CHAPTER 10

Taxation, Efficiency and Economic Growth

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Abstract

In this chapter we present a dynamic general equilibrium methodology for evaluating alternative proposals for tax reform. We illustrate this methodology by comparing alternative proposals that would remove barriers to efficient allocation of capital and labor inputs. These proposals are based on two broad approaches to reform: (i) Remove discrepancies in the tax treatment of different categories of income and (ii) shift the tax base from income to consumption. To illustrate our methodology we construct a dynamic general equilibrium model of the US economy. An intertemporal price system clears markets for outputs of consumption and investment, and inputs of capital and labor services. This price system links the past and the future through markets for investment goods and capital services. The government sector is coupled to the commodity markets through the tax system. We identify Efficient Taxation of Income as the most effective approach to tax reform. This involves equalizing tax burdens on business and household assets, especially owner-occupied housing. The graduated tax on labor income would be replaced by a proportional tax and equity would be preserved by different tax rates on capital and labor incomes. Another effective approach would be to substitute a proportional National Retail Sales Tax for the existing income tax, but this would involve a serious loss in equity.

Keywords

Dynamic general equilibrium, tax reform, corporate taxation, individual taxation, efficiency, progressivity

JEL classification codes

C01, C68, D58, D61, D90, E6, H21

10.1 INTRODUCTION

In June 2001, President George W. Bush signed the Economic Growth and Tax Relief and Reconciliation Act into law, initiating a multiyear program of reductions in taxes on individual income. In January 2003, President Bush approved the Jobs and Growth Tax Relief Reconciliation Act of 2003, substantially cutting taxes on business income. The tax legislation of 2001 and 2003 has led to major declines in federal revenue. In January 2005, President Bush convened the President's Advisory Panel on Federal Tax Reform.

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The Panel presented its report, *Simple, Fair, and Pro-Growth: proposals to Fix America's Tax System*, in November 2005.

The proposals of President Bush's Advisory Panel did not lead to further legislation. In February 2010, President Barack Obama established the National Commission on Fiscal Responsibility and Reform. The purpose of this Commission was "… to improve the fiscal situation in the medium term and to achieve fiscal sustainability in the long run."[1] These objectives were to be attained through reductions in government expenditures and increases in government revenues. The Commission's report, *The Moment of Truth*,[2] was released on 1 December 2010.

The National Commission's proposed tax reform would eliminate almost all "tax expenditures." These are provisions of tax law that provide relief from taxation for specific categories of transactions. Part of the increased government revenue would reduce the federal deficit and the remainder would reduce tax rates for individual and corporate income. On 17 December 2010, one week after the release of the National Commission's final report, President Obama signed into law the Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010. This had the effect of extending the Bush tax cuts, scheduled to expire or "sunset" in 2010, for an additional two years.[3]

In this chapter we model the impact of tax reforms that would remove the barriers to efficient allocation of capital and labor. These barriers arise from disparities in the tax treatment of different forms of income. The centerpiece of the Bush Administration's 2003 tax cuts on business income was the reduction of taxes on dividend income at the individual level. This helped to mitigate one of the most glaring deficiencies of the US tax system, i.e. double taxation of corporate income.

In the US, as in most countries, corporate income is taxed (i) through the corporate income tax and (ii) through individual taxes on corporate distributions, such as dividends.

This leads to a disparity with the taxation of non-corporate income, which is taxed only at the individual level. President Bush's Advisory Panel[4] identified substantial differences between the tax treatment of corporate and non-corporate income that remained after the 2003 tax cuts.

The Bush Administration's tax legislation in 2001 and 2003 failed to address a second major barrier to efficient capital allocation. This is the exclusion of owner-occupied

1 President's Advisory Panel on Tax Reform (2005). See: http://www.fiscalcommission.gov/.

2 National Commission on Fiscal Responsibility and Reform (2010). See: http://www.fiscalcommission.gov/sites/fiscalcommission.gov/files/documents/TheMomentofTruth12_1_2010.pdf.

3 A comprehensive review of proposals for tax reform, including the proposals of the Advisory Panel and the National Commission, is presented by the Tax Policy Center (2012). See: http://www.taxpolicycenter.org/taxtopics/Tax_Reform_Proposals.cfm.

4 President's Advisory Panel on Tax Reform (2005, Figure 5.5, p. 71).

housing from the tax base. While income for non-corporate business is taxed at the individual level and corporate income is taxed at both corporate and individual levels, income from owner-occupied housing is not taxed at either level.

In Jorgenson and Yun (2005) we have shown that allowing owner-occupied housing to remain untaxed would sacrifice most of the gains in economic efficiency from tax reform. President Bush's instructions to the Advisory Panel on Tax Reform included "preservation of incentives for home ownership" — language intended to preserve the tax-free status of owner-occupied housing. Unfortunately, President Bush's instructions nullified most of the potential gains from tax reform at the outset.

In Jorgenson and Yun (2001) we have shown that progressivity of labor income taxation is another major source of inefficiency in the US tax system. This produces marginal tax rates on labor income that are far in excess of average tax rates. A high marginal tax rate results in a large wedge between the wages and salaries paid by employers and those received by households. A proportional tax on labor income would equalize marginal and average tax rates, and would sharply curtail the losses in economic efficiency due to high marginal rates.

An important challenge for tax reform is to eliminate the barriers to efficient capital allocation arising from "double" taxation of assets held in the corporate sector and the exclusion of owner-occupied housing from the tax base. A drastic, but effective, way of meeting this challenge is to shift the tax base from income to consumption. This would remove new investments from the tax base and add revenue from a consumption tax. As investments grow, taxation of income from capital would gradually be eliminated.

During the 1990s, the Committee on Ways and Means of the US House of Representatives held extensive hearings on proposals to shift the federal tax base from income to consumption. The proposals included replacing individual and corporate income taxes by one of three alternative consumption taxes — a European-style value-added tax, the Flat Tax proposed by Robert Hall and Alvin Rabushka (Hall and Rabushka, 1983, 1995), and a National Retail Sales Tax (NRST).

All three approaches to a consumption tax were considered by President Bush's Advisory Panel before settling on the Growth and Investment Tax Plan. This Plan is closely modeled on David Bradford's (Bradford, 2004) X-Tax — an approach to consumption taxation similar to the Hall—Rabushka Flat Tax. Bradford's X-Tax preserves the basic structure of the Flat Tax, described in more detail below, but would add a progressive tax on consumption.

A less drastic approach to removing barriers to efficient allocation of capital and labor inputs is to reform the existing income tax system. President Bush's Advisory Panel presented a Simplified Income Tax Plan that would eliminate double taxation of corporate income. Although the corporate income tax would remain, distributions of income subject to the tax, such as dividends, would be exempt from the individual income tax.

Integration of the individual and corporate income tax systems was proposed by the US Department of the Treasury (1992) in a widely cited study, *Integration of the Individual and Corporate Income Tax Systems: Taxing Business Income Once*. President Bush's Advisory Panel[5] pointed out that the Simplified Income Tax Plan would have only a modest impact on disparities in the tax treatment of corporate and non-corporate income. More important, it would exacerbate the differences between the tax treatment of business income and income from owner-occupied housing.

In Jorgenson and Yun (2005) we proposed to equalize the tax treatment of all forms of capital income. The key to this proposal, which we call Efficient Taxation of Income, is a system of investment tax credits. Each dollar of new investment would generate a credit against taxes on business income. These credits would be calibrated to equalize the tax burdens.

In order to remove the barriers to efficient allocation of capital, it is critically important to equalize tax burdens on business and household assets, especially owner-occupied housing but also consumers' durables like automobiles. Efficient Taxation of Income would include a system of prepayments of future taxes on household investments. This new source of revenue would precisely offset the new tax credits for business investment, preserving revenue neutrality.

To generate further gains in efficiency the graduated tax on labor income would be replaced by a proportional labor income tax. This would reduce the marginal tax rate to the much lower average tax rate. The combination of equal tax burdens on different types of capital and a proportional tax on labor income would produce gains in consumer welfare well in excess of the gains from substituting consumption for income as the tax base.

In modeling alternative proposals for tax reform we begin by describing the US tax system. We classify assets by three different legal forms of organization in order to capture the differences in taxation most relevant to modeling the impact of tax reforms. Income from assets held by households and non-profit institutions is not subject to tax at either individual or corporate levels, while income from assets held by non-corporate businesses is subject to tax at the individual level, but not the corporate level. Finally, income from corporate assets is subject to tax at both the individual and corporate levels.

We further subclassify assets within each of the three sectors — corporate business, non-corporate business, and households and non-profit institutions — between long-lived and short-lived assets. This reflects the fact that capital income from assets with different tax lifetimes are taxed differently. The description of the tax system in terms of this cross-classification of assets is an integral part of our modeling strategy.[6]

5 President's Advisory Panel on Tax Reform (2005, Figure 5.5, p. 71).

6 In Jorgenson and Yun (2001) we compare this classification of assets with others employed in the literature.

Our next step is to model the impact of alternative tax policies on US economic growth. To simplify this task we distinguish two categories of output, consumption and investment, and two categories of input, capital and labor. Investment and consumption make up the gross domestic product (GDP), while capital and labor comprise the gross domestic income (GDI). We model the allocation of capital among the three legal forms of organization and long-lived and short-lived assets.

