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A Summary of the Dynamic Analysis of the Tax Reform Options Prepared for the President's Advisory Panel on Federal Tax Reform

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Executive Summary

Background:

The President's Advisory Panel on Federal Tax Reform (the Tax Panel) released its report on reform of the federal income tax on November 1, 2005. The Tax Panel unanimously recommended two reform options: the Simplified Income Tax (SIT) and the Growth and Investment Tax (GIT). Both reform options are a hybrid of an income and consumption based tax. The Tax Panel also extensively examined a Progressive Consumption Tax (PCT). The Treasury Department's Office of Tax Analysis (OTA) provided estimates to the Tax Panel on the likely growth effects for each of these plans.

Dynamic Analysis:

The Office of Tax Analysis (OTA) provided a dynamic analysis of the Tax Panel's tax reform options. This paper illustrates the value that dynamic analysis can provide to policy makers on the economic benefits of changes in tax policy. The dynamic analysis of the Tax Panel's tax reform options focused on the broad economic effects in both the long-run and over the transition path. The analysis also illustrated that the various tax reform options considered by the panel can be expected to have very different effects on economic growth depending primarily to what extent they reduce the tax on capital income.

Dynamic Analysis Models:

Three different models were used in the dynamic analysis to reflect the uncertainty inherent in modeling individual and firm behavior and the associated tax-induced behavioral responses. The use of several modeling frameworks allowed for a range of estimates to reflect the sensitivity of the results to underlying assumptions and modeling approaches. The models were structured to account for the effects of changes in the effective tax rate on capital and labor income and the consequent effects on economic growth.

The three models used by the Treasury Department for this dynamic analysis include:

(1) Solow growth model;
(2) Ramsey infinite horizon growth model; and
(3) Overlapping generations (OLG) life-cycle model.

Summary of Results:

All of these models predict that fundamental tax reform could lead to substantial increases in the national capital stock and national income. For example, the models suggest that the GIT recommended by the Tax Panel could lead to long-run increases in the capital stock ranging from 5.6 to 20.4 percent and long-run increases of national income ranging from 1.4 to 4.8 percent. The simulated growth effects of the SIT plan were considerably smaller, with long-run increases in the capital stock ranging from 0.9 to 2.3 percent and national income increases ranging from 0.2 to 0.9 percent. The growth effects of the PCT were the largest of the three plans, with long-run increases in the capital stock ranging from 8.0 to 27.9 percent, and long-run increases in national income ranging from 1.9 to 6.0 percent.

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1. Introduction

On January 7, 2005, President Bush established the President's Advisory Panel on Federal Tax Reform (hereafter, the Tax Panel). The President charged the Tax Panel to develop revenue neutral options to reform the federal income tax code that would: (1) reduce compliance and administrative costs relative to existing law; (2) maintain an appropriate level of progressivity and reflect the importance of homeownership and charitable giving; and (3) promote long-run economic growth and job creation. The Tax Panel released its report on November 1, 2005.[1]

The Tax Panel unanimously recommended two reform options: the Simplified Income Tax (SIT) and the Growth and Investment Tax (GIT). Both reform options are a hybrid of an income and consumption based tax. The Tax Panel also extensively examined a Progressive Consumption Tax (PCT).[2] The Office of Tax Analysis in the Department of the Treasury provided estimates to the Tax Panel on the likely growth effects for each of these three plans.

This paper provides background information on the models and assumptions used to simulate the economic growth effects of the tax reform options presented in the Tax Panel's report. The paper also illustrates the value that dynamic analysis can provide to policy makers on the economic benefits of changes in tax policy. The analysis focuses on the broad economic effects of the Tax Panel's proposed reform options in both the long-run and over the transition path. Importantly, all of the proposed reforms would increase national income or output, some by as much as 6.0 percent in the long-run.

The Treasury used variants of three standard economic growth models to estimate the macroeconomic responses associated with the Tax Panel's proposed reform options. The use of multiple models reflects the uncertainty that is inherent in modeling individual and firm behavior and the associated tax-induced behavioral responses. The use of several modeling frameworks allows for a broader range of potential economic effects in an effort to provide a reasonable range of results. These types of models have all been used to estimate the dynamic effects of policy changes in prior policy analyses, most notably in the 1997 Joint Committee on Taxation Symposium on Dynamic Scoring and in recent analyses by both the staffs of the Joint Committee on Taxation and the Congressional Budget Office.[3]

The three models used by the Treasury for this analysis include: (1) a Solow growth model (similar to that found in many macroeconomic textbooks); (2) a Ramsey infinite horizon growth model; and (3) an overlapping generations (OLG) life-cycle model. The models are structured to account for the effects of changes in the effective tax rate on capital and labor income and the consequent effects on economic growth. The models ignore cyclical disruptions in the

[1] The President's Advisory Panel on Federal Tax Reform (2005).
[2] See the tables in the appendix for important features of the reform plans.
[3] See Joint Committee on Taxation (1997) and Congressional Budget Office (2005).

employment of capital and labor, assuming instead that all resources in the economy are always fully employed. The Solow and Ramsey models are closed economy models that abstract from international capital flows and foreign trade. The OLG model includes a simple international sector. The OLG model also includes four production sectors, while the other two models have a single aggregate production sector.

The Solow growth model is the simplest of the three models. The model assumes the economy produces a single good, and the amount of production is determined by the amount of labor and capital supplied by the household sector. The amount of savings and investment in each period depend only on the prices in that period. The responsiveness of savings (capital supply) to the after-tax interest rate is determined by a parameter in the aggregate savings supply function. This parameter is chosen so that the savings response in the model falls within the range of empirical evidence. In this version of the model, labor supply does not vary with changes in the after-tax wage rate.

There are three main differences between the Solow growth model and the other two models. First, the Ramsey and the OLG models assume that consumers and firms incorporate future prices into their current period decisions of how much to save, work and produce. Second, the Ramsey and the OLG models assume that representative consumers maximize their level of well being by choosing consumption and leisure over their lifetimes subject to resource constraints on time and money. These individual level decisions determine the aggregate level of labor supply and savings in each year. Third, reform-induced asset price effects that result from the differential treatment of old and new capital under some tax reform proposals are allowed to affect economic decisions of firms and individuals in the Ramsey and OLG models.

The primary difference between the Ramsey and OLG models is that households in the Ramsey model have an infinite time horizon, that is, current households care about the well being of their children in the future just as much as their own welfare. In contrast, in the OLG model, households are assumed to live an economic life of 55 years corresponding to real-life ages from 21 to 75.[4] Thus, households in the OLG model do not respond to economic events beyond the end of their lifespan.

All of these models predict that fundamental tax reform could lead to substantial increases in the national capital stock and national income. For example, the models suggest that the GIT plan recommended by the Tax Panel could lead to long-run increases in the capital stock ranging from 5.6 to 20.4 percent and long-run increases of national income ranging from 1.4 to 4.8 percent. The simulated growth effects of the SIT plan were considerably smaller, with long-run increases in the capital stock ranging from 0.9 to 2.3 percent and national income increases ranging from 0.2 to 0.9 percent.

The remainder of the paper is organized as follows. Section 2 describes each of the three models used in this analysis in greater detail. Section 3 outlines the methodology employed in simulating the economic effects of the tax reform options. Section 4 describes and explains the results and the last section concludes.

[4] Concerns of parents about their children are incorporated through a bequest motive that specifies a target bequest that is independent of economic conditions beyond the time of death of the donor.

