# BACKGROUND INFORMATION ABOUT THE DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL USED BY THE STAFF OF THE JOINT COMMITTEE ON TAXATION IN THE MACROECONOMIC ANALYSIS OF TAX POLICY

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## INTRODUCTION AND SUMMARY

This document,[1] prepared by the staff of the Joint Committee on Taxation ("Joint Committee staff"), describes a new model developed by the Joint Committee staff for use in analyzing how changes in tax policy may affect the nation's economy. 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. Three of these models, the Joint Committee macroeconomic equilibrium growth model ("MEG"), the overlapping generations lifecycle model ("OLG"),[2] and the Global Insight econometric model ("GI") have been described in other Joint Committee staff documents.[3] The Joint Committee staff has recently begun using an additional model, a dynamic stochastic general equilibrium neoclassical growth model with infinitely lived agents ("DSGE"). The Joint Committee staff welcomes comment on this model.

The DSGE model provides two key additional analytic capabilities for macroeconomic analysis: (1) it has the ability to assume people make decisions using information-constrained rational expectations about future policy, 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; and (2) it allows for the analysis of differential consumption decisions between low-income and high-income earners, which can potentially provide important additional information about the distributional impacts of tax policy.

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[1] This document may be cited as follows: Joint Committee on Taxation, *Background Information about the Dynamic Stochastic General Equilibrium Model Used by the Staff of the Joint Committee on Taxation in the Macroeconomic Analysis of Tax Policy*, (JCX-52-06), December 14, 2006.

[2] The OLG model is leased from Tax Policy Advisers, LLC.

[3] Joint Committee on Taxation, *Macroeconomic Analysis of Various Proposals to Provide $500 Billion in Tax Relief (*JCX-4-05) March 1, 2005, 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.

# I. DESCRIPTION OF THE DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL

This model is a dynamic stochastic general equilibrium model with microeconomic foundations, based on the neoclassical growth framework, including the assumption that all available resources are fully employed each period. There is no unemployment, and the amount of output in the economy is determined by peoples' decisions regarding how much they are willing to work, consume, save, and invest in response to the after-tax costs and benefits of these activities. It is a closed, real economy model; thus, there are no international flows or capital, goods, or services, and no monetary sector in the model.

The term "dynamic" means that the model simulates the path of the economy over a long period of time. The term "stochastic" refers to the presence of uncertainty about future Federal fiscal policy initiatives, implemented by allowing Federal taxes to vary in future periods by a random amount. Dynamic models implicitly include an assumption about how much people know about the future path of the economy when they are making their work and savings decisions in the present. Many models, including the Joint Committee staff's MEG model, assume people are myopic, or have no information about what the economy will look like in future periods. Another typical modeling assumption is that people have perfect foresight, or complete information, about what the economy will look like in the future. Building in a stochastic process for expectations about tax policy allows the DSGE model to impose a less extreme information assumption about the amount of information taxpayers have about future policy than the zero information of myopic models or the complete information of perfect foresight models. The DSGE model assumes that in every year people know the exact tax policy for the next year; for future periods they believe that tax policy is likely to be persistent but subject to some random disturbances.

In its simplest form, a neoclassical growth model typically consists of three types of economic decision-makers: a large number of identical, infinitely-lived, people, sometimes collectively referred to as a "representative agent," perfectly competitive firms, and a government that has access to revenues from a simple head tax levied against the representative agent. The dollar amount of the tax is determined by what the government needs to finance its spending; it is not related to the income generated by the agent.[4] The DSGE model used by the Joint Committee staff introduces several features to this framework to make the model more useful for tax policy analysis. It adds a second group of people, often referred to as spenders or rule-of-thumb agents in the literature; it builds in investment friction by introducing an investment adjustment cost; and it allows government to levy taxes proportional to income earned in the economy and to issue debt to pay for tax cuts.

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[4] For an example of this type of a model see Mankiw, N. G., and M. Weinzierl, "Dynamic Scoring: A Back-of-the-Envelope Guide," *Journal of Public Economics* (forthcoming).

