risk aversion preferences over the consumption good and leisure which are additively separable. Their intertemporal preferences are also additively separable and discounted geometrically. Households which are able to access capital and bond markets, or Ricardians, face the following optimization problem:

$$\max_{c_t^r, x_t, l_t^r, b_t, k_t} E_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{(c_t^r)^{1-\gamma}}{1-\gamma} + \frac{(1-l_t^r)^{1-\theta}}{1-\theta} \right]$$

s.t.

$$\begin{aligned} c_t^r + x_t + b_t = \frac{R_t}{\Pi_t} b_{t-1} + w_t^* l_t^r - \tau_t^{l,r}(w_t^* l_t^r - ded_t^r) + tr_t + r_t^{*k} k_{t-1} + cr_t^r \\ -\tau_t^k \left( r_t^{*k} k_{t-1} - x_t \theta_t - \sum_{\upsilon=0}^{\infty} \delta (1-\delta)^{\upsilon} (1-\theta_{t-\upsilon}) \frac{P_{t-\upsilon} x_{t-\upsilon}}{P_t} \right) \quad (0) \end{aligned}$$

$$k_t = k_{t-1}(1-\delta) + exp(\omega_t) \left( 1 - S\left( \frac{x_t}{x_{t-1}} \right) \right) x_t \quad (1)$$

Investment, $x_t$, is transformed into capital via an adjustment cost function. The function $S$ is continuous and behaves such that $S(1) = 0$, $S'(1) > 0$ and $S''(1) > 0$. Each period the Ricardian household is able to deduct a fraction, $\theta_t$, of investment from their capital tax liability. The remaining fraction of the nominal amount of investment is deducted via a geometric depreciation schedule in later periods. The variable $\omega_t$ represents investment productivity which follows the process:

$$\omega_t = \rho_\omega \omega_{t-1} + \upsilon_t^\omega$$

Non-Ricardian households optimize the same preference structure. with their choice of consumption and labor subject to the following constraint:

$$c_t^n = l_t^n w_t^* - \tau_t^{l,n}(l_t^n w_t^* - ded_t^n) + tr_t + cr_t^n \quad (0)$$

## C Appendix:Firms

We assume that there exists a continuum of intermediate goods and their respective firms $i \in [0,1]$. There also exists a zero profit final good packer with a constant elasticity of substitution production function over all intermediate goods. If the packer chooses the lowest cost combination of intermediate goods given prices, $p_t(i)$, to produce an amount of output, $y_t^d$, then the packer's demand function for intermediate good $i$ must be:

$$y_t(i) = \left(\frac{p_t(i)}{p_t}\right)^{-\epsilon} y_t^d$$

Intermediate goods producers have Cobb-Douglass production functions:

$$y_t(i) = A_t(k_{t-1}(i))^{\alpha}(l_t^d(i))^{1-\alpha} - \phi$$

Where $k_{t-1}(i)$ is the capital rented by the firm and $l_t^d(i)$ is the amount of labor rented by the firm. And the aggregate productivity shock follows the process:

$$log(A_t) = \rho_A log(A_{t-1}) + \upsilon_t^A$$

The parameter $\phi$ represents fixed costs and is typically set so that economic profits are zero in steady state. Intermediate good producers face a two stage problem. First, given rental rates and a level of output they must decide the lowest cost combination of capital and labor. Equating marginal product to marginal cost ratios yields the equation:

$$k_{t-1}(i) = \frac{\alpha}{1-\alpha}\frac{w_t^*}{r_t^*} l_t^d(i) \tag{-3}$$

Combining this equation with the production function, which has constant returns to scale, one can then derive the marginal cost of output:

$$mc_t(i) = \left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha} \frac{1}{\alpha}\frac{(w_t^*)^{1-\alpha}(r_t^*)^{\alpha}}{A_t} \tag{-3}$$