2. Model Descriptions

We used variants of three standard economic growth models.

2.1 Neoclassical Growth (Solow) Model

A representative competitive firm combines capital (K) and labor (L) inputs according to a standard Cobb-Douglas technology to produce the economy's single good,

$$Y_t = f(K,L) = AK_t^{\alpha} L_t^{1-\alpha}, \quad 0 < \alpha < 1, \tag{1}$$

where α is the parameter that determines capital's share of income and A is the scale parameter. The firm demands labor until the wage equals the marginal product of labor and demands capital until the interest rate equals the marginal product of capital.

In the Solow model, economic decisions depend only on current year economic conditions. In addition, households and firms do not optimize an objective function, such as individual well being or business profits. Instead it is a reduced form model; that is, aggregate labor supply and savings adjust to after-tax wage and interest rates assuming responses that are determined by fixed parameters that are set consistent with the consensus range of empirical estimates. In this version of the model, the labor supply elasticity with respect to the wage rate equals zero, at the bottom of this range.

The rate of savings out of national income (s_t) is determined by,

$$s_t = b\left[r_t\left(1-\tau_k\right)\right]^{\eta} \tag{2}$$

where r_t is the rate of return to capital at time t, τ_k is the tax rate on capital income, η is the savings rate elasticity with respect to the after-tax rate of return and b is a constant. The savings rate elasticity is set equal to 0.4.[5]

Government raises revenue through a flat rate labor tax and a flat rate capital tax rate set equal to the estimated marginal effective tax rate on capital income. Government revenues finance an exogenously specified time path of public services.

The Solow model easily conforms to empirical estimates of labor and saving supply elasticities. In contrast, in the Ramsey and OLG models the labor supply and savings behaviors are more complicated, can vary over time, and depend on parameters that can be difficult to estimate. However, aggregate savings elasticities are also extremely difficult to measure and the type of estimates used for this model are not invariant to policy or demographic changes.[6]

[5] See Engen, Gravelle and Smetters (1997) and Bernheim (2002) for reviews of the literature.
[6] See Elmendorf (1996) and Bernheim (2002) for further discussion.

2.2 Ramsey Growth Model

Production of the model's single good is determined by the amount of labor and capital supplied by the household sector using the same Cobb-Douglas production technology employed in the Solow model, where labor is hired until the wage equals the marginal product of labor. Firm investment decisions follow the "*q*" theory of investment, where firms invest as long as the increase in the stock market value of the firm exceeds the replacement cost of the asset. Specifically, firms invest until the marginal after-tax cost of the investment equals the value of the firm.

$$q_t = 1 - z\tau_t, \tag{3}$$

where *z* is the fraction of investment that is effectively expensed and τ is the firm's tax rate. This approach distinguishes between the tax treatment of old and new capital and incorporates asset price changes caused by changes in the tax regime.[7] However, the simple version of the Ramsey model used in the simulations does not include adjustment costs associated with expanding or contracting the stock of capital.

A representative consumer chooses levels of annual consumption (*C*) and leisure (*LE*) to maximize lifetime utility,

$$LU = \frac{1}{1-\frac{1}{\sigma}}\left(\sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^t\left(C_t^{1-1/\gamma} + \alpha_e LE_t^{1-1/\gamma}\right)^{\frac{1-\frac{1}{\sigma}}{1-\frac{1}{\gamma}}}\right), \tag{4}$$

subject to a lifetime budget constraint, where α_e is the preference parameter for leisure, σ is the intertemporal elasticity of substitution, γ is the intratemporal elasticity of substitution between consumption goods and leisure and ρ is the rate of time preference. As indicated in Table 1, the intertemporal substitution elasticity equals 0.25 and the intratemporal elasticity equals 0.8.

The government raises revenue through a flat rate labor tax and a capital tax that approximates the current and proscribed tax burden on old and new capital through a combination of a flat tax rate on capital income plus the portion of investment that is effectively expensed.[8] Government revenues finance an exogenously specified time path of public services, which are assumed to be separable from the consumption of other goods and services and leisure in the utility function.

The Ramsey model assumes that the representative consumer lives forever and has perfect foresight. While in actuality the economy is not populated by individuals with infinite life spans, an infinite planning horizon can be justified if consumers are members of families in which each generation cares as much about the well-being of future generations as it would about its own well-being for each period in the future. An important implication of the forward looking nature

[7] See Auerbach and Kotlikoff (1987) for further discussion of this approach.
[8] See Auerbach (1996) for further description of this method of approximating capital income taxation.

of consumers in the Ramsey model is that future fiscal policies, such as those used to achieve budget neutrality, affect current economic decisions made by consumers.

The structure of the Ramsey model implies that in the long-run the capital stock will always adjust sufficiently to keep the after-tax return to capital constant. This implies an infinitely elastic supply of savings in the long-run.

2.2 Overlapping Generations Model (OLG)

For the Tax Panel report analysis, the Treasury Department used the OLG model developed by Tax Policy Advisers, LLC.[9] An overview of the model follows, with important equations and further explanation provided in Appendix B. Firm behavior is modeled for each of the four production sectors – corporate, noncorporate, owner-occupied housing and rental housing; in the owner-occupied housing sector, home owners are treated as "firms" who produce housing and rent it to themselves, taking into account the tax advantages of home ownership. Similar to the previous two models, each production function takes the standard Cobb-Douglas form.

Firm managers choose the optimal levels of labor demand and investment to maximize the value of the firm, or profits, in each period. Investment in each sector is determined according to the "*q*" theory of investment modified to include adjustment costs, as firm managers explicitly calculate the time path of investment in response to a change in the tax structure as a function of the tax-induced change in "*q*", which denotes the ratio of the market value of capital assets to their replacement costs, taking into account convex costs of adjusting the level of investment from its steady state level. Differences in the level of depreciation allowances for tax purposes and economic depreciation are modeled explicitly, as is the value of the existing tax basis at any point in time. The debt to capital ratio is assumed to be fixed in each industry, and dividends in the corporate sector are assumed to be a fixed fraction of after-tax corporate earnings. The model assumes the traditional view of dividend taxes, which implies dividend taxes increase the cost of capital to firms.

The model has a conventional overlapping generations structure. All individuals in a given cohort are identical, with each living for 55 years, the last 10 of which are spent in retirement.[10] Each individual has perfect foresight and chooses consumption (and thus saving) to maximize lifetime utility – an aggregation of utility in each of the 55 periods of the lifecycle, discounted at a fixed rate of time preference that is common to all individuals – subject to a lifetime budget constraint that takes into account a hump-shaped age-wage profile, inheritances and a target bequest. Utility in each period, similar to the Ramsey model, is a CES function of leisure and an aggregate consumption good which is in turn an aggregation of four goods – a composite good produced by the corporate sector, a composite good produced by the non-corporate sector, owner-occupied housing and rental housing. The intertemporal elasticity of substitution equals

[9] See http://www.taxpolicyadvisers.com.

[10] An alternative approach would be to allow the retirement age to be endogenous so that individuals could come out of retirement and rejoin the work force in response to reform-induced changes in the after-tax wage. This potential labor supply response is precluded by assuming a fixed retirement age.