The model distinguishes between two types of people: those who save and those who do not.[5] Savers own the entire capital stock of the economy and also hold government debt. Spenders consume all disposable income each period. Thus, spenders' consumption/savings decisions are not made with the same intertemporal optimizing framework as the savers' decisions, but are determined by their lack of liquidity. Generally consistent with empirical evidence, spenders are assumed to be those in the lower portion of the income distribution.[6] The *Survey of Consumer Finances*[7] reports that about 40 percent of households did not save in 2001. In the model, spenders are those in the bottom 40 percent of the filers who have positive labor income. This partitioning between spenders and savers allows for an analysis of the differential effects of proposals on relatively low versus high income households.

The introduction of an investment adjustment cost is designed to mimic the delayed response of investment to changes in the after tax rate of return to capital that has been observed in empirical studies of investment responses to changes in tax policy. This addition of adjustment costs results in a more gradual change in capital stock in response to tax policy changes than occurs in models without this feature.

Government in the DSGE model can run permanently higher debt resulting from a tax cut as long as fiscal solvency is maintained. Fiscal solvency means that government debt cannot grow permanently faster than the output of the economy. In order to restore fiscal solvency for policies that would otherwise result in government debt that grows more rapidly than gross domestic product ("GDP"), the model has a range of fiscal reaction functions that can be simulated. Government can respond to increases in debt either by reducing its consumption (spending on goods and services) or transfer payments, or by increasing taxes on labor income or capital income with a delay of some specified time period.[8] While government consumption contributes to GDP, it is not valued by savers or spenders, and it is not an input to production.

The DSGE model is calibrated such that the consumption-output ratio, investment-output ratio, and the portion of their available time people spend working in a steady state are

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[5] The two-agent configuration largely follows the savers-spenders specification in Campbell, J. Y., and N. G. Mankiw, "Consumption, Incomes, and Interest Rates: Reinterpreting the Time Series Evidence," in *NBER Macroeconomics Annual 1989*, ed. by O. J. Blanchard and S. Fischer, MIT Press (1989) pp. 185-216, and Mankiw, N. G., "The Savers-Spenders Theory of Fiscal Policy," *American Economic Review Papers and Proceedings*, May 2000, pp. 120-125.

[6] In reality, there are some spenders in higher income categories and some savers in lower income categories. However, most people in high income categories are savers. See Aizcorbe, A. M., A. B. Kennickell, and K. B. Moore, "Recent Changes in U.S. Family Finances: Evidence from the 1998 and 2001 Survey of Consumer Finances," *Federal Reserve Bulletin*, January 2003, pp. 1-32.

[7] *Ibid*.

[8] Leeper, E. M., and S.-C. S. Yang, "Dynamic Scoring: Alternative Financing Schemes," NBER Working Paper 12103, 2006.

comparable to those of the postwar average of these ratios in U.S. data. Table 1 summarizes the values of some structural parameters and some policy variables for the calibrated economy.

Tax rates on individual income are generated using the Joint Committee staff's individual income tax microsimulation model, which allows calculation of effective marginal and average tax rates after taking into account all of the exclusions, exemptions, deductions, and credits that make up the present law tax system.[9] Labor income taxes include the payroll tax, income taxes on wages and salaries, and the individual income tax applied to half of proprietor's income. The tax rate on labor income for savers is the effective labor income tax rate for those in the top 60 percent of the labor income distribution among filers with positive labor income; the tax rate on labor income for spenders is the effective labor income tax rate for the remaining 40 percent. The calculation of the effective tax rate applied to income from capital is complicated by the dual, corporate/non-corporate taxation of business income. The effective tax rate on non-corporate capital income is calculated by, again, using the Joint Committee staff's individual income tax microsimulation model to determine the effective tax rate on interest, rental income, and half of proprietor's income. This model is also used to calculate the effective rate on dividend and capital gains income (adjusted to account for the accrual nature of capital gains). To determine the total effective tax rate in the corporate sector, the tax rate on dividends and capital gains is added to the effective corporate tax rate, which is calculated using the Joint Committee staff's corporate income tax microsimulation model. The final input to the DSGE model for the effective tax rate on income from capital is an income-weighted average of these two (non-corporate and corporate) effective rates.