Economic growth is the consequence of the growth of labor input, capital input and productivity. Growth of labor input takes place through increases in the labor force, and improvements in labor quality through education and experience. We project future growth in the labor force and labor quality, and model the supply of labor at each point of time. Growth of capital input occurs through investment in new assets. We model the growth of capital input as a consequence of this investment.

We describe our model of economic growth as a dynamic general equilibrium model. The model includes markets for the four commodity groups – investment, consumption, capital and labor. Supply and demand for these commodity groups is equilibrated through the four commodity prices. The market for capital input is linked to past investments, while the market for investment is linked to the future through the arbitrage between the price of new investment goods and future rental values of capital services.

The government sector is coupled to the commodity markets through the tax system. Transactions in the markets for outputs of investment and consumption goods, and inputs of capital and labor services generate government revenues. For example, a proportional tax on consumption produces revenues that depend on the value of consumption. Our model includes budget constraints for consumers, producers and governments. Combining demands and supplies for the four commodity groups with these budget constraints, we obtain a model of the growth of the US economy.

We refer to the alternative tax reform proposals as the policy cases. We compare the time path of economic growth under the policy cases with economic growth under the base case with no change in tax policy. Since the purpose of economic activity is to provide consumption in the form of goods and services and leisure, we focus on the time path of future consumption associated with the base case and each of the alternative policy cases.

We order the alternative policies in terms of the equivalent variation in wealth associated with each policy. The equivalent variation is a standard measure of economic welfare and answers the following question: how much additional wealth would be required at the prices of the base case to achieve the level of consumer welfare in the policy case? If the equivalent variation is positive, the tax reform of the policy case is preferred to the base case with no change in policy.

Since comparisons among tax policies are expressed in prices of the base case, the equivalent variation provides a consistent ranking of the policy cases. This ranking enables us to choose the policy that achieves the highest level of consumer welfare. An important advantage of the equivalent variation is that the ranking of alternative policies is expressed in monetary terms and provides a money metric of consumer welfare. This metric can be compared with other monetary magnitudes, such as the level of wealth of the economy.

In Jorgenson and Yun (1996a) we construct a dynamic general equilibrium model of the US economy. We employ this model to analyze the economic impact of the US tax reforms of 1981 in Jorgenson and Yun (1996b). In Jorgenson and Yun (1996c) we present an updated version of our model and use it to examine the impact of the Tax Reform Act of 1986.[7] Finally, in Jorgenson and Yun (2001), we present a new version of the model and analyze tax reforms like those considered below.

Our model of the US economy incorporates the main features of the US tax system and the alternative proposals for tax reform. These features require the distinctions among different types of assets that correspond to differences in taxation. We have radically simplified the description of consumer behavior by employing a single, representative consumer. Our measure of economic welfare – the equivalent variation in wealth – captures the change in efficiency that would result from each tax change, but not the change in equity.[8]

Debates about tax policies often include both efficiency and equity considerations. Measures of efficiency like the equivalent variation in wealth provide an indicator of potential consumer welfare. This is the welfare that could be attained through tax reform and a costless redistribution of income to maximize consumer welfare. Actual redistributions would require distorting taxes that would lower consumer welfare, so that our measure of efficiency provides an upper bound to the gains in welfare from a change in tax policy.

Measures of the distributional impact of specific tax policies, like those considered by President Bush's Advisory Panel and President Obama's National Commission, are available from the Tax Policy Center.[9] Official estimates of distributional impacts of specific legislative proposals are provided by the Joint Committee on Taxation in the US Congress and the Office of Tax Analysis in the US Department of the Treasury.[10] The TAXSIM model, maintained by the National Bureau of Economic Research, is a valuable resource for measuring the distributional impact of tax policies.[11]

7 More details are given by Yun (2000).

8 Jorgenson *et al.* in Chapter 8 of this Handbook present similar measures of welfare for individual households, and analyze the distributional impact of alternative energy and environmental policies, including tax policies. For further discussion of efficiency and equity, see Jorgenson (1997).

9 See: http://www.taxpolicycenter.org/taxtopics/Tax_Reform_Proposals.cfm.

10 See: http://www.jct.gov/ and http://www.treasury.gov/about/organizational-structure/offices/Pages/Office-of-Tax-Analysis.aspx.

11 See: http://www.nber.org/~taxsim/.

In this chapter we summarize dynamic general equilibrium modeling of the two broad approaches to tax reform. The first is reform of the existing income tax by removing discrepancies among the tax treatments of different forms of capital income and different types of labor income. It is worth emphasizing that this does not entail equalizing the tax treatment of capital and labor incomes. The second broad approach to tax reform is to replace the income tax base for taxation by a consumption tax base.

Comprehensive treatments of tax reform are given in *The Benefit and the Burden: Tax Reform — Why We Need It and What It Will Take* by Bruce Bartlett (Bartlett, 2012) and *Corporate Tax Reform: Taxing Profits in the 21st Century* by Martin A. Sullivan (Sullivan, 2011). Both of these include extensive bibliographies on all aspects of tax reform, including recent tax policy changes in the US. Comprehensive and detailed descriptions of US tax policy are provided by Joel Slemrod and Jon Bakija (Slemrod and Bakija, 2008), Taxing Ourselves: *A Citizen's Guide to the Debate over Taxes*, and Steuerle (Steuerle, 2008), *Contemporary Tax Policy.*

We present our model of economic growth in Section 10.2. This is based on a dynamic general equilibrium model that incorporates demands and supplies for four commodity groups — consumption, investment, capital and labor — and budget constraints for three main actors — consumers, producers and governments. The mechanisms that generate economic growth are represented in neoclassical models of economic growth.[12] We incorporate tax policy through a description of the tax system that captures the distinction between individual and corporate income taxes, as well as taxes on commodities and taxes on property.

In Section 10.3 we present econometric models that describe the behavior of consumers and producers. In order to simplify the description of the US economy, our model of consumer behavior is based on a single, infinitely-lived, household. This representative household demands capital services from housing and consumers' durables, other goods and services, and leisure.[13] The household supplies capital and labor services. Our model of producer behavior is based on a single, representative firm. The representative firm demands capital and labor services and supplies investment and consumption goods. We incorporate the econometric models of Section 10.3 into the neoclassical model of economic growth in Section 10.2 to obtain our dynamic general equilibrium model of the US economy.

In Section 10.4 we present a methodology for evaluating the welfare effects of tax reform. For this purpose we design a computational algorithm for determining the growth of the economy following the reform. (i) We solve for the unique steady

12 See, e.g. Barro and Sala-i-Martin (2004).

13 This approach is standard in neo-classical models of economic growth, but sacrifices the heterogeneity of consumers captured by lifecycle models like those surveyed by Diamond and Zodrow in Chapter 11 of this Handbook. Distributional analyses of change in tax policy by the Tax Policy Center (http://www.taxpolicycenter.org/taxtopics/Tax_Reform_Proposals.cfm) are even more detailed.

state corresponding to any tax policy. (ii) We determine the transition path consistent with the steady-state and the initial conditions. We describe the dynamics of our general equilibrium model in terms of the saddle-point configuration of this transition path.

In Section 10.5 we estimate the gains to consumer welfare from Efficient Taxation of Income. This would combine equalizing the tax burden for all sources of capital income and replacing the progressive tax on labor income by a proportional labor income tax. The potential gain in welfare would be $7.0 trillion (2011 US$)! The additional wealth generated by corporate tax integration, the core of the Advisory Panel's Simplified Income Tax Plan, would be only $2.3 trillion, slightly less than a third of the gains from Efficient Taxation of Income.

Efficient Taxation of Income would also have a much greater impact on welfare than a revenue-neutral version of the Hall—Rabushka Flat Tax. In Section 10.6 we estimate that the Flat Tax would yield $3.8 trillion in additional wealth, a little over half the gains from Efficient Taxation of Income. President Bush's Advisory Panel has proposed a Growth and Investment Tax Plan similar to the Flat Tax. The gains would be diminished by the Panel's introduction of a substantial tax subsidy to owner-occupied housing and a progressive tax on consumption at the individual level.

Tax reform proposals, like cherry blossoms, are hardy perennials of the Washington scene. Occasionally, a new approach to tax reform appears and changes the course of the debate. President Reagan's proposal of May 1985 is the most recent example of a new approach to tax reform. Like the Reagan proposal, Efficient Taxation of Income retains the income tax rather than shifting to a consumption tax. In Section 10.7 we conclude that this remains the most rewarding direction for reform.

10.2 MODELING ECONOMIC GROWTH

In this section we present a new version of our dynamic general equilibrium model. This incorporates an updated description of the US tax system. In the following section we present econometric models of producer and consumer behavior based on data for the US economy for the period 1970—2010. In Section 10.2.1 we present a system of notation for demands and supplies of the four commodity groups included in our model — capital and labor services, and consumption and investment goods.

Equilibrium in our model is characterized by an intertemporal price system. The price system clears the markets for all four commodity groups in every time period. This price system links the past and the future through markets for investment goods and capital services. Assets are accumulated as a result of past investments, while asset prices are equal to present values of future capital services.

In Section 10.2.2 we present a model of producer behavior based on a production possibility frontier for the representative producer and the corresponding objective function. The first stage of the producer's optimization problem is to choose outputs of investment and consumption goods, and inputs of capital and labor services. In our model, inputs of corporate and non-corporate capital services are treated separately. The second stage is to allocate capital services within each of these sectors between long-lived and short-lived assets.