0.35 and the intratemporal substitution elasticity between goods and leisure equals 0.6.[11] These parameter values yield an aggregate labor supply elasticity that is lower than the value assumed in Altig *et al*. (2001) and Auerbach and Kotlikoff (1987). This labor supply elasticity is consistent with most of the empirical literature; it is, however, inconsistent with the relatively large labor supply elasticities found in the recent work of Prescott (2005) and Davis and Henreckson (2005).[12]

The model includes a simple characterization of the Social Security program. Government services are separable in the individual utility function and government debt is a constant fraction of GDP in the initial steady state. The government must finance an exogenously specified time path of public services and satisfy an annual budget constraint.[13] The tax instruments available to the government in the initial equilibrium include (1) a corporate income tax, (2) an individual income tax with a progressive wage income tax structure and a tax base that is adjusted for various exclusions, exemptions, deductions and credits, and (3) constant rate capital income taxes, applied at different average rates to interest income, dividends and capital gains.

Although the focus of the model is on the U.S. domestic economy, it includes a simple representation of international capital flows, which are assumed to respond to differences in after-tax rates of return in the U.S. and the "rest of the world" through a constant elasticity expression.[14] This approach represents a compromise between the standard closed economy approach and the alternative of a completely open economy in which international capital is perfectly mobile and the international return to capital is fixed. There is no international trade of goods in the current version of the model.

3. Framework for analysis

Each model is calibrated to replicate certain economic aggregates over the Administration's policy baseline over the 10-year budget window. In particular, the initial model tax rates on labor and capital income are set to match the respective average marginal effective tax rates under the Administration's policy baseline averaged over the budget window.[15] In the initial equilibrium, the economic growth rate equals the combined population growth rate and rate of

[11] See Elmendorf (1996), Engen, Gravelle, and Smetters (1997) and Altig *et al.* (2001) for discussion on the plausible range of values for these parameters.

[12] To be precise, the parameters yield a Frisch elasticity of labor supply, which measures the labor supply elasticity holding the marginal utility constant, equal to 0.48 which is consistent with the range of estimates reported in Browning, Hansen, and Heckman (1999).

[13] The model can also accommodate the issuance of debt as long as the ratio of government debt to GDP constant in the long run. Thus, the government is required to adjust revenues so that the debt issues do not grow at a faster rate than GDP.

[14] This elasticity is set equal to 0.2 in the base case, which implies that international capital flows are not very sensitive to differences in the after-tax rate of return in the U.S. compared to the rest of the world.

[15] The Administration's baseline assumes the current individual tax rates, including the special rates on dividends and capital gains would remain at 2005 levels and not increase as under current law. Also, the temporary patch on the individual Alternative Minimum Tax (AMT) would not be extended and the Administration's Lifetime Savings Accounts (LSAs) and Retirement Savings Accounts (RSAs) budget proposals would be enacted.

growth in technological change, both of which are held fixed over time.[16] The changes to the tax system are assumed to occur simultaneously and without anticipation by households or firms. As households and firms respond to the effect of the tax changes on after-tax wages and interest rates, savings and investment increase, the capital stock increases and labor supply changes. Eventually the economy returns to the original steady-state rate of growth, but at a different level of economic activity along the new growth path than the previous steady-state growth path. This implies that the percentage changes reported in Table 3 are changes in levels, not growth rates.

Table 1 shows the important behavioral parameter assumptions made for each model. The economic results discussed below are sensitive to these parameter values and it is common to include sensitivity analysis of changing certain parameter values in this type of research. We do not include sensitivity analysis in this paper for two reasons. First, previous research has generally demonstrated the extent to which each of the models used in this analysis are sensitive to parameter values.[17] Second, our use of multiple models for this analysis with our chosen parameter values already provides a certain amount of sensitivity analysis. The Solow growth model, with no labor response and a moderate savings response, represents the lower end of the likely behavioral responses, while the Ramsey model with its infinitely elastic savings response represents the upper end. The OLG model's savings response, with its target bequests, is generally in between these two models, and its labor supply substitution response is calibrated to be lower than the Ramsey model.[18]

Each of the plans has been estimated by the Treasury to be revenue neutral over the budget window compared to the Administration's policy baseline under conventional scoring procedures. The new average marginal tax rates on capital and labor income over the budget window that result from this standard revenue estimating analysis are then used to specify the initial tax parameters for the reformed tax system in the dynamic models. Table 2 lists the initial tax rates for the policy baseline and each of the reform options. Yet given the simplifying assumptions in the dynamic models as well as the embedded behavioral responses, there is no reason to expect that budget neutrality would be maintained for any particular year in the models by using these tax rates. There are numerous fiscal policy responses that could be adopted to meet the government's budget balance requirements throughout the period of reform.[19] The analysis in this report assumes that average and marginal tax rates are adjusted in each year to maintain a constant level of real government spending for each year after the reform.[20] This implies that each tax reform plan raises the same amount of revenue in each period within the models, even if the initial specifications for the plans imply different present values of revenues.

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[16] Note that this approach ignores the structural fiscal imbalance of the Social Security and Medicare systems, but this assumption seems appropriate in generating the likely independent effect of tax reform and is commonly used in this type of analysis.

[17] See Engen, Gravelle and Smetters (1997), Auerbach (1996) and Altig *et al.* (2001).

[18] The Frisch labor supply elasticity is approximately 0.5 in the OLG model and 0.7 in the Ramsey model. It is possible for the initial labor supply response to be stronger in the OLG model due to intergenerational redistribution.

[19] For example, tax rates could be held constant over the budget window and government debt could be increased or decreased during that time in order to maintain government spending at constant levels. The government budget would then need to be balanced in years outside of the budget window through either changing taxes or the level of government spending.

[20] In the Solow and Ramsey models average and marginal tax rates on wages and capital income are adjusted in each year to maintain a constant level of real government spending. In the OLG model only the average and marginal wage tax rates are adjusted in each year to maintain a constant level of real government spending.

The transition relief provided for existing capital at the time of reform is assumed to be financed by increasing tax rates temporarily in each transition year it is allowed. This implies that transition relief does not affect the steady-state estimates, although short-run economic results are affected as labor taxes increase in the short-run to pay for the transition relief. Previous work has noted the profound difference between the long-run economic effects of replacing an income tax with a consumption tax versus a wage tax, which can be thought of as a consumption tax with complete transition relief for existing capital.[21] The approach used in this paper, however, is consistent with the static revenue estimates where the revenue neutral tax rates over the budget window account for the revenue loss due to transition relief.

4. Macroeconomic Effects

4.1 Progressive Consumption Tax Plan

The Tax Panel's Progressive Consumption Tax (PCT) is a modified version of David Bradford's X-tax.[22] The plan is a bifurcated subtraction-method VAT where labor compensation is deducted at the business level and taxed at the individual level at progressive rates of 15, 25 and 35 percent. All business investment is expensed and interest is generally neither includible in nor deductible from the tax base.[23] To conform to the President's directive that tax reform recognize the importance of owner-occupied housing, the PCT includes a 15 percent nonrefundable capped tax credit for home mortgage interest payments.

The PCT is equivalent to a broad-based consumption tax imposed at a statutory rate of 35 percent that provides subsidies to debt-financed owner-occupied housing (through the 15 percent mortgage interest credit) and to the wages of lower income individuals.[24] In general, the primary distinction between income and consumption based taxes is that under an income tax the normal return to capital is taxed, while under a consumption tax the normal return to capital is not taxed.[25] In the case of the PCT, expensing of business investment implies a marginal effective tax rate equal to zero on the normal rate of return to business investment since the value of the upfront deduction just equals the present value of tax paid on the normal return to that investment. As shown in Table 2, the marginal effective tax rate on all investment under the PCT is a negative 3.7 percent due to the subsidy provided to owner-occupied housing.