Changes in tax rates on labor income influence people's willingness to work both by affecting their marginal return to labor (the substitution effect) and by affecting their disposable income (the income effect). In the DSGE model, in the short run, the substitution effect dominates the income effect so both spenders and savers respond to changes in labor income tax rates. In the longer run, as savers' wealth is affected by changes in disposable income over time, they may eventually want to change their consumption of leisure. For instance, if reduced tax rates on labor income lead to higher disposable labor income, and therefore to increased saving and increased wealth over time, they eventually choose to enjoy more leisure, reducing the amount of labor supplied for production of goods and services. The main parameter in the model that determines the magnitude of labor supply responses is the elasticity of intertemporal substitution of leisure.

Labor supply responses in the longer run also depend on which offsetting policy is assumed to be employed to maintain fiscal solvency. In the case in which government transfers are reduced to maintain budget solvency, spenders may increase labor inputs to compensate for

[9] In a progressive tax rate structure such as exists under the present-law U.S. Internal Revenue Code, the tax rate paid on the last dollar earned can be different from the average tax rate, calculated as total tax liability divided by income. In the DSGE model, while spenders and savers are assumed to face different tax rates, there is no distinction between average and marginal tax rates. This feature implicitly assumes that the two groups of people (a) are subject to a proportional, not a progressive tax rate structure; and (b) that there is no movement of people between the spenders and savers categories.

their loss of disposable income. In the case in which a reduction in government consumption provides the fiscal offset to a reduction in taxes people experience the resulting increase in disposable income as an increase in their wealth, while, by assumption, experiencing no offsetting decrease in wealth from the reduction in government consumption. The positive wealth effects from a smaller government enable people to work less and enjoy more leisure.

Changes in taxes on capital income have a direct impact on savers' investment decisions. Reductions in capital tax rates on capital income increase the return to investment; savers sacrifice consumption initially in order to invest more. Lower consumption makes savers work harder as the marginal benefit for supplying additional hours of labor is higher. The wage rate falls initially because savers are willing to work more hours, thus creating an excess supply of labor. Because spenders 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, firms demand more labor, and the wage rate increases. The increased wage rate leads spenders to supply more labor to the economy. Conversely, in the long run, the build-up in the capital stock leads to more capital income accruing to savers, which reduces savers' incentive to work, causing their supply of labor to decrease.

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

**Table 1.−Values of Some Structural Parameters and Policy Variables in a Steady State**

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Capital income share | 0.36 | Economic long-run output growth rate | 1.0217 |
| Annual discount factor | 0.96 | Share of savers (intertemporal optimizing agents) | 0.6 |
| Elasticity of intertemporal substitution of consumption | 1 | Long-run share of time to work | 0.2 |
| Elasticity of intertemporal substitution of leisure | 0.25 | Share of government transfers to savers | 0.3 |
| Annual economic capital depreciation rate | 0.06 | Share of government consumption | 0.1884 |
| Annual capital depreciation rate for tax purposes | 0.07 | Average tax rate on consumption | 0.084 |

## APPENDIX

**Basic structure of the DSGE model**

The model economy comprises two types of infinitely-lived agents: savers and spenders, a large number of perfectly competitive firms, and government. Savers consume, work, and save each period. With predetermined capital and government debt, a representative saver chooses consumption ($C_t^a$), capital ($K_t^a$), labor ($L_t^a$), and government bonds ($B_t^a$) to maximize utility over consumption and leisure

$$E_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{\left(C_t^a\right)^{1-\gamma} - 1}{1-\gamma} + \chi^a \frac{\left(1 - L_t^a\right)^{1-\theta} - 1}{1-\theta} \right],$$

subject to the budget constraint

$$\left(1+\tau_t^C\right)C_t^a + I_t^a + B_t^a \le \left(1-\tau_t^K\right) r_t K_{t-1}^a + \left(1-\tau_t^L\right) W_t v L_t^a + \delta^T \tau_t^K K_{t-1}^a + B_{t-1}^a R_{t-1} + TR_t^a .$$