In Section 10.2.3 we present a model of household behavior based on an intertemporal welfare function for the representative consumer and the corresponding budget constraint. The first stage of the consumer's optimization problem is to allocate wealth among all time periods. The second stage is to allocate consumption in each time period among capital services, other goods and services, and leisure. We derive labor supply by subtracting leisure demand from the household's time endowment. The third and final stage is to allocate capital services between the services of long-lived and short-lived assets.

In Section 10.2.4 we present accounts for the government and rest-of-the-world sectors based on identities between income and expenditure. We first outline the generation of government revenue from taxes on consumption and investment goods and capital and labor services. We complete the government budget by generating purchases of consumption and investment goods and labor services. The deficit of the government sector is the difference between expenditure and revenue. Similarly, net foreign investment is equal to the difference between US imports and exports to the rest of the world.

Finally, we describe intertemporal equilibrium in our model in Section 10.2.5. Equilibrium requires that supply must be equal to demand for each of the four commodity groups — consumption goods, investment goods, capital services and labor services. We show that demand and supply functions satisfy Walras' law; one of the four market clearing conditions is implied by the three remaining conditions, together with identities between income and expenditure for the household, business, government and rest-of-the-world sectors. In addition, the model is homogeneous of degree zero in prices and nominal income and wealth.

10.2.1 Commodities

In our model the US economy is divided into household, business, government and rest-of-the-world sectors. The household sector includes both households and non-profit institutions, while the business sector includes both corporate and non-corporate businesses. Although we do not model production in the corporate and non-corporate sectors separately, we distinguish between assets and capital services in these two sectors. The government sector includes general government and government enterprises. Finally, the rest-of-the-world sector encompasses transactions between the US economy and the rest of the world.

Our model includes four commodity groups – consumption goods, investment goods, capital services and labor services. To represent the quantities of these commodity groups we introduce the following notation:

C personal consumption expenditures, excluding household capital services
I gross private domestic investment, including purchases of consumers' durables
K private national capital stock, including the stock of household capital
L labor services.

Consumption and investment correspond closely to the concepts employed in the US National Income and Product Accounts (NIPA).[14] However, purchases of consumers' durables are included in personal consumption expenditures and excluded from gross private domestic investment in the US national accounts. Our accounting system treats consumers' durables symmetrically with other forms of capital. To denote prices we place a P before the corresponding symbol for quantity. For example, PC is the price of private national consumption, excluding household capital services.

We require notation for the supply and demand of consumption goods, investment goods, and labor services by all four sectors. Private national consumption C represents purchases of consumption goods by the household sector. The remaining components of supply and demand for consumption goods are as follows:

CE supply of consumption goods by government enterprises
CG government purchases of consumption goods
CR rest-of-the-world purchases of consumption goods
CS supply of consumption goods by private enterprises.

Similarly, gross private domestic investment I represents purchases of investment goods by the business and household sectors. The remaining components of supply and demand for investment goods are as follows:

IG government purchases of investment goods
IR rest-of-the-world purchases of investment goods
IS supply of investment goods by private enterprise.

We distinguish among assets and capital services in the corporate, non-corporate and household sectors. We further distinguish between short-lived and long-lived assets within each sector. Short-lived assets include producers' and consumers' durable equipment, while long-lived assets include residential structures, non-residential

[14] Bureau of Economic Analysis (2011). See: http://www.bea.gov/national/pdf/NIPAchapters1-9.pdf.

structures, inventories and land. Altogether, we represent six types of assets, cross-classified by legal form of organization and durability, in the model.

The classification of assets by legal form of organization enables us to model differences in the tax treatment of capital income in the corporate, non-corporate and household sectors. The classification of assets differing in durability is useful in introducing the effects of asset-specific tax rules, such as the investment tax credit and capital consumption allowances. Ignoring the interasset tax wedges within the corporate and non-corporate sectors would omit an important source of tax distortions. Similarly, a classification of assets based only on differences in durability would neglect the impact of intersectoral tax wedges.[15]

We distinguish between debt and equity claims on capital income for corporate, non-corporate and household sectors. We take the debt—equity ratios to be fixed exogenously for all three sectors. Financial market equilibrium requires that after-tax rates of return to equity are equalized across the three sectors. In addition, rates of return on debt issued by the private sectors and the government must equal the market interest rate. Conditions for financial market equilibrium determine the allocation of capital among the sectors and the allocation of financial claims between debt and equity.

We have simplified the representation of technology in our model by introducing a single stock of capital at each point of time. Capital is perfectly malleable and allocated to equalize after tax rates of return to equity in the corporate, non-corporate and household sectors. Capital services, say KD, are proportional to private national capital stock K. A complete system of notation that includes the six classes of assets in our model is as follows:

HD	household capital services
HL	household capital services from long-lived assets
HS	household capital services from short-lived assets
MD	non-corporate capital services
ML	non-corporate capital services from long-lived assets
MS	non-corporate capital services from short-lived assets
QD	corporate capital services
QL	corporate capital services from long-lived assets
QS	corporate capital services from short-lived assets.

15 In Jorgenson and Yun (2001, Chapter 2) we show how to incorporate past and current tax rules into the rental prices of assets. The proposals for tax reform discussed in Sections 10.4 and 10.5 below are also represented in terms of these prices.

The household sector is the only sector with a time endowment. Part of this endowment is consumed as leisure by the household sector. The rest is supplied as labor services to the business, government and rest-of-the-world sectors. The components of demand and supply for labor services are as follows:

LD	private enterprise purchases of labor services
LE	government enterprise purchases of labor services
LG	general government purchases of labor services
LH	time endowment
LJ	leisure time
LR	rest-of-the-world purchases of labor services.

10.2.2 Producer behavior

The business sector includes both corporate and non-corporate enterprises, so that we have divided capital services between corporate and non-corporate capital services. Similarly, we have divided capital services in each sector between long-lived and short-lived components to capture differences in the tax treatment of income from long-lived and short-lived assets. We model the tax treatment of capital income by incorporating specific features of the tax structure into the prices of capital services.

Our model of producer behavior provides a highly schematic representation of the US economy. This model is based on two-stage allocation. At the first stage a representative producer employs capital and labor services to produce outputs of consumption and investment goods. At the second stage the values of both types of capital services are allocated between long-lived and short-lived assets.

To represent our model of producer behavior we first require some notation. We denote the shares of outputs and inputs in the value of labor input as follows:

$$v_{CS} = \frac{PCS \cdot CS}{PLD \cdot LD}, v_{IS} = \frac{PIS \cdot IS}{PLD \cdot LD}, v_{MD} = -\frac{PMD \cdot MD}{PLD \cdot LD}, v_{QD} = -\frac{PQD \cdot QD}{PLD \cdot LD}.$$

The value shares for outputs are positive, while the value shares for inputs are negative. We also introduce the following notation:

$v = (v_{CS}, v_{IS}, v_{MD}, v_{QD})$	vector of value shares
$\ln P = (\ln PCS, \ln PIS, \ln PMD, \ln PQD)$	vector of logarithms of prices of outputs and inputs.

We characterize the technology of the business sector in terms of labor requirements. Labor services are a function of consumption and investment goods outputs and corporate and non-corporate capital inputs. The technology is characterized by constant returns to scale. By modeling the substitution between consumption and investment goods in production, we introduce external costs of adjustment in the response of investment to changes in tax policy.[16]

Under constant returns to scale we can represent the technology in dual form through the price function, giving the price of labor services as a function of the prices of consumption and investment goods, corporate and non-corporate capital services, and time as an index of technology. The price function must be homogeneous of degree one, non-decreasing in the prices of outputs and non-increasing in the prices of inputs, and convex in the prices of outputs and inputs. We have incorporated these restrictions into the system of supply and demand functions presented in the following section. The rate of productivity growth is endogenous and depends on the prices of inputs and outputs.[17]

We employ the transcendental logarithmic or translog form of the price function:[18]

$$\ln PLD = \ln P'\alpha_P + \alpha_T T + \frac{1}{2}\ln P' B_{PP} \ln P + \ln P'\beta_{PT} T + \beta_{TT} T^2. \qquad (10.1)$$

In this representation the scalars $\{\alpha_T, \beta_{TT}\}$, the vectors $\{\alpha_P, \beta_{PT}\}$, and the matrix $\{B_{PP}\}$ are constant parameters. This representation facilitates the expression of demands and supplies as functions of the prices of inputs and outputs. The parameters embody the elasticities of demand and supply that are critical for the evaluation of alternative tax policies.

A model of producer behavior based on the translog price function has an important advantage over models based on Cobb—Douglas or constant elasticity of substitution production functions. Although explicit demand and supply functions can be derived from these production functions, all elasticities of substitution must be same.[19] This frustrates the basic objective of determining the elasticities of demand and supply empirically in order to model the response of producer behavior to changes in tax policy.

The value shares for outputs and inputs can be expressed in terms of the logarithmic derivatives of the price function with respect to the logarithms of the prices of the output and input prices:

$$v = \alpha_P + B_{PP} \ln P + \beta_{PT} T. \qquad (10.2)$$

16 Models with internal costs of adjustment are surveyed by Hayashi (2000).
17 Our approach to endogenous productivity growth was originated by Jorgenson and Fraumeni (2000).
18 The translog price function was introduced by Christensen *et al*. (2000).
19 McFadden (1963) and Uzawa (1962) have shown that this restriction is implicit in constant elasticity of substitution production functions.