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[21] See Auerbach and Kotlikoff (1987).

[22] See Bradford (1986).

[23] To maintain the economic effect of expensing for financial institutions, the cash flow treatment extends to financial transactions, that is, principal and interest inflows would be taxable and principal and interest outflows would be deductible.

[24] The PCT differs from a pure consumption base in other ways as it retains preferences for charitable giving and for employee compensation given in the form of employer provided health insurance, although in the latter case the preference is capped and smaller than under current law.

[25] Recent literature, for example, see Hubbard (2005), has emphasized that the return to capital is comprised of four components: (1) the normal return to waiting; (2) returns to market power, entrepreneurial skills or ideas (economic rents); (3) the return to risk-taking; and (4) returns that reflect good or bad luck. Only the first component is exempted from taxation under a consumption tax. The models used in this paper assume economic certainty and perfect competition, implying that the latter three components of the return to capital are not directly included in the models.

While the business cash flow tax effectively exempts the normal rate of return on new investments from taxation, it does impose a one-time tax on business capital existing at the time of reform to the extent that transition relief is not provided. The PCT includes transition relief for old capital equivalent to approximately $400 billion over the first four years following the enactment of tax reform.[26] The present value of the transitional depreciation deductions is approximately one-quarter of the present value of future depreciation deductions under current law, which implies that the vast majority of existing business capital faces a one-time tax.[27]

For each of our three models, Table 3 shows the effects of the PCT on selected economic aggregates. We expect that a switch to a consumption tax would lead to more saving and investment which would translate into higher levels of output and eventually into higher levels of consumption. Each of our three models obtains these qualitative results. In the long-run, for example, the capital stock compared to the baseline increases by 27.9 percent in the Ramsey model, 14.0 percent in the OLG model, and by 8.0 percent in the Solow model. This leads to an increase in national income (Net National Product) of 6.0 percent in the Ramsey model, 2.8 percent in the OLG model and by 1.9 percent in the Solow model, while consumption rises by 5.5 percent in the Ramsey model, 2.2 percent in the OLG model, and 1.9 percent in the Solow model.

These results are similar to other estimates of consumption tax reforms found in the literature.[28] For example, using an OLG model, Altig *et al.* (2001) estimated that an X-tax would lead to a 6.4 percent long-run increase in national income and a 21 percent increase in the capital stock.[29] Engen, Gravelle and Smetters (1997), using the same response parameters as in the Solow and Ramsey models in this paper, estimated that replacing a 20 percent flat income tax with a consumption tax would lead to an increase in national output of 2.3 percent in a Solow model and 6.8 percent in a Ramsey model. Our estimates are slightly lower than their responses primarily due to the lower initial tax burden on capital income under the policy baseline compared to their models.[30]

As indicated by these results, the quantitative results differ across the three models. In general, the effects of tax reform are largest in the Ramsey model, followed by the OLG model, and then

[26] Depreciation allowances for property placed in service before the reform would be phased out evenly over a period of 5 years. In the first year of reform, 80 percent of the previous law depreciation allowance would be allowed. In the second year this percentage would drop to 60 percent, then 40 percent in the third year, 20 percent in the fourth year and zero for the fifth year and following. Similar treatment is allowed for business interest payments and receipt and for home mortgage interest.

[27] Auerbach (1996) estimated that the present value of remaining depreciation deductions for existing nonresidential capital to be approximately one-half the value of these assets.

[28] These other estimates generally involve consumption taxes with clean bases. The lack of a clean base in the Tax Panel plans does lower the long-run output effects in the OLG model.

[29] Altig *et al.* (2001) do not examine the effect of including transition relief for their estimates of the X-tax, although they do consider allowing full continuation of depreciation allowances for existing assets under the Flat tax, where they model transition relief as a reduction in the business cash-flow rate. They find that transition relief reduces the long-run gain in national output under the Flat tax from 4.5 to 1.8 percent. Employing their methodology would reduce the long-run gains in output from our OLG and Ramsey models, but not to a great extent given that the level of transition relief provided under the panel plans is only about one-quarter the amount assumed in their paper.

[30] Engen, Gravelle and Smetters (1997) assumed a decline in the marginal effective tax rate on capital income of 20 percentage points. Under the PCT, the marginal effective tax rate on capital income falls by 17.6 percentage points.

by the Solow model. The Solow model generates smaller long-term results than the other two models because its saving response is smaller and labor supply is inelastic.

Changes in the accumulation of capital in the short-run generally follow the same pattern across models, but the magnitude of these changes vary widely. The Ramsey model generates larger short-run effects than the OLG model, while the Solow model generates significantly smaller short-run effects. The differences in the short-run effects generated by the OLG and the Ramsey model reflect the inclusion of adjustment costs in the OLG model but not in the Ramsey model, which slows the expansion of the capital stock, and the lower overall savings response in the OLG model.

The bigger difference, however, is between the OLG and Ramsey models, on one side, and the Solow model on the other. With respect to changes in national income, this difference primarily reflects labor supply effects, although the Solow model's relatively small savings elasticity also contributes to the smaller increase in output. In the Solow model, labor supply is assumed to be unaffected by tax changes. In contrast, short-run labor supply increases in both the OLG and Ramsey models. This increase reflects the intertemporal substitution of leisure caused by the increase in the after-tax rate of return. In the OLG model, the short-run increase in labor supply also reflects the shift in the tax burden from younger to older generations as a result of the reduction in taxation of the return to capital and the one-time tax on old capital. The tax on old capital reduces lifetime resources at the time of reform for older generations which leads these generations to decrease their consumption of leisure and other goods in response to the negative income effect.[31] The elimination of the tax on the normal rate of return to lifetime saving, which raises the after-tax return, induces younger generations to work more in order to take advantage of the higher rate of return (stated differently, the higher return they earn as a result of the intergenerational shift in the tax burden induces them to shift both consumption and leisure into the future). In both models, the increase in labor supply increases national income in the short run, but the increase in labor supply in the Ramsey model is larger. The larger labor supply response in the Ramsey model over the budget window relative to the OLG model is explained by the use of the flat labor tax system in the Ramsey model, which leads to a smaller increase in marginal tax rates than in the OLG model under the reform.