The law of motion for capital is

$$K_t^a = \left(1-\delta\right) K_{t-1}^a + I\left(I_t^a, I_{t-1}^a\right).$$

The superscript *a* indicates variables associated with savers, while the superscript *p* indicates variables associated with spenders. $E_t$ is expectation operator conditional on agents' information set at *t*, which contains all variables dated at *t* and before. The discount factor is $\beta$ ($0 < \beta < 1$). The inverse-elasticities of intertemporal substitution of consumption and leisure for savers are $\gamma$ and $\theta$ ($\gamma > 0$ and $\theta \ge 0$), respectively. The preference weight that savers place on leisure is $\chi^a$. The depreciation rate on capital for tax purposes is $\delta^T$, and for economic purposes is $\delta$, ($0 \le \delta^T, \delta \le 1$). Resources devoted to investment, including the investment adjustment cost, are $I_t^a$. Government transfer to savers are $TR_t^a$. Tax rates on savers' labor income, consumption, and capital income are $\tau_t^{La}$, $\tau_t^C$, and $\tau_t^K$ respectively. Government debt at the end of time t is $B_t^a$, which pays $R_t B_t$ at time *t+1*. The rental rate of capital is $r_t$, and the wage rate is $W_t$. Savers' labor input is weighted by *v*, which also represents savers' population weight.

The investment function is defined as $I\left(I_t^a, I_{t-1}^a\right) \equiv \left[1 - S\left(\frac{I_t^a}{I_{t-1}^a}\right)\right] \times I_t^a$. In a steady state, assume $S(h) = S'(h) = 0$ and $s \equiv S''(h) > 0$, where *h* is the output growth rate in a steady state. The solution method does not require the specification of *S*(.), the investment adjustment cost function. (See Burnside, Eichenbaum, and Fisher (2004).)

A representative spender maximizes utility over consumption and leisure at the current period.

$$\frac{\left(C_t^p\right)^{1-\gamma} - 1}{1-\gamma} + \chi^P \frac{\left(1 - L_t^p\right)^{1-\theta} - 1}{1-\theta},$$

subject to the budget constraint

$$\left(1+\tau_t^C\right)C_t^P \le \left(1+\tau_t^{Lp}\right)W_t\left(1-v\right)L_t^P + TR_t^P,$$

where 1-*v* is the weight on spenders' labor input. As spenders cannot save, the optimal consumption level is to consume all disposable income. In the literature, models with spenders or rule of thumb agents often assume that spenders' labor decisions follow savers' choices. [10] This copy-cat rule would yield the odd result that a change in the savers' labor income tax rate that did not affect the spenders' labor income tax rate would nonetheless affect the spenders' labor decisions. The adoption of an intratemporal optimization problem over consumption and leisure yields a more reasonable result for spenders' labor choice than the copy-cat rule.

A representative firm rents capital from savers and labor from both types of agents to maximize the profit

$$A_t K_{t-1}^{\alpha}\left\{h^t\left[vL_t^a + \left(1-v\right)L_t^p\right]\right\}^{1-\alpha},$$

where *h* is the constant growth rate of labor augmenting technology, $\alpha$ is the share of capital income, and $A_t$ is the total factor productivity.

Government each period chooses $\left\{TR_t^a, TR_t^p, G_t, B_t, \tau_t^K, \tau_t^{La}, \tau_t^{Lp}, \tau_t^C\right\}$ to satisfy its budget constraint

$$\begin{aligned} &TR_t^a + TR_t^p + G_t + R_{t-1}B_{t-1} + \delta^T \tau_t^K K_{t-1} \\ &= \tau_t^{La} v W_t L_t^a + \tau_t^{Lp}\left(1-v\right)W_t L_t^a + \tau_t^K r_t K_{t-1} + \tau_t^C C_t + B_t, \end{aligned}$$

where $C_t = C_t^a + C_t^p$, $K_t = K_t^a$, $B_t = B_t^a$, and $G_t$ is the government consumption. An equilibrium also requires an infinite sequence of fiscal policies to satisfy the intertemporal budget constraint,