The parameters $\{B_{PP}\}$ can be interpreted as *share elasticities* and represent the degree of substitutability among inputs and outputs, while the parameters $\{\beta_{PT}\}$ are *biases of productivity growth* and represent the impact of changes in productivity on the value shares.[20]

Similarly, the rate of productivity growth, say v_T, is the negative of the growth of the price of labor input, holding the prices of outputs and inputs constant:

$$-v_T = \alpha_T + \beta_{PT} \ln P + \beta_{TT} T. \tag{10.3}$$

The parameter β_{TT} is the *deceleration* of productivity growth. To assure existence of a balanced growth equilibrium, we assume that productivity growth is labor-augmenting and takes place at a constant rate:

$$\beta_{PT} = 0, \beta_{TT} = 0.$$

To represent the second stage of our model of producer behavior we first denote the shares of long-lived and short-lived assets in the value of non-corporate and corporate capital as follows:

$$v_{ML} = \frac{PML \cdot ML}{PMD \cdot MD}, v_{MS} = \frac{PMS \cdot MS}{PMD \cdot MD}, v_{QL} = \frac{PQL \cdot QL}{PQD \cdot QD}, v_{QS} = \frac{PQS \cdot QS}{PQD \cdot QD}.$$

These value shares are positive. We also find it convenient to introduce the notation:

$v_M = (v_{ML}, v_{MS})$	vector of value shares in non-corporate capital input
$v_Q = (v_{QL}, v_{QS})$	vector of value shares in corporate capital input
$\ln PM = (\ln PML, \ln PMS)$	vector of logarithms of prices of capital inputs in the non-corporate sector
$\ln PQ = (\ln PQL, \ln PQS)$	vector of logarithms of prices of capital inputs in the corporate sector.

We represent the prices of corporate and non-corporate capital services as functions of the prices of their long-lived and short-lived components. These price functions must be homogeneous of degree one, non-decreasing in the prices of inputs, and concave in the input prices. We have incorporated these restrictions into the demand functions presented in the following section.

20 For further discussion of share elasticities and biases of productivity growth, see Jorgenson (2000).

As before, we employ the translog form for the price functions:

$$\ln PMD = \ln PM' \alpha_{PM} + \frac{1}{2} \ln PM' B_{PM} \ln PM$$

$$\ln PQD = \ln PQ' \alpha_{PQ} + \frac{1}{2} \ln PQ' B_{PQ} \ln PQ. \tag{10.4}$$

In this representation the matrices $\{B_{PM}, B_{PQ}\}$ are constant parameters that embody the elasticities of demand for capital inputs needed for analyzing the response of producer behavior to changes in tax policy.

The value shares can be expressed in terms of the logarithmic derivatives of the price functions with respect to the logarithms of the prices:

$$v_M = \alpha_{PM} + B_{PM} \ln PM$$

$$v_Q = \alpha_{PM} + B_{PQ} \ln PQ. \tag{10.5}$$

The *share elasticities* $\{B_{PM}, B_{PQ}\}$ represent the degree of substitutability between the capital services of short-lived and long-lived assets within the non-corporate and corporate sectors. There is no role for productivity growth in the second stage of our model of producer behavior.

10.2.3 Consumer behavior

The household sector includes both households and non-profit institutions. This sector owns the private capital in the US economy, as well as having claims on the government and the rest of the world. Claims on the government sector represent liabilities owed by the government to its own citizens. Similarly, claims on the rest of the world correspond to liabilities owed by the rest of the world sector. Household wealth is the sum of tangible capital in the private sector and claims on the government and rest-of-the-world sectors.

Capital services from housing and consumers' durables are directly consumed by the household sector. We have divided these services between long-lived and short-lived components in order to capture differences in the tax treatment of income from these assets. We incorporate features of the tax structure specific to household assets into the prices of capital services.

Our model of consumer behavior is based on a representative consumer with an infinite time horizon. Barro (1974) has provided a rationale for the infinite-horizon representative consumer model in terms of intergenerational altruism. Our assumption is an alternative to the life-cycle theory in modeling consumer behavior. The implications are very different from those of the life-cycle theory, based on a finite lifetime for each consumer.[21]

[21] More details are given by Diamond and Zodrow in Chapter 11 of this Handbook.

The objective of the representative consumer is to maximize welfare through allocation of lifetime wealth. Our model is based on an intertemporally additive utility function that depends on levels of full consumption in all time periods. Full consumption is an aggregate of consumption goods, household capital services and leisure. To simplify the model we endow the representative consumer with perfect foresight about future prices and rates of return.[22]

To represent our model of consumer behavior we introduce the following notation:

F_t full consumption *per capita* with population measured in efficiency units

PF_t price of full consumption *per capita*

n_t rate of population growth

$-\alpha_T$ rate of labor-augmenting productivity growth

ρ nominal private rate of return.

Labor-augmenting productivity growth is incorporated into our representation of the technology. Since full consumption includes consumption goods, household capital services and leisure, we take the rate of productivity growth in both sectors to be the same. This assumption assures the existence of balanced growth equilibrium. We represent full consumption *per capita* in a time-invariant form by defining population in efficiency units, the number of individuals augmented by growth in productivity.

In our model of consumer behavior the representative consumer maximizes the *intertemporal welfare function*:

$$V = \frac{1}{1-\sigma}\sum_{t=0}^{\infty}\prod_{s=0}^{t}\left(\frac{1+n_s}{1+\gamma}\right)U_t^{1-\sigma}, \tag{10.6}$$

where σ is the inverse of the intertemporal elasticity of substitution and γ is the subjective rate of time preference.

The intertemporal welfare function is a discounted sum of products of total population, which grows at the rate n_t, and *per capita* welfare U_t ($t = 0, 1, \ldots$). These depend on full consumption *per capita* F_t with population measured in efficiency units:

$$U_t = F_t(1-\alpha_T)^t, t = 0, 1, \ldots. \tag{10.7}$$

The representative consumer maximizes the welfare function (10.6), subject to the *intertemporal budget constraint*:

[22] Perfect foresight models of tax incidence are presented by Chamley (1981), Diamond and Zodrow in Chapter 11 of this Handbook, and many others.

$$W = \sum_{t=0}^{\infty} \frac{PF_t F_t (1-\alpha_T)^t \prod_{s=0}^{t}(1+n_s)}{\prod_{s=0}^{t}(1+\rho_s)}, \tag{10.8}$$

where W is full wealth. Full wealth is the present value of full consumption over the future of the economy, where full consumption is discounted at the nominal private rate of return ρ_s.

The function V is additively separable in the welfare functions U_t ($t = 0, 1, \ldots$). These depend on the consumption of leisure, consumption goods and capital services, so that we can divide the representative consumer's optimization problem into two stages. The consumer first allocates full wealth among different time periods. In the second stage, the consumer allocates full consumption among leisure, consumption goods and household capital services in each period.

The necessary conditions for optimization are given by the discrete-time Euler equation:

$$\frac{F_t}{F_{t-1}} = \left[\frac{PF_{t-1}}{PF_t}\,\frac{1+\rho_t}{(1+\gamma)(1-\alpha_T)^{\sigma}}\right]^{\frac{1}{\sigma}}, \quad t = 1, 2, \ldots. \tag{10.9}$$

This describes the optimal time path of full consumption, given the sequence of prices and nominal rates of return. We refer this as the *transition equation* for full consumption. The growth rate of full consumption is given by the transition equation, so that the level of full consumption in any period determines the optimal time path.

In a steady state with no inflation, the level of full consumption *per capita* with population measured in efficiency units is constant. Therefore, the only private nominal rate of return consistent with the steady state, say $\tilde{\rho}$, is:

$$\tilde{\rho} = (1+\gamma)(1-\alpha_T)^{\sigma} - 1. \tag{10.10}$$

This depends on the rate of labor-augmenting productivity growth and the parameters of the intertemporal welfare function, but is independent of tax policy.

We denote the rate of inflation in the price of full consumption by π_t, where:

$$\pi_t = \frac{PF_t}{PF_{t-1}} - 1, \quad t = 1, 2, \ldots$$

In a steady state with a constant rate of inflation $\tilde{\pi}$ the nominal private rate of return is:

$$\tilde{\rho} = (1+\gamma)(1-\alpha_T)^{\sigma}(1+\tilde{\pi}) - 1. \tag{10.11}$$

If we denote the real private rate of return by r_t, where:

$$r_t = \frac{PF_{t-1}}{PF_t}(1+\rho_t) - 1, \quad t = 1, 2, \ldots.$$

the steady-state real private rate of return is:

$$\tilde{r} = (1+\gamma)(1-\alpha_T)^{\sigma} - 1. \tag{10.12}$$

This rate of return is independent of tax policy and the rate of inflation.

The transition equation for full consumption implies that if the real private rate of return exceeds the steady-state rate of return, full consumption rises; conversely, if the rate of return is below its steady-state value, full consumption falls. To show this we take the logarithm of both sides of the transition equation, obtaining:

$$\ln \frac{F_t}{F_{t-1}} = \frac{1}{\sigma}\left[\ln(1+r) - \ln(1+\tilde{r})\right]. \tag{10.13}$$

To a first-order approximation, the growth rate of full consumption is proportional to the difference between the real private rate of return and its steady-state value.[23] The constant of proportionality is the intertemporal elasticity of substitution $1/\sigma$. The greater this elasticity, the more rapidly full consumption approaches its steady-state level.