4.2 Growth and Investment Tax Plan

The Tax Panel did not recommend a complete replacement of the existing income tax system with a consumption tax. Instead the Tax Panel recommended the hybrid Growth and Investment Tax (GIT), which is similar to the PCT, but on top of the bifurcated VAT structure, interest, dividends and capital gains are subject to a 15 percent tax rate at the individual level. This allows for lower tax rates on business cash-flow and wages compared to the PCT. The plan also expands opportunities to save in tax-preferred accounts that are similar to the Administration's Lifetime Savings Accounts (LSAs) and Retirement Savings Accounts (RSAs) proposals, but with higher annual contribution limits. In particular, the plan would allow Save for Family accounts and Save for Retirement accounts. Each account would have an annual contribution limit of $10,000 in after-tax dollars, earnings would accumulate tax-free and qualified

[31] However, note that the retirement decision is exogenous, so retired workers do not re-enter the work force and as workers reach the models retirement age of 45 they are forced to retire.

withdrawals would be tax-free. Withdrawals from the Save for Retirement accounts could be made without penalty only at age 58 and older, or in the event of death or disability. Withdrawals from Save for Family accounts could be made without penalty at any time for qualified expenditures for health or medical costs, education or training expenses, purchases of a primary residence, and for taxpayers age 58 and older. In addition, $1,000 may be withdrawn annually from the Save for Family account for any purpose without penalty.[32]

The combination of the effects of the new savings accounts and the relatively low statutory tax rate on individual capital income implies that the marginal effective tax rate is only 4.8 percentage points higher under the GIT in relation to the PCT, and thus, we would expect the growth effects for the GIT to be almost as large as the PCT.[33]

This is confirmed by the results shown in Table 3. Again, moving to full expensing of business investment encourages growth in the capital stock, and hence national income over time, which is tempered slightly by the increase in taxation of capital income at the individual level. For example, the growth in the capital stock in the long-run equals 20.4, 9.8 and 5.8 percent in the Ramsey, OLG and Solow growth models, respectively, which is over 70 percent of the growth in the capital stock experienced under the PCT for each model. Similarly, the long run increase in national income under the GIT for each model is greater than 70 percent of the increase for the PCT, with increases of 4.8, 2.2 and 1.4 percent for the Ramsey, OLG and Solow growth models, respectively.

The explanations for the differences in the results across the models are similar to the explanations for the differences under the PCT. Savings responses in the Ramsey and OLG models are greater than in the Solow model, which leads to greater capital accumulation and output in the long-run in those models compared to the Solow model. In the short-run, the output responses are dominated by the labor response. It is unclear, however, whether labor supply should increase more under the GIT relative to the labor supply response under the PCT. Lower tax rates on labor income should increase labor supply through the substitution effect, but the increased taxation of capital income reduces the initial increase in the after-tax rate of return and thus the intertemporal substitution of leisure would be less important under the GIT compared to the PCT. In the Ramsey model, the initial labor supply response is slightly smaller under the GIT, but in the long-run as the after-tax rate of return returns to the steady-state level and the intertemporal effect disappears, the increase in labor supply is larger under the GIT. The initial labor supply responses in the OLG model are higher than under the PCT and nearly as high as in the Ramsey model. Long-run output gains in the Ramsey model are larger than the OLG model due to greater capital accumulation in the Ramsey model.

4.3 Simplified Income Tax Plan

The other Tax Panel recommendation is the Simplified Income Tax (SIT). The plan reduces the double taxation of corporate income by providing full dividend exclusion and 75 percent

[32] In contrast, the Administration's LSA/RSA proposal limits annual contributions to $5,000 and withdrawals from LSAs can be made for any purpose without penalty.

[33] Given the relatively high tax rate on labor income in the PCT, it is possible that implementing a low-rate capital income tax and reducing labor taxes could lead to an increase in output.

exclusion of capital gains on corporate stock. Other capital gains are taxed at ordinary rates. The top marginal rate for corporations falls to 31.5 percent and the top individual rate falls to 33 percent. The rate reductions are paid for by broadening the individual and business tax bases. As in the GIT, tax preferred saving opportunities are also expanded. A simplified system for depreciation allowances is also proposed; note that using the parameters suggested in the report would slow down the cost recovery for capital slightly. On net, the effective marginal tax rate on capital income falls by just under 2 percentage points compared to the baseline under the SIT and the corresponding dynamic effects are expected to be small.

Again, the results from Table 3 confirm the expectation that the SIT will have a relatively small effect on long-term capital deepening and economic growth. For example, the capital stock is only 2.3 percent higher in the long-run in the Ramsey model, 1.3 percent higher in the OLG model, and 0.9 percent higher in the Solow model. The growth in national income is only 0.3 percent in the Ramsey model and 0.2 percent in the Solow model.

The surprising result for the SIT is that long-run national income increases by 0.9 percent in OLG model. The OLG model is the only model that includes multiple production sectors and efficiency gains should occur as capital reallocates away from the noncorporate and housing sectors towards the corporate sector. This leads to an increase in the tax base which leads to lower marginal tax rates on labor income and an increase in labor supply. While it is not too surprising that the OLG results are larger than the Ramsey model for the SIT, the results are nonetheless surprisingly large.

5. Discussion and Conclusion

The Tax Panel was charged with developing options for reforming the current federal income tax system that are simple, fair and pro-growth. Tradeoffs are inherent in the design of a tax system as simple tax plans may not be considered fair, and options that are considered fair may be relatively inefficient. This paper examines the economic growth effects of three of the tax reform options discussed by the Tax Panel. We find that the options that move the tax system in the direction of a consumption tax base the most, the PCT and GIT, provide the greatest increases in capital accumulation and national output. This result is consistent with a wide body of previous research.[34]

The models and methodology used in this analysis are commonly applied in other research on the macroeconomic effects of tax reform. Nevertheless, the models face certain limitations, which we will now discuss briefly. First, the Ramsey and Solow growth models do not account for international trade or capital flows and, as a result, could overestimate or underestimate the investment response to tax reform. The lack of an international sector in these models generally is due to the complexity in properly modeling this sector.

The OLG model does include a simple representation of international capital flow sensitivity to after-tax rates of return, but this inclusion has small effects on the overall results. For the PCT and GIT, the after-tax rate of return to capital in the U.S. increases in the short-run, leading to an increase in net foreign capital flows into the U.S. relative to the baseline. Then as capital

[34] For example, see Joint Committee on Taxation (1997) and Altig *et al.* (2001).

deepening occurs the after-tax return to capital falls and in the long-run net foreign capital flows into the U.S. decrease relative to the baseline. Indeed, including international capital flows mitigates the long-run increase in investment and net national product that result from implementation of the reforms as suggested in the closed economy version of the OLG model.

Second, the OLG and Ramsey models generally are frictionless, that is, it is costless to change capital and labor supply in any particular period, easier than is likely in the real world. The OLG model accounts for this on the investment side by including adjustment costs to changing investment levels, which helps to moderate the initial savings response in the model. The Ramsey model does not include adjustment costs and thus short-run investment levels in this model are likely to be higher than would realistically occur. Likewise, the initial labor supply response in both models may be overstated since adjustment costs are ignored.

Third, these models do not account for short-term disruptions in the economy that may occur when moving to a new tax system. Nor do these models account for changes in monetary policy. However, the focus of these models is on long-term growth and how changes in the tax system could enhance economic growth and thus abstracting from short-term cyclical effects is useful for clarifying this analysis.

Fourth, none of these models directly account for risk. Since a portion of savings is precautionary and not very sensitive to changes in the interest rate, the implied elasticity of savings with respect to the after-tax interest rate in the certainty Ramsey and OLG models is likely to be higher than in a model that incorporate risk.[35] To partially offset the lack of risk in these models, the intertemporal elasticity of substitution used in the models was chosen to reflect values near the lower range of the empirical estimates. Also, in the OLG model, households have a simple target bequest motive that also tends to mitigate the savings response.[36]

Finally, these models do not capture all of the gains likely to occur from reforming the tax system, such as: (1) the reduced costs of compliance and administration that would come from a simpler tax system; (2) the efficiency gains resulting from reducing the tax distortion between debt and equity financing; (3) with the exception of the OLG model, the models do not account for any gains resulting from a more efficient allocation of capital across production sectors; and (4) the efficiency gains from reducing current law distortions in the taxation of different types of capital, such as equipment and structures.

[35] This would only affect the short-run response in the Ramsey model.