Intermdiate goods firms, like labor unions, are given probability $\theta_p$ that they will not be able to set their wages in a given period. These firms will then maximize profits through the choice of price for their goods subject to the demand of the labor packer. Firms will discount future profits using, $\lambda_t^r$, from the Ricardian households. Their problem can be represented as:

$$\max_{p_{it}} E_t \sum_{\tau=0}^{\infty} (\beta\theta_p)^{\tau} \frac{\lambda_{t+\tau}^r}{\lambda_t^r} \prod_{s=1}^{\tau} \Pi_{t+s-1}^{\chi} \frac{p_{it}}{p_{t+\tau}} - mc_{t+\tau}$$

s.t.

$$y_{it+\tau} = \left(\prod_{s=1}^{\tau} \Pi_{t+s-1}^{\chi} \frac{p_{it}}{p_{t+\tau}}\right)^{-\epsilon} y_{t+\tau}^d$$

Since all firms face the same demand from the final good packer we assume a symmetric equilibrium where all firms able to set price at time $t$ choose $p_t^*$. The first order condition to the producer problem equates two infinite sums. These sums can be redefined using the following helper variables:

$$g_t^1 = \lambda_t mc_t y_t^d + \beta\theta_p E_t \left(\frac{\Pi_t^{\chi}}{\Pi_{t+1}}\right)^{-\epsilon} g_{t+1}^1 \tag{-5}$$

$$g_t^2 = \lambda_t \Pi_t^* y_t^d + \beta\theta_p E_t \left(\frac{\Pi_t^{\chi}}{\Pi_{t+1}}\right)^{1-\epsilon} \frac{\Pi_t^*}{\Pi_t} g_{t+1}^2 \tag{-5}$$

Where $\Pi_t^*$ represents the ratio $\frac{p_t^*}{p_t}$. Now we can express our first order condition as:

$$g_t^1 = g_t^2 \tag{-5}$$

It can be shown that the aggregate intermediate good price evolves according to:

$$1 = \theta_p p_{t-1}^{1-\epsilon} \left(\frac{\Pi_{t-1}^{\chi_p}}{\Pi_t}\right)^{1-\eta} + (1-\theta_p)(\Pi_t^*)^{1-\epsilon} \tag{-5}$$

# D Appendix:Aggregation

Since we assume complete markets the invidual Ricardian household variables will be identical across Ricardian households. Aggregating these variables we find:

$$c_t^r = \int_{\mu}^{1} c_{jt} dj$$

$$c_t^r = \int_{0}^{\mu} c_{jt} dj$$

$$C_t = \int_{0}^{1} c_{jt} dj = (1-\mu)c_t^r + \mu c_t^n$$

$$X_t = \int_{\mu}^{1} x_{jt} dj = (1-\mu)x_t^r$$

$$B_t = \int_{\mu}^{1} b_{jt} dj = (1-\mu)b_t^r$$

$$K_t = \int_{\mu}^{1} k_{jt} dj = (1-\mu)k_t^r$$

The government budget constraint is then:

$$tr_t + g_t + \frac{R_t}{Pi_t} b_{t-1}^r (1-\mu) = b_t^r(1-\mu) + \tau_t^{l,r}(w_t^* l_t^r - ded_t^r)(1-\mu) + \tau_t^{l,n}(w_t^* l_t^n - ded_t^n)(1-\mu)$$
$$+\tau_t^k(r_t^{*k} k_{t-1} - x_t\theta_t - Liab_t)(1-\mu) - cr_t^r(1-\mu) - cr_t^n \mu \tag{-11}$$

The monetary authority sets interest rates according to the following rule:

$$\frac{R_t}{R_{ss}} = \left(\frac{R_{t-1}}{R_{ss}}\right)^{\gamma_r} \left(\frac{\Pi_t}{\Pi_{ss}}\right)^{\gamma_\pi(1-\gamma_r)} \left(\frac{y_t}{y_{ss}}\right)^{\gamma_y(1-\gamma_r)} \upsilon_t^m \tag{-11}$$

To close the model we must specify a resource constraint as follows:

$$y_t^d = C_t + g_t + X_t \tag{-11}$$

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