We have assumed that consumption decisions can be separated into three stages. At the first stage the value of full wealth is allocated among different time periods. At the second stage full consumption is allocated among nondurable consumption goods, household capital services and leisure. The third stage involves the allocation of household capital services between long-lived and short-lived assets.

To complete the representation of preferences of the household sector we require some additional notation. We denote the shares of consumption goods, household capital services and leisure in full consumption as follows:

$$v_C = \frac{PC \cdot C}{PF \cdot F}, v_{HD} = \frac{PHD \cdot HD}{PF \cdot F}, v_{LJ} = \frac{PLJ \cdot LJ}{PF \cdot F}.$$

Similarly, we denote the shares of long-lived and short-lived assets in household capital services as follows:

$$v_{HL} = \frac{PHL \cdot HL}{PHD \cdot HD}, v_{HS} = \frac{PHS \cdot HS}{PHD \cdot HD}.$$

These value shares are positive.

We find it convenient to introduce the notation:

[23] Chamley (1981) derives this formula in a continuous time framework with a single good and fixed labor supply.

$\nu_D = (\nu_C, \nu_{HD}, \nu_{LJ})$	vector of value shares of full consumption
$\nu_H = (\nu_{HL}, \nu_{HS})$	vector of value shares of household capital input
$\ln PD = (\ln PC, \ln PHD, \ln PLJ^*)$	vector of logarithms of prices of consumption goods, household capital services and leisure, where PLJ^* is the price of leisure, defined in terms of labor measured in efficiency units
$\ln PH = (\ln PHL, \ln PHS)$	vector of logarithms of prices of capital inputs in the household sector.

By taking the preferences of the household sector to be homothetic, we can represent the second stage of our model by expressing the price of full consumption as a function of the prices of nondurable consumption goods, household capital services and leisure. This price function must be homogeneous of degree one, non-decreasing in the prices of the three commodity groups and concave in these prices. We have incorporated these restrictions into the demand functions presented in the following section.

As before, we employ the translog form for the price function:[24]

$$\ln PF = \ln PD' \alpha_{PD} + \frac{1}{2} \ln PD' B_{PD} \ln PD. \tag{10.14}$$

The parameters B_{PD} embody elasticities of demand needed for analyzing the response of consumer behavior to changes in tax policy.

Similarly, we can express the price of household capital services as a function of its long-lived and short-lived components. This price function must also be homogeneous of degree one, non-decreasing in the prices of the two components and concave in these prices. We incorporate these restrictions into the model of consumer behavior presented in the following section. Employing the translog form for this price function:

$$\ln PHD = \ln PH' \alpha_{PH} + \frac{1}{2} \ln PH' B_{PH} \ln PH. \tag{10.15}$$

The matrix B_{PH} is constant and embodies elasticities of demand for household capital services.

The value shares can be expressed in terms of logarithmic derivatives of the price functions with respect to the logarithms of the prices:

24 The translog indirect utility function was introduced by Christensen *et al.* (1997).

$$v_D = \alpha_{PD} + B_{PD} \ln PD$$

$$v_H = \alpha_{PH} + B_{PH} \ln PH. \tag{10.16}$$

The *share elasticities* B_{PD} and B_{PH} represent the degree of substitutability among commodity groups within the household sector.

10.2.4 Government and rest of the world

We consolidate federal and the state and local governments into a single government sector. The government collects taxes from the household and business sectors, issues government debt to households to finance deficits, and spends its revenues on consumption goods, investment goods, labor services, interest on the government debt, and transfer payments to households and the rest of the world. Similarly, we consolidate the federal and state and local government enterprises into a single government enterprise sector. Government enterprises purchase labor services to produce consumption goods and turn over any surplus to the general government.

10.2.4.1 Government revenue

To represent the tax revenues of the government sector we introduce some additional notation. We use the symbol R for government revenues and the symbol t for tax rates. For sales taxes our notation is as follows:

R_{C}	sales tax revenues from consumption goods
R_{I}	sales tax revenues from investment goods
t_{C}	sales tax rate on consumption goods
t_{I}	sales tax rate on investment goods.

Government revenues from taxes on consumption goods and investment goods are generated by the following equations:

$$R_{\mathrm{C}} = t_{\mathrm{C}} PCS \cdot CS$$

$$R_{\mathrm{I}} = t_{\mathrm{I}} PIS \cdot IS. \tag{10.17}$$

Property taxes are levied on the lagged values of assets, so that we require the following notation:

$R_{\mathrm{q}}^{\mathrm{p}}, R_{\mathrm{m}}^{\mathrm{p}}, R_{\mathrm{h}}^{\mathrm{p}}$	property tax revenues from corporate, non-corporate and household assets
$t_{\mathrm{q}}^{\mathrm{p}}, t_{\mathrm{m}}^{\mathrm{p}}, t_{\mathrm{h}}^{\mathrm{p}}$	property tax rates on corporate, non-corporate and household assets
VQL, VML, VHL	lagged values of corporate, non-corporate and household assets
VGL, VRL	lagged values of claims on government and rest of the world.

Government revenues from property taxes are generated by:

$$R_{\mathrm{q}}^{\mathrm{p}} = t_{\mathrm{q}}^{\mathrm{p}} VQL$$

$$R_{\mathrm{m}}^{\mathrm{p}} = t_{\mathrm{m}}^{\mathrm{p}} VML$$

$$R_{\mathrm{h}}^{\mathrm{p}} = t_{\mathrm{h}}^{\mathrm{p}} VHL. \tag{10.18}$$

Wealth taxes include federal estate and gift taxes and state and local death and gift taxes. These taxes are levied on the lagged value of wealth, so that we require the notation:

R_{w}	wealth tax revenues
WL	lagged value of wealth
t_{w}	wealth tax rate.

The lagged value of wealth is the sum of the lagged values of corporate, non-corporate and household assets, together with the lagged values of claims on government and rest of the world sectors:

$$WL = VQL + VML + VHL + VGL + VRL.$$

Wealth tax revenues are generated by:

$$R_{\mathrm{w}} = t_{\mathrm{w}} WL. \tag{10.19}$$

10.2.4.2 Corporate income tax

Income from corporate capital is taxed both at the corporate level and the individual level. The base of the corporate income tax is corporate property compensation less depreciation allowances. At the federal level this is reduced by tax deductions for interest expenses, state and local property taxes, and state and local corporate income taxes. During part of the period covered by our study, tax liabilities were reduced by the investment tax credit.

Replicating the actual practice for calculating capital consumption allowances and investment tax credits would require a detailed description of tax law and vintage accounts of all depreciable assets. However, we can approximate the economic effects of these tax provisions very accurately by converting the allowances and credits into imputed flows that are proportional to the flow of capital services.

To represent the corporate income tax we require the following notation:

α	dividend payout rate
β_q	debt-capital ratio of the corporate sector
δ_q^s, δ_q^l	economic depreciation rates on short-lived and long-lived corporate assets
DC	proportion of nominal capital gains excluded from the individual income tax base
DQ	imputed corporate capital consumption allowances
$DSLI$	deduction of state and local income taxes for federal tax purposes
$DSLQ$	deduction of state and local taxes on corporate property for federal tax purposes
i	interest rate
k_q^s, k_q^l	corporate investment tax credit rates on short-lived and long-lived assets
$ITCQ$	imputed corporate investment tax credit rate
r^e	real rate of return on corporate equity after corporate taxes
r^q	nominal discount rate for corporate investment
ρ^e	nominal private rate of return on corporate equity
t_q^e	marginal tax rate on corporate dividends
t_q^g	marginal tax rate on capital gains on corporate equity
t_q	corporate income tax rate
t_q^f, t_q^s	corporate income tax rates, federal and state and local
VQL^s, VQL^l	lagged values of corporate capital stock of short-lived and long-lived assets
z_q^s, z_q^l	present values of corporate capital consumption allowances on short-lived and long-lived assets.

The base of corporate income tax BQ is defined as:

$$\begin{aligned} BQ = {} & PQD \cdot QD - DQ - [\beta_q(1 - DI)i + \alpha \cdot DD(1 - \beta_q)r^e]VQL \\ & -\left[t_q^s + t_q^f\left(DSLQ - DSLIt_q^s\right)\right]R_q^p / t_q, \end{aligned} \tag{10.20}$$

where imputed corporate capital consumption allowances DQ are:[25]

$$DQ = z_q^s\left[r^q - \pi + (1 + \pi)\delta_q^s\right]VQL^s + z_q^l\left[r^q - \pi + (1 + \pi)\delta_q^l\right]VQL^l.$$

The real rate of return on corporate equity after taxes is:

$$r^e = \frac{\rho^e - \pi\left[1 - (1 - DC)t_q^g\right]}{1 - \left[\alpha t_q^e + (1 - \alpha)t_q^g\right]}.$$

25 We give additional details in Jorgenson and Yun (2001, Chapter 2, especially section 2.7).

Equation (10.20) shows how the tax treatment of various types of corporate expenses affects the corporate tax burden. For example, when state and local taxes are fully deductible at the federal level, the term involving revenue from taxes on corporate property reduces to R_q^p. Similarly, if interest expenses are not indexed for inflation, so that DI is equal to zero, all of nominal interest payments are deductible. If indexing of interest expenses is complete, then only real interest expenses can be deducted.