[36] It is worth noting, however, that Hurst *et al*. (2005) recently estimated that precautionary savings account for less than 10 percent of total wealth.

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Table 1

Base Case Parameters

Model	Ramsey	OLG	Solow
Savings rate elasticity	n/a	n/a	0.40
Uncompensated price elasticity of labor supply	n/a	n/a	0.00
Intertemporal substitution elasticity	0.25	0.35	n/a
Intratemporal substitution elasticity (between leisure and goods)	0.80	0.60	n/a
Factor substitution elasticity (between capital and labor)	1.00	1.00	1.00
Adjustment costs	no	yes	no
Capital income share	0.25	0.25	0.25
Other Key Initial Variables			
Capital/output ratio	3.40	2.82	2.98

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Table 2

Tax Parameters

	Policy Baseline	PCT	GIT	SIT
Average Marginal Tax Rate on Labor Income	0.240	0.264	0.235	0.240
Average Tax Rate on Labor Income	0.130	0.147	0.133	0.128
Marginal Effective Tax Rate on Capital Income	0.139	-0.037	0.011	0.120

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Table 3

Macroeconomic Effects of Tax Reform Options: Percentage Change from Initial Steady-State for Selected Variables and Years After Reform

	PCT			GIT			SIT		
	Budget Window*	Year 20	Long-run	Budget Window*	Year 20	Long-run	Budget Window*	Year 20	Long-run
National Income									
Ramsey Growth Model	2.3%	4.5%	6.0%	1.9%	3.7%	4.8%	0.0%	0.2%	0.3%
OLG Model	0.7%	2.6%	2.8%	1.5%	2.1%	2.2%	0.4%	0.8%	0.9%
Solow Growth Model	0.2%	0.6%	1.9%	0.1%	0.4%	1.4%	0.0%	0.1%	0.2%
Capital Stock									
Ramsey Growth Model	5.1%	16.7%	27.9%	3.7%	12.1%	20.4%	0.4%	1.4%	2.3%
OLG Model	3.3%	9.8%	14.0%	3.0%	7.5%	9.8%	0.1%	0.7%	1.3%
Solow Growth Model	0.7%	2.5%	8.0%	0.5%	1.8%	5.8%	0.1%	0.3%	0.9%
Labor Supply									
Ramsey Growth Model	1.4%	0.7%	-0.5%	1.3%	1.0%	0.1%	-0.1%	-0.2%	-0.3%
OLG Model	0.5%	1.0%	0.9%	1.2%	0.7%	0.6%	0.3%	0.4%	0.4%
Solow Growth Model	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Consumption									
Ramsey Growth Model	-2.7%	2.0%	5.6%	-1.6%	2.0%	4.8%	-0.4%	-0.1%	0.2%
OLG Model	-1.7%	1.3%	2.2%	-0.4%	1.3%	1.8%	0.4%	0.8%	1.0%
Solow Growth Model	-0.4%	0.2%	1.9%	-0.3%	0.1%	1.4%	-0.1%	0.0%	0.2%
Net Investment									
Ramsey Growth Model	59.1%	43.7%	27.9%	42.6%	31.9%	20.4%	4.8%	3.4%	2.3%
OLG Model	30.7%	22.4%	15.2%	26.2%	15.3%	10.7%	1.3%	2.1%	1.3%
Solow Growth Model	7.9%	7.9%	8.0%	5.7%	5.7%	5.8%	0.9%	0.9%	0.9%

*Average percentage change over the first ten years after reform enacted.

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Appendix A: Summary of the Tax Panel Reform Options

Table A.1. Summary of Tax Panel Reform Plans for Businesses

Provisions	Simplified Income Tax Plan (SIT)	Growth and Investment Tax Plan (GIT)	Progressive Consumption Tax Plan (PCT)
Small Business			
Tax rates	Taxed at individual rates	Sole proprietorships taxed at individual rates; other small businesses taxed at 30%	Sole proprietorships taxed at individual rates; other small businesses taxed at 35%
Recordkeeping	Simplified cash-basis accounting	Business cash flow tax	
Investment	Expensing (exception for land and buildings under the SIT)		
Large Business			
Tax rates	31.5%	30%	35%
Investment	Simplified accelerated depreciation	Expensing for all new investment	
Interest paid	Deductible	Not deductible (except for financial institutions)	
Interest received	Taxable	Not taxable (except for financial institutions)	
International tax system	Territorial tax system	Destination-basis (border tax adjustments)	
Corporate AMT	Repealed		

Source: The President's Advisory Panel on Federal Tax Reform (2005)

Table A.2. Summary of Tax Panel Reform Plans for Households

Provisions	Simplified Income Tax Plan (SIT)	Growth and Investment Tax Plan (GIT)	Progressive Consumption Tax Plan (PCT)
Households and Families			
Tax rates	15%, 25%, 30% and 33%	15%, 25% and 30%	15%, 25%, and 35%
Alternative Minimum Tax	Repealed		
Personal Exemption	Replaced with Family Credit available to all taxpayers: $3,300 credit for married couples, $2,800 credit for unmarried taxpayers with child, $1,650 credit for unmarried taxpayers, $1,150 credit for dependent taxpayers; additional $1,500 credit for each child and $500 credit for each other dependent		
Standard Deduction			
Child Tax Credit			
Earned income tax credit	Replaced with Work Credit (and coordinated with the Family Credit); maximum credit for working family with one child is $3,570; with two or more children is $5,800		
Marriage penalty	Reduced; tax brackets and most other tax parameters for couples are double those of individuals		
Other Major Credits and Deductions			
Home mortgage interest	Home Credit equal to 15% of mortgage interest paid; available to all taxpayers; mortgage limited to average regional price of housing (limits ranging from about $227,000 to $412,000)		
Charitable giving	Deduction available to all taxpayers (who give more than 1% of income); rules to address valuation abuses		
Health insurance	All taxpayers may purchase health insurance with pre-tax dollars, up to the amount of the average premium (estimated to be $5,000 for an individual and $11,500 for a family); the limits for the PCT plan are lower, $8,400 for a family		
State and local taxes	Not deductible		
Education	Taxpayers can claim Family Credit for some full-time students, simplified savings plans		
Individual Savings and Retirement			
Defined contribution plans	Consolidated into Save at Work plans that have simple rules and use current-law 401(k) contribution limits; AutoSave features point working in a pro-saving direction (GIT and PCT plans would make Save at Work accounts "prepaid" or Roth-style)		
Defined benefit plans	No change		
Retirement savings plans	Replaced with Save for Retirement accounts ($10,000 annual limit) available to all taxpayers		All savings exempt from tax
Education savings plans	Replaced with Save for Family accounts ($10,000 annual limit); would cover education, medical, new home costs and retirement saving needs; available to all taxpayers; refundable Saver's Credit available to low-income taxpayers		All savings exempt from tax
Health savings plans			All savings exempt from tax
Dividends received	Exclude 100% of dividends of U.S. companies paid out of domestic earnings	Taxed at 15% rate	All savings exempt from tax
Capital gains received	Exclude 75% of corporate capital gains from U.S. companies, other capital gains taxed at ordinary rates	Taxed at 15% rate	All savings exempt from tax
Interest received (other than tax exempt municipal bonds)	Taxed at ordinary income tax rates	Taxed at 15% rate	All savings exempt from tax
Social Security benefits	Replaces three-tiered structure with a simple deduction. Married taxpayers with less than $44,000 in income $22,000 if single) pay no tax on Social Security benefits; fixes marriage penalty; indexed for inflation		

Source: The President's Advisory Panel on Federal Tax Reform (2005)

Appendix B: Description of the Tax Policy Advisers OLG Model

The model has four production sectors – owner-occupied housing, rental housing, non-corporate non-housing goods and services, and a corporate non-housing goods and services sector. The time path of investment demands in all three sectors is modeled explicitly, taking into account capital stock adjustment costs. On the consumption side, the current tax advantage of owner-occupied housing relative to other assets is taken into account in modeling the demands for the four goods. This section outlines the basic structure of the model, which combines various features from similar and well-known models constructed by Auerbach and Kotlikoff (1987), Goulder and Summers (1989), Goulder (1989), Keuschnigg (1990) and Fullerton and Rogers (1993), with the time path of investment in each production sector calculated to maximize firm value in the presence of convex (quadratic) adjustment costs, following Hayashi (1982). The full details of the model are provided in Diamond and Zodrow (2005).