$$B_t = E_t \sum_{j=1}^{\infty} h^{j-1} \prod_{i=0}^{j-1} R_{t+i}^{-1} \begin{bmatrix} \left(1-\alpha\right)\tau_{t+j}^{La} v W_{t+j} L_{t+j}^a + \left(1-\alpha\right)\tau_{t+j}^{La}\left(1-v\right)W_{t+j}L_{t+j}^p \\ +\alpha \tau_{t+j}^K r_{t+j} K_{t+j-1} - \delta^T \tau_{t+j}^K K_{t+j-1} \\ +C_{t+j}\tau_{t+j}^C - G_{t+j} - TR_{t+j}^a - TR_{t+j}^p \end{bmatrix}.$$

The intertemporal budget constraint implies that $E_t \lim_{T\to\infty} \beta^{t+T} u'\left(c_{t+T}\right)\frac{B_{t+T}}{h^{t+T}} = 0$, and hence the transversality condition for debt is satisfied. This restriction means that debt cannot forever grow faster than the economy. At time *t*, a debt-financed tax cut leads to higher $B_t$. The intertemporal budget constraint says that at least one of the fiscal variables on the right hand side must adjust: one or more of the tax rates have to rise, or government consumption or transfers have to fall relative to the values in the path without a tax shock.

Many paths of fiscal policies can satisfy the intertemporal government budget constraint. Two offsetting policies are considered here: either government consumption or transfer

[10] Erceg, C. J., L. Guerrieri, and C. J. Gust, "Expansionary Fiscal Shocks and the Trade Deficit," International Finance Discussion Papers, No. 835, Board of Governors of the Federal Reserve System, 2005.

payments would adjust outside of the budget window to a deteriorating budget after the tax cut. The adjustment magnitude can vary so long as fiscal solvency is maintained.[11]

**Calibration**

The model is calibrated at an annual frequency. The choice of some structural parameters and steady state policy variables are presented in the table below.

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| $\alpha$ | 0.36 | $H$ | 1.0217 |
| $\beta$ | 0.96 | $V$ | 0.6 |
| $\gamma$ | 1 | $S$ | 0.8 |
| $\theta$ | 4 | $T^a/Y$ | 0.3 |
| $\delta$ | 0.06 | $T^p/Y$ | 0.7 |
| $\delta^T$ | 0.07 | $G/Y$ | 0.1884 |

$\theta$=4 implies that the Frisch labor elasticity is 0.25. Since intertemporal labor elasticity is an important parameter driving macroeconomic effects of tax policy, sensitivity analysis also considers $\theta$=10.

[11] For economic dynamics under similar policy rules, see Leeper and Yang, *ibid*.

## REFERENCES

Aizcorbe, A. M., A. B. Kennickell, and K. B. Moore, “Recent Changes in U.S. Family Finances: Evidence from the 1998 and 2001 Survey of Consumer Finances,” *Federal Reserve Bulletin*, January, 2003, pp. 1−32.

Burnside, C., M. Eichenbaum, and J. D. M. Fisher, “Fiscal shocks and their consequences,” *Journal of Economic Theory*, 115(1), 2004, pp 89-117.

Campbell, J. Y., and N. G. Mankiw, “Consumption, Incomes, and Interest Rates: Reinterpreting the Time Series Evidence,” in *NBER Macroeconomics Annual 1989*, ed. by O. J. Blanchard, and S. Fischer, MIT Press, 1989, pp. 185-216.

Erceg, C. J., L. Guerrieri, and C. J. Gust, “Expansionary Fiscal Shocks and the Trade Deficit,” International Finance Discussion Papers, No 835, Board of Governors of the Federal Reserve System.

Leeper, E. M., and S.-C. S. Yang, “Dynamic Scoring: Alternative Financing Schemes,” NBER Work Paper 12103, 2006.

Mankiw, N. G., “The Savers-Spenders Theory of Fiscal Policy,” *American Economic Review Papers and Proceedings*, May, 2006, pp., 120-125.

Mankiw, N. G., and M. Weinzierl (forthcoming), “Dynamic Scoring: A Back-of-the-Envelope Guide,” *Journal of Public Economics*.