Finally, tax revenues from corporate taxes R_q are generated by:

$$R_q = t_q \cdot BQ - ITCQ, \tag{10.21}$$

where the imputed corporate investment tax credit $ITCQ$ is defined as:

$$ITCQ = k_q^s \left[r^q - \pi + (1+\pi)\delta_q^s \right] VQL^s + k_q^l \left[r^q - \pi + (1+\pi)\delta_q^l \right] VQL^l.$$

10.2.4.3 Individual income tax

To represent the individual income tax we require the following notation:

$\beta_m,\ \beta_h$	debt-capital ratios of the non-corporate and household sectors
δ_m^s, δ_m^l	economic depreciation rates on short-lived and long-lived non-corporate assets
DHI	proportion of household interest expense deductible for tax purposes
DM	imputed non-corporate capital consumption allowances
$DSLM$	deduction of state and local taxes on non-corporate property for federal tax purposes
$DSLH$	deduction of state and local taxes on household property for federal tax purposes
HDI	proportion of the household interest payments deducted for indexation for inflation
r^m	nominal discount rate for non-corporate investment
t_m^e	marginal tax rate on income from non-corporate equity
$t_m^{ef},\ t_m^{es}$	marginal tax rates on income from non-corporate equity, federal and state and local
t_h^e	marginal tax rate for deductions from household equity income
$t_h^{ef},\ t_h^{es}$	marginal tax rates for deductions from household equity income, federal and state and local
t_m^g	marginal tax rate on capital gains on non-corporate assets
t_h^g	marginal tax rate on capital gains on household assets
VDQ	economic depreciation on corporate assets
$VML^s,\ VML^l$	lagged values of non-corporate capital stock of short-lived and long-lived assets
$VHL^s,\ VHL^l$	lagged values of household capital stock of short-lived and long-lived assets
$z_m^s,\ z_m^l$	present values of non-corporate capital consumption allowances on short-lived and long-lived assets.

In modeling the taxation of individual income, we distinguish between income from labor and capital. All labor compensation is included in the individual income tax base BL, defined as:

$$BL = PLD \cdot LD + PLE \cdot LE + PLG \cdot LG + PLR \cdot LR. \tag{10.22}$$

Interest income is the sum of interest earned on corporate, non-corporate and household debt and on claims on government and the rest of the world. We assume that households own claims on the rest of the world through US corporations and that these corporations pay income taxes to the host countries on the earnings of US assets abroad. We assume, further, that the rate of return on these claims after corporate taxes is the same as on domestic corporate capital. Interest originating in the household sector is taxable to the creditor and deductible from the income of the debtor. Under these assumptions the interest income of individuals BD is:

$$BD = [\beta_{\mathrm{q}}(VQL + VRL) + \beta_{\mathrm{m}} VML + \beta_{\mathrm{h}} VHL + VGL](1 - DI)i, \tag{10.23}$$

where VQL is the value of lagged capital stock of both short-lived and long-lived corporate assets and VML and VHL are the values of lagged capital stock of the corresponding non-corporate and household assets, respectively.

Income from equity includes income from corporate and non-corporate assets. Income from equity in household assets is not taxed, but interest expenses and property taxes on these assets are deductible from the income of the owner. Since nominal capital gains on assets are taxed only on realization, we define the marginal tax rate on capital gains in such a way as to convert accrued capital gains to a realization basis.[26]

Taxable income from equity BE includes corporate profits after taxes, together with earnings on claims on the rest of the world. This income also includes non-corporate property compensation – net of interest expenses, property taxes, and depreciation allowances – less property taxes and interest expenses on household assets. Finally, income from equity includes nominal capital gains on private capital. Taxable income from equity is defined as:

$$\begin{aligned} BE = {} & PQD \cdot QD - R_{\mathrm{q}}^{\mathrm{p}} - R_{\mathrm{q}} + (1 - \beta_{\mathrm{q}}) r^{\mathrm{e}} \cdot VRL - \beta_{\mathrm{q}}(i - \pi) VQL - VDQ \\ & + PMD \cdot MD - DM - \beta_{\mathrm{m}} VML \cdot (1 - DI)i - \left[t_{\mathrm{m}}^{\mathrm{es}} + t_{\mathrm{m}}^{\mathrm{ef}}\left(DSLM - DSLIt_{\mathrm{m}}^{\mathrm{es}}\right)\right] R_{\mathrm{m}}^{\mathrm{p}} / t_{\mathrm{m}}^{\mathrm{e}} \\ & - DHI \cdot \beta_{\mathrm{h}}(1 - HDI) VHL \cdot i - \left[t_{\mathrm{h}}^{\mathrm{es}} + t_{\mathrm{h}}^{\mathrm{ef}}\left(DSLH - DSLIt_{\mathrm{h}}^{\mathrm{es}}\right)\right] R_{\mathrm{h}}^{\mathrm{p}} / t_{\mathrm{h}}^{\mathrm{e}} + \\ & \left[\left(1 - \beta_{\mathrm{q}}\right)(VQL + VRL) t_{\mathrm{q}}^{\mathrm{g}} / t_{\mathrm{q}}^{\mathrm{e}} + (1 - \beta_{\mathrm{m}}) VMLt_{\mathrm{m}}^{\mathrm{g}} / t_{\mathrm{m}}^{\mathrm{e}} + (1 - \beta_{\mathrm{h}}) VHLt_{\mathrm{h}}^{\mathrm{g}} / t_{\mathrm{h}}^{\mathrm{e}}\right]\left(1 - DC\right)\pi, \end{aligned} \tag{10.24}$$

where economic depreciation on corporate assets VDQ is defined as:

[26] We give additional details in Jorgenson and Yun (2001, Chapter 2).

$$VDQ = (1+\pi)\left[\delta_q^s VQL^s + \delta_q^l VQL^l\right],$$

and imputed non-corporate capital consumption allowances DM are defined as:

$$DM = z_m^s\left[r^m - \pi + (1+\pi)\delta_m^s\right]VML^s + z_m^l\left[r^m - \pi + (1+\pi)\delta_m^l\right]VML^l.$$

To complete the representation of the individual income tax we require the following notation:

$ITCH$	imputed household investment tax credit
$ITCM$	imputed non-corporate investment tax credit
$k_h^s,\ k_h^l$	household investment tax credit rates on short-lived and long-lived assets
$k_m^s,\ k_m^l$	non-corporate investment tax credit rates on short-lived and long-lived assets
R_l	tax revenues from labor income
R_e	tax revenues from equity income
R_d	tax revenues from interest income
t_L^a	average tax rate on labor income
t_e^a	average tax rate on equity income
t_d^a	average tax rate on interest income.

Tax revenues from individual income taxes are generated by:

$$\begin{aligned} R_l &= t_L^a BL \\ \mathrm{R}_e &= t_e^a BE - ITCM - ITCH \\ R_d &= t_d^a BD, \end{aligned} \tag{10.25}$$

where the imputed household and non-corporate investment tax credits $ITCH$ and $ITCM$ are defined as:

$$ITCH = k_h^s\left[r^h - \pi + (1+\pi)\delta_h^s\right]VHL^s + k_h^s\left[r^h - \pi + (1+\pi)\delta_h^l\right]VHL^l$$

$$ITCM = k_m^s\left[r^m - \pi + (1+\pi)\delta_m^s\right]VML^s + k_m^s\left[r^m - \pi + (1+\pi)\delta_m^l\right]VML^l.$$

Ordinarily, average tax rates on labor, equity, and interest incomes are the same.

To represent the government budget we require the following notation:

t_L^{m} marginal tax rate on labor income

$t_{\mathrm{g}}^{\mathrm{d}}$ marginal tax rate on government interest payments

t_{t} effective rate of non-tax payments

DG government deficit

EL government transfers to households

ER government transfers to foreigners

GS real government expenditures, net of interest payments

PGS price deflator, government expenditures

R government revenue

R_{ge} surplus of government enterprises

R_{t} revenue from non-tax payments

R_{lum} government revenues from a lump-sum tax

$SGOV$ share of government expenditures in GDP

SCE proportion of consumption goods produced by government enterprises to business sector production

SLE proportion of the labor compensation of government enterprises in the value of labor supply

SCG proportion of government purchases of consumption goods in government expenditures, net of interest payments

SIG proportion of government purchases of investment goods in government expenditures, net of interest payments

SLG proportion of government purchases of labor services in government expenditures, net of interest payments

SEL proportion of transfers to households in government expenditures, net of interest payments

SER proportion of transfers to foreigners in government expenditures, net of interest payments

$XPND$ government expenditures, including interest payments.