The Corporate and Non-Corporate Non-Housing Production Sector

In each period *s*, firms in the corporate and non-corporate production sectors produce output (X_s), which includes all non-housing goods and services, using capital K_s^X and labor L_s^X using a CES production function with an elasticity of substitution in production σ_X and a capital share parameter a_X. Firms are assumed to choose the time path of investment to maximize the present value of firm profits or, equivalently, maximize firm value V_X, net of all taxes. Total taxes in the corporate and non-corporate production sectors in period *s*, are

$$T_s^X = \tau_{bs}^X \left[p_s^X X_s - w_s L_s^X - f_{FT} I_s^X - \Phi_s^X I_s^X - f_{IT} i_s B_s^X - f_{IT} \delta_\tau^X K_{\tau s}^X \right] + (1-\tau_{bs}^X)\tau_{ps}^X K_s^X ,$$

where τ_{bs}^X is the tax rate on business income in sector X, p_s^X is the price of the good in sector X, w_s is the wage rate, I_s^X is gross investment, Φ_s^X are (deductible) adjustment costs per unit of investment, i_s is the before-tax interest rate, B_s^X is total indebtedness, $\delta_{\tau s}^X$ is depreciation for tax purposes, $K_{\tau s}^X$ is the remaining tax basis of the capital stock, τ_{ps}^X is the property tax rate in sector X, with property taxes assumed to be fully deductible against the business income tax, and f_{IT} (f_{FT}) is one under the income tax (consumption tax) and zero otherwise.[37] Following Goulder and Summers (1989) and Cummins, Hassett and Hubbard (1994), the adjustment cost function per unit of investment is assumed to be a quadratic function of gross investment per unit of capital

$$\Phi_s\left(\frac{I_s^X}{K_s^X}\right) = \frac{p_s^X(\beta^X/2)(I_s^X/K_s^X - \mu^X)^2}{I_s^X/K_s^X}$$

[37] That is, depreciation and interest expense are deductible under an income tax, while expensing is allowed under a consumption tax with no interest deductions. The property tax on businesses is treated as a tax on capital rather than a benefit tax (Muthitacharoen and Zodrow, forthcoming).

where β^X is the parameter that determines the level of adjustment costs and μ^X is set so that adjustment costs are zero in the steady state.

Assuming firms do not make any financial investments, total net cash receipts, including net new bonds issued B_s^X and net new shares issued (new equity investment in the non-corporate sector) VN_s^X, must either be used to finance new investments (including adjustment costs) or distributed to shareholders

$$[p_s^X X_s - w_s L_s^X - i_s B_s^X] - T_s^X + BN_s^X + VN_s^X = I_s^X \left(1 + \Phi_s^X\right) + DIV_s^X ,$$

where DIV_s^X is the dividend payout in sector X. Each firm is assumed to maintain a fixed debt/asset ratio b^X and pay out a constant fraction of earnings after taxes and depreciation (the non-corporate firm distributes all net income) in each period. This implies that new investments in the corporate sector are financed with debt and new share issues if retained earnings do not supply enough equity to finance the desired level of investment. New investments in the non-corporate sector are financed with debt and new equity investments since there are no retained earnings in this sector.

The model assumes individual level arbitrage, which implies that the after-tax return to bonds must equal the after-tax return received by the owners of the firm, or

$$\left(1-\tau_{bs}^X\right) i_s = \frac{\left(1-\tau_{ds}\right) DIV_s^X + \left(1-\tau_{gs}\right)\left(V_{s+1}^X - V_s^X - VN_s^X\right)}{V_s^X},$$

where τ_{is} is the average marginal personal income tax rate on interest income, τ_{ds} is the average marginal tax rate on dividends, τ_{gs} is the average effective annual accrual tax rate on capital gains $\left(V_{s+1}^X - V_s^X - VN_s^X\right)$. Solving this expression for V_s^X, subject to the transversality condition requiring a finite value of the firm, yields

$$V_s^X = \sum_{u=s}^{\infty} \frac{\left[\left(1-\tau_{du}\right)/\left(1-\tau_{gu}\right)\right] DIV_u^X - VN_u^X}{\prod_{v=s}^{u}\left[1+(1-\tau_{iu})i_u/(1-\tau_{gu})\right]},$$

That is, the value of the firm in the composite good sector equals the present value of all future net distributions to the owners of the firm. The time path of investment that maximizes this expression in the presence of adjustment costs is

$$\frac{I_s^X}{K_s^X} = \frac{q_{s+1}^X - 1 + b^X + f_{FT}\Omega_s^X \tau_{bs} + f_{IT} Z_{s+1}^X}{\mathrm{p_s}\beta^X\left(1-\tau_{bs}\Omega_s^X\right)},$$

where q_{s+1}^X is shadow price of additional capital (commonly referred to as 'marginal q' which equals the ratio of the market value of a marginal unit of capital to its replacement cost), Ω_s^X is a weighted average of the dividend and capital gains tax rates divided by one minus the capital gains tax rate, and Z_{s+1}^X is the tax savings from accelerated depreciation allowances on future investments.

The relationship between 'marginal q' and 'average q' (denoted as Q_s^X) is

$$q_s^X = \frac{V_s^X - X_s^X}{K_s^X} = Q_s^X - \frac{X_s^X}{K_s^X}$$

where X_s^X is the value of future depreciation deductions on the existing stock of capital used in the production of thee good in sector X.

The Owner-Occupied and Rental Housing Production Sectors

Housing is produced in the owner-occupied and rental housing production sectors where, following Goulder and Summers (1989) and Goulder (1989), rental housing is produced by non-corporate landlords and owner-occupied housing is produced by the owners. The technology used in the production of rental housing (R_s) and owner-occupied housing (O_s) is assumed to be identical – capital and labor combined in a CES production function with an elasticity of substitution in production of σ_H and a capital share parameter of a_H .[38] Landlords and owner-occupiers are also are assumed to choose time paths of investment to maximize the equivalent of firm value, net of total taxes.