To complete the specification of the government budget we determine revenues from non-tax payments and government enterprises, as well as government expenditures. We assume that federal and state and local personal non-tax payments are given as a proportion of before-tax labor income, so that revenue from non-tax payments is generated by:

$$R_{\mathrm{t}} = t_{\mathrm{t}} BL. \tag{10.26}$$

We assume that the value of labor compensation from government enterprises is given as a proportion of the value of total labor compensation:

$$PLE \cdot LE = SLE \frac{PLH \cdot LH - PLJ \cdot LJ}{1 - t_L^{\mathrm{m}}}. \tag{10.27}$$

Government enterprises employ labor to produce consumption goods; surpluses of these enterprises are revenues of the general government. We assume that the production of consumption goods by government enterprises CE is proportional to business production of these goods:

$$CE = SCE \cdot CS. \tag{10.28}$$

The surplus of government enterprises R_{ge} is the difference between the value of output and labor compensation:

$$R_{\mathrm{ge}} = PC \cdot CE - PLE \cdot LE. \tag{10.29}$$

We assume that the government allocates total expenditures, net of interest payments on government debt, among consumption goods, investment goods, labor services and transfer payments to the household and rest-of-the-world sectors in the following proportions:

$$\begin{aligned}
PC \cdot CG &= SCG(XPND - VGL \cdot i) \\
PI \cdot IG &= SIG(XPND - VGL \cdot i) \\
PLG \cdot LG &= SLG(XPND - VGL \cdot i) \\
EL &= SEL(XPND - VGL \cdot i) \\
ER &= SER(XPND - VGL \cdot i).
\end{aligned} \tag{10.30}$$

Under our assumptions on the allocation of government expenditures, we can aggregate the five categories of government expenditures by means of a linear logarithmic or Cobb–Douglas price function. The price index for government expenditures is defined as:

$$\ln PGS = SCG \cdot \ln(PCG) + SIG \cdot \ln(PIG) + SLG \cdot \ln(PLG), \tag{10.31}$$

where the price indexes of transfer payments to households and the rest of the world are equal to unity. The quantity of government expenditures net of interest payments is then defined as:

$$GS = \frac{XPND - VGL \cdot i}{PGS}. \tag{10.32}$$

In some experiments with alternative tax policies, we control the paths of real government expenditures and government debt, and use a "lump-sum tax" levied on the household sector to generate government revenue. We can express the revenue of the government as the sum of tax revenues, including this lump-sum tax, non-tax receipts and the surplus of government enterprises. Government revenue is defined as:

$$R = R_{\mathrm{C}} + R_{\mathrm{I}} + R_{\mathrm{q}} + R_{\mathrm{l}} + R_{\mathrm{e}} + R_{\mathrm{d}} + R_{\mathrm{ge}} + R_{\mathrm{q}}^{\mathrm{p}} + R_{\mathrm{m}}^{\mathrm{p}} + R_{\mathrm{h}}^{\mathrm{p}} + R_{\mathrm{t}} + R_{\mathrm{w}} + R_{\mathrm{lum}}. \tag{10.33}$$

We assume that government expenditures are a constant proportion of GDP:

$$XPND = SGOV \cdot GDP, \tag{10.34}$$

where GDP is defined below. The government budget constraint, including the government deficit, is defined by:

$$XPND = R + DG. \tag{10.35}$$

10.2.4.4 Rest of the world

To represent the rest-of-the-world sector we require the following notation:

DR current account deficit of the rest of the world

SCR proportion of purchases of consumption goods by the rest of the world to domestic purchases

SLR proportion of purchases of labor services by the rest of the world in the value of labor supply

SIR proportion of purchases of investment goods by the rest of the world to domestic supply.

We assume that purchases of consumption goods, labor services, and investment goods by the rest of the world are given by:

$$\begin{aligned} CR &= SCR(C + CG) \\ IR &= SIR \cdot IS \\ PLR \cdot LR &= SLR \frac{PLH \cdot LH - PLJ \cdot LJ}{1 - t_{\mathrm{L}}^{\mathrm{m}}}. \end{aligned} \tag{10.36}$$

The value of net exports from the US, together with earnings from claims on the rest of the world, net of the government transfers to foreigners, is added to the US claims on the rest of the world. The deficit of the rest of the world or surplus of the US is given by:

$$DR = PC \cdot CR + PI \cdot IR + PLR \cdot LR + \left[\left(1 - \beta_{\mathrm{q}}\right)\mathrm{r}^{\mathrm{e}} + \beta_{\mathrm{q}}(i - \pi)\right] VLR - ER. \tag{10.37}$$

10.2.4.5 National income and wealth

To represent the national income and product accounts we require the following notation:

D	economic depreciation
GDP	gross domestic product
GNP	gross national product
S	gross private national saving
V	revaluation of domestic capital
VK	value of private domestic capital
Y	gross private national income.

We define GDP as the market value of goods and services produced domestically, which is equal to the sum of the value of domestically employed labor and capital services, indirect taxes, and the surplus of government enterprises. Gross national product GNP is defined as the sum of GDP and the value of labor and capital services employed abroad:

$$\begin{aligned} GDP = {} & PLD \cdot LD + PLG \cdot LG + PLE \cdot LE \\ & + PQD \cdot QD + PMD \cdot MD + PHD \cdot HD + R_{\mathrm{C}} + R_{\mathrm{I}} + R_{\mathrm{ge}}. \\ GNP = {} & GDP + PLR \cdot LR + \left[\left(1 - \beta_{\mathrm{q}}\right)r^{\mathrm{e}} + \beta_{\mathrm{q}}(i - \pi)\right] VRL. \end{aligned} \tag{10.38}$$

Gross private national income Y is the sum of labor and capital incomes after taxes:

$$\begin{aligned} Y = {} & PLD\cdot LD + PLG\cdot LG + PLE\cdot LE + PLR\cdot LR - R_{\mathrm{l}} \\ & + PQD\cdot QD + PMD\cdot MD + PHD\cdot HD + \left[\left(1-\beta_{\mathrm{q}}\right)r^{\mathrm{e}} + \beta_{\mathrm{q}}(i-\pi)\right] VRL \\ & + VGL\cdot i - \left(R_{\mathrm{q}}^{\mathrm{p}} + R_{\mathrm{m}}^{\mathrm{p}} + R_{\mathrm{h}}^{\mathrm{p}} + R_{\mathrm{q}} + R_{\mathrm{e}} + R_{\mathrm{d}} + R_{\mathrm{w}} + R_{\mathrm{t}} + R_{\mathrm{lum}}\right). \end{aligned} \tag{10.39}$$

Gross private domestic saving S is defined as gross private national income plus government transfers to households, less household expenditures on consumption goods and capital services:

$$S = Y + EL - (PC\cdot C + PHD\cdot HD). \tag{10.40}$$

Saving is used to finance gross private domestic investment and the deficits of the government and rest of the world:

$$S = PI\cdot ID + DG + DR. \tag{10.41}$$

Private domestic investment is allocated among the six categories of private assets – short-lived and long-lived assets in the corporate, non-corporate and household sectors. We assume that tangible assets are perfectly malleable and can be transformed from one category to another. Under this assumption we can represent the accumulation of capital by:

$$VK = VKL + PI\cdot ID - D + V, \tag{10.42}$$

where VK is the current value of capital stock and VKL is the lagged value. For each asset category the value of economic depreciation is the product of the rate of economic depreciation and the current value of lagged capital stock and revaluation is the difference between the current and lagged values of the lagged capital stock.

The accumulation of nominal government debt is represented as:

$$VG = DG + VGL, \tag{10.43}$$

where VG is the current value of outstanding government debt. Similarly, the accumulation of claims on the rest of the world is represented as:

$$VR = DR + (1+\pi)VRL, \tag{10.44}$$

where VR is the current value of claims on the rest of the world.

10.2.5 Market equilibrium

We represent markets in the US economy corresponding to consumption goods, investment goods, labor services, and capital services. The business sector and government enterprises supply the consumption goods purchased by the household, government and rest-of-the-world sectors. The value of consumption goods supplied is equal to the value demanded:

$$(1+t_C)PCS \cdot CS + PC \cdot CE = PC \cdot (C + CG + CR). \tag{10.45}$$

We assume, further, that the products of the business sector and government enterprises are homogenous, so that balance between supply and demand implies:

$$CS + CE = C + CG + CR. \tag{10.46}$$

Equivalently, we can replace this equation with the relationship between the producer and consumer prices:

$$PC = (1+t_C)PCS.$$

We use the price deflator *PC* for consumption goods produced by government enterprises and for purchases by the household, government and rest-of-the-world sectors.

The business sector supplies the investment goods purchased by the household, government and rest-of-the-world sectors. Since private domestic saving is used to finance private investment, as well as the deficits of government and rest of the world sectors, the demand for private investment is given by:

$$PI \cdot ID = S - DG - DR. \tag{10.47}$$

The value of investment goods supplied is equal to the value demanded:

$$(1+t_I)PIS \cdot IS = PI \cdot (ID + IG + IR), \tag{10.48}$$

and the balance between supply and demand implies:

$$IS = ID + IG + IR. \tag{10.49}$$

As before, we can replace this equation with the relationship between the producer and consumer prices:

$$PI = (1+t_I)PIS. \tag{10.50}$$

We assume that the consumer is endowed with a fixed amount of time, fourteen hours per day. This can be consumed as leisure or supplied as labor services. The remaining time is required for personal maintenance. Labor supply is the difference between the time endowment of the household sector and the consumption of leisure. This supply is allocated among the business, government, government enterprise and rest-of-the-world sectors. For the economy as a whole, we distinguish among individuals by sex, level of education and age, and allow for the fact that wage rates vary among individuals. Since the composition of the time endowment, leisure and employment in the various sectors of the economy differs, we use separate price indexes for the time endowment and its various uses.

The demand for labor originates from businesses, governments, government enterprises and the rest of the world. The value of labor supplied is equal to the value demanded:

$$PLH \cdot LH - PLJ \cdot LJ = (PLD \cdot LD + PLG \cdot LG + PLE \cdot LE + PLR \cdot LR)\left(1 - t_{\mathrm{L}}^{\mathrm{m}}\right). \tag{10.51}$$

Since we have no mechanism to determine the relative prices of the time endowment, the consumption of leisure and labor demanded, we take the relative prices to be exogenous. We find it convenient to express the prices of labor in terms of the price for labor demanded by the business sector:

$$\begin{aligned} PLH &= \left(1 - t_{\mathrm{L}}^{\mathrm{m}}\right) A_{LH} \cdot PLD \\ PLJ &= \left(1 - t_{\mathrm{L}}^{\mathrm{m}}\right) A_{LJ} \cdot PLD \\ PLG &= A_{LG} \cdot PLD \\ PLE &= A_{LE} \cdot PLD \\ PLR &= A_{LR} \cdot PLD, \end{aligned} \tag{10.52}$$

where the factors of proportionality – A_{LH}, A_{LJ}, A_{LG}, A_{LE} and A_{LR} – are given exogenously.