In the case of the rental housing sector, the firm is modeled as a non-corporate firm. This implies that landlords are taxed at the individual level, so total taxes paid are

$$T_s^R = \tau_{bs}^R \left[p_s^R R_s - w_s L_s^R - f_{FT} I_s^R - \Phi_s^R I_s^R - f_{IT} i_s B_s^R - mK_s^R - f_{IT} \delta_\tau^R K_{\tau s}^R \right] + (1 - \tau_{bs}^R) \tau_{ps}^R K_s^R,$$

where τ_{bs}^R is the average marginal tax rate applied to rental housing income,[39] m is annual maintenance expenditures per unit of rental housing capital, and the definitions of all other variables are analogous to those in the composite good production sector. Solving the cash flow equation in the rental housing sector for after-tax rents received by landlords S_s^R yields

[38] Thus, the producer prices of rental and owner-occupied housing services are identical. However, rental and owner-occupied housing services are not perfect substitutes, so that the mix of rental and owner-occupied housing services changes along the transition path to a new equilibrium.

[39] The tax rate on rental housing income is a weighted average of the non-corporate tax rate on landlord profits and the corporate tax rate. The weight is determined by the share of rental housing produced in the corporate sector, which is equal to 10 percent.

$$S_s^R = p_s^R F_s^R(\cdot) - w_s L_s^R - i_s B_s^R - mK_s^R - T_s^R + BN_s^R + E_s^R - I_s^R(1+\Phi_s^R),$$

where E_s^R is net new equity invested by landlords in the rental housing sector. Individual arbitrage in this case implies

$$(1-\tau_{is})i_s = \frac{S_s^R + (1-\tau_{gs})(V_{s+1}^R - V_s^R - E_s^R)}{V_s^R}$$

which can be solved for the value of the rental housing firm

$$V_s^R = \sum_{u=s}^{\infty} \frac{\left[1/(1-\tau_{gu})\right] S_s^R - E_s^R}{\prod_{v=s}^{u}\left[1+(1-\tau_{iu})i_s/(1-\tau_{gu})\right]}.$$

The time path of investment that maximizes this expression in the presence of adjustment costs is

$$\frac{I_s^R}{K_s^R} = \frac{q_{s+1}^R - \Omega_s^R + b^R\Omega_s^R + f_{FT}\Omega_s^R\tau_{bs}^R + f_{IT}Z_{s+1}^R}{\mathrm{p}_s\Omega_s^R\beta^R(1-\tau_{bs}^R)}.$$

The expression for relationship between 'marginal q' and 'average q' in the rental housing sector is analogous to that in the composite good sector.

By comparison, in the owner-occupied housing sector, since imputed rents are untaxed and maintenance expenditures are not deductible while mortgage interest and property taxes are deductible, total taxes are

$$T_s^O = -z_s\tau_{is}i_s B_s^O + (1-z_s\tau_{is})\tau_{ps}^O K_s^O,$$

where z_s is the fraction of individuals who are itemizers. The flow of (untaxed) imputed rents to owner-occupiers is

$$S_s^O = p_s^O F_s^O - w_s L_s^O - i_s B_s^O - T_s^O - mK_s^O + BN_s^O + E_s^O - I_s^O(1+\Phi_s^O)$$

The expressions for individual level arbitrage and firm value are analogous to those in the rental housing sector, and investment in the owner-occupied sector is

$$\frac{I_s^O}{K_s^O} = \frac{q_{s+1}^O - \Omega_s^O + b^O\Omega_s^O}{\mathrm{p}_s\Omega_s^O\beta^O}.$$

The expression for relationship between 'marginal q' and 'average q' in the owner-occupied housing sector is analogous to that in the composite good sector.

Individual Behavior

On the individual side, the model has a dynamic overlapping generations framework with fifty-five generations alive at each point in time. There is a representative individual for each generation, who has an economic life span (which begins upon entry into the work force) of fifty-five years, with the first forty-five of those years spent working, and the last ten spent in retirement. Individual tastes are identical so that differences in behavior across generations are due solely to differences in lifetime budget constraints. An individual accumulates assets from the time of "economic birth" that are used to finance both consumption over the life cycle, especially during the retirement period, and the making of bequests. The model follows Fullerton and Rogers (1993) in including a relatively primitive "target model" of bequests, with the real values of bequests assumed to be fixed and thus unaffected by changes in economic conditions, including changes in income.

At any point in time *s*, the consumer maximizes rest-of-life utility LU_s subject to a lifetime budget constraint that requires the present value of lifetime wealth including inheritances to equal the present value of lifetime consumption including bequests. In particular, an individual of age *a* at time *s* = *t* chooses the time path of consumption of an aggregate consumption good and leisure in each period *s* to maximize rest-of-life utility

$$LU_s = \frac{\sigma}{\sigma - 1} \sum_{s=t}^{t+54-a} \frac{U_s(a)^{\left(1-\frac{1}{\sigma}\right)}}{(1+\rho)^{s-t}},$$

where σ is the intertemporal elasticity of substitution, ρ is the pure rate of time preference, and $U_s(a)$ is assumed to be a CES function of consumption of the aggregate consumption good and leisure in period *s* with an intratemporal elasticity of ε and a leisure share parameter of a_E. The aggregate consumption good is modeled as a CES function of the composite good and aggregate housing services (including a minimum purchase requirement for both goods), with aggregate housing services in turn modeled as CES function of owner-occupied and rental housing services. In addition, as described in detail in Diamond and Zodrow (2005), the model includes a simple social security system, government purchases of the composite good, transfer payments, a hump-backed wage profile over the life cycle, a progressive tax on wage income, and constant average marginal tax rates applied to interest income, dividends, and capital gains. The progressive labor tax uses a quadratic approximation to average and marginal tax rates similar to the method used by Auerbach and Kotlikoff (1987).

International capital flows

Although the focus of the model is on the U.S. domestic economy, it includes a simple representation of international capital flows, which are assumed to respond to differences in after-tax rates of return in the US and the "rest of the world." This approach represents a compromise between the standard closed economy approach and the alternative of a completely open economy in which international capital is perfectly mobile and the international return to

capital is fixed. Following Goulder, Shoven and Whalley (1983), capital imports (or exports) in period s are governed by the constant elasticity expression

$$\frac{K^W - K_s^F}{K^W} = \left(\frac{r_s^{US}}{r^W} \right)^{\varepsilon\kappa},$$

where K^W is the fixed rest-of-the-world capital stock,[40] r^W is the fixed rest-of-the-world return to capital, r_s^{US} is the return after taxes to capital in the US (given the fixed debt-asset ratio of b), K_s^F is foreign exports of capital to the US in period s, and $\varepsilon\kappa$ is a constant (positive) elasticity that determines the extent of international capital flows in the model. Thus, foreign exports of capital to the US are

$$K_s^F = K^W \left[1 - \left(\frac{r^W}{r_s^{US}} \right)^{\varepsilon\kappa} \right].$$

For example, if $r_s^{US} > r^W$ as a result of the reform, then the US has positive capital imports in period s $(K_s^F > 0)$. There is no international trade in goods or services in the current version of the model.

Market Equilibrium

All markets are assumed to be perfectly competitive. Market equilibrium in the model requires that total consumer demand, obtained by aggregating the demands of each of the 55 generations alive at any point in time, must equal aggregate supply in each of the four production sectors. In addition, factor demands must equal factor supplies in the labor and capital markets, the total amounts of debt and equity held as individual wealth must equal firm stocks of debt and equity, the government is allowed to finance government spending with tax revenues and government bonds as long as the debt to GDP ratio is constant in the long run, and both individual and firm expectations regarding the time paths of future prices must be satisfied in equilibrium.

[40] Note that K^W is fixed within a period, but must increase between each period at a rate equal to the growth rate of the US economy so that a long run equilibrium can be attained.