Households are the sole suppliers of capital services and own all private capital. The demand side of the market includes corporate and non-corporate businesses, as well as households. As in the case of labor services, we take the relative prices of the six types of capital assets to be exogenous. Under the assumption of perfect malleability of capital any type of capital can be converted into any other type of capital with rates of transformation given by the relative prices. In order to describe the equilibrium of capital market, we introduce the following notation:

K_{QS} quantity of short-lived corporate capital stock

K_{QL} quantity of long-lived corporate capital stock

K_{MS} quantity of short-lived non-corporate capital stock

K_{ML} quantity of long-lived non-corporate capital stock

K_{HS} quantity of short-lived household capital stock

K_{HL} quantity of long-lived household capital stock.

We define capital services and capital stock in such a way that one unit of each of the six categories of capital stock generates one unit of capital services. The quantity index of the demand for capital services of a particular category is equal to the quantity index of the capital stock necessary to meet the demand for capital services, i.e., $K_{QS} = QS$,

$K_{QL} = QL$, $K_{MS} = MS$, $K_{ML} = ML$, $K_{HS} = HS$ and $K_{HL} = HL$. Given differences in tax rates, investment tax credits, capital consumption allowances, and economic rates of depreciation, a dollar's worth of assets in different categories of capital generates different amounts of capital services.

Equilibrium in the market for capital services is achieved when the total value of demands for all six categories of capital services is equal to the value of the capital stock available:

$$\begin{aligned} & PK_{QS}\cdot QS + PK_{QL}\cdot QL + PK_{MS}\cdot MS + PK_{ML}\cdot ML + PK_{HS}\cdot HS + PK_{HL}\cdot HL \\ & \quad = (1+\pi)VKL, \end{aligned} \tag{10.53}$$

where π is the rate of inflation in the price of capital assets, PK_{QS} is the current price of short-lived corporate capital stock and PK_{QL}, the current price of long-lived corporate capital stock, and so on. The equilibrium values of economic depreciation D and revaluation V are based on the allocation of capital among the six categories of assets.

In order to express Walras' law we can define the value of excess demand, say SXD, as the sum of differences between the values of supply and demand in each of the four markets. Substituting the definitions of tax revenues and the surplus of government enterprises, we obtain the following expression for the value of excess demands:

$$\begin{aligned} SXD =\ & PC(C + CG - CE) - (PCS\cdot CS + R_{\mathrm{C}}) + PI(ID + IG) - (PIS\cdot IS + R_{\mathrm{I}}) \\ & + (PLD\cdot LD + PLE\cdot LE + PLG\cdot LG) - \left[\frac{PLH\cdot LH - PLJ\cdot LJ}{1 - t_{\mathrm{L}}^{\mathrm{m}}}(1 - t_{\mathrm{L}}^{\mathrm{a}}) + R_{\mathrm{l}}\right] \\ & + (PQD\cdot QD + PMD\cdot MD + PHD\cdot HD) - (PQS\cdot K_{QS} + PQL\cdot K_{QL} + PMS\cdot K_{MS} \\ & + PML\cdot K_{ML} + PHS\cdot K_{HS} + PHL\cdot K_{HL}). \end{aligned} \tag{10.54}$$

where $K_{QS} = QS$, $K_{QL} = QL$, $K_{MS} = MS$, $K_{ML} = ML$, $K_{HS} = HS$ and $K_{HL} = HL$ are substituted from (10.53).

By successive substitutions we arrive at the following expression for the value of excess demand:

$$SXD = (PQD\cdot QD + PMD\cdot MD + PLD\cdot LD) - (PIS\cdot IS + PCS\cdot CS),$$

which is the zero profit condition of the business sector. Walras' law implies that the market clearing condition for one market is implied by the conditions for the other three markets and the budget constraints of the household, business, government and rest-of-the-world sectors. In solving the model, we drop the condition for equilibrium of the labor market.

In modeling the allocation of full consumption, production and the allocation of demand for capital services, we have imposed homogeneity of degree one on the price functions. For each of the six categories of capital services the price of capital services is homogeneous of degree one in the current and lagged prices of capital stock, given the rate of revaluation and the nominal rate of return. Finally, gross private national income and savings are homogenous of degree one in prices, given the nominal rate of return. We conclude that the model is homogeneous of degree zero in the prices and the nominal magnitudes, such as income and wealth, given the rate of inflation and the real private rate of return.

We normalize the prices by setting the current prices of capital assets and investment goods and the rate of inflation exogenously. Under this normalization, it is natural to define the rate of inflation as the rate of change in the price of capital assets and investment goods. As a consequence, we use the terms "rate of inflation" and "rate of revaluation" synonymously.

10.3 MODELING CONSUMER AND PRODUCER BEHAVIOR

In this section we present econometric estimates of the parameters of the models of consumer and producer behavior that we have introduced in the previous section. A more common methodology is to calibrate the parameter values to a single data point. Econometric methods are more burdensome from the computational point of view, but incorporate considerably more information.[27]

In order to estimate the parameters describing preferences in Section 10.3.1, we begin by specifying econometric models corresponding to the transition equation for full consumption and the share equations for allocating full consumption and household capital services within each time period. We impose the restrictions required for concavity of the underlying price functions at all data points in our sample. We combine the transition equation and the two sets of share equations and estimate the parameters simultaneously. The resulting parameter estimates generate our econometric model of consumer behavior.

We follow a similar strategy in estimating the parameters that describe technology. We first specify an econometric model corresponding to the share equations for outputs of consumption and investment goods and inputs of capital services from corporate and non-corporate assets. We then specify the share equations for allocating corporate and non-corporate capital services between short-lived and long-lived assets separately. We impose curvature restrictions on the underlying price functions at all data points in our sample. We estimate the three sets of equations simultaneously. The resulting estimates generate our econometric model of producer behavior in Section 10.3.2.

[27] More details on econometric methods for general equilibrium modeling are given by Jorgenson *et al.* in Chapter 17 of this Handbook.

We describe our econometric models of consumer and producer behavior in terms of price elasticities of demand and supply in Section 10.3.3. We present estimates of own-price and cross-price elasticities for each model. We also provide an estimate of the compensated elasticity of labor supply in our model of consumer behavior, holding consumer welfare constant. Finally, we provide estimates of the elasticities of substitution for both consumer and producer models. The intertemporal elasticity of substitution of full consumption is a constant parameter and we present an estimate of this elasticity as well.

We also assign values to the remaining parameters employed in our dynamic general equilibrium model in Section 10.3.4. We employ historical averages to represent debt—asset ratios in corporate, non-corporate and household sectors, the dividend pay-out ratio in the corporate sector, and the real interest rate. We use similar averages for the shares of different commodity groups in government expenditure, and the shares of the labor force employed by the rest of the world and government enterprises. Finally, we choose relative prices of different types of capital assets and investment goods and relative prices of different types of labor to coincide with historical relationships.

We choose values for the parameters that determine steady-state values for the debt of the government and rest of the world sectors to assure the existence of a viable long-run equilibrium of the US economy. The key parameter for the government sector is the share of government expenditures in GDP. For the rest-of-the-world sector the key parameters are net exports of consumption and investment goods as proportions of the domestic demand for consumption goods and domestic production of investment goods, respectively.

10.3.1 Consumer behavior

The lifetime budget constraint and the transition equation for full consumption determine the allocation of the household sector's wealth over time. To generate an econometric model for this allocation we add a disturbance term to the transition Equation (10.13), obtaining:

$$\ln\frac{F_{\mathrm{t}}}{F_{\mathrm{t}-1}} = \frac{1}{\sigma}[\ln(1+r_{\mathrm{t}}) - \ln(1+\tilde{r})] + \varepsilon_{Ft}, \quad t = 1,2,\ldots,T, \tag{10.55}$$

where r_t is the real private rate of return:

$$r_{\mathrm{t}} = \frac{PF_{\mathrm{t}-1}}{PF_{\mathrm{t}}}(1+\rho_{\mathrm{t}}) - 1,$$

and $\tilde{r}$ is the steady-state value of this rate of return:

$$\tilde{r} = (1+\gamma)(1-\alpha_T)^{\sigma} - 1.$$

The parameter σ is the inverse of the intertemporal elasticity of substitution and the parameter γ is the subjective discount rate, as in (10.13). We estimate the parameter α_T, the negative of the rate of labor-augmenting productivity growth, as part of the model of producer behavior described below. The disturbances ε_{Ft} correspond to random deviations from the optimal allocation of full consumption as well as errors in measurement of the growth rate of consumption. We assume that the disturbance term is distributed independently over time with expected value zero and constant variance.

Under homotheticity of preferences we can describe the allocation of full consumption among different commodity groups by means of the price function (10.14). The value shares (10.16) sum to unity, since this function is homogeneous of degree one in the prices. In addition, the matrix of share elasticities B_{PD} must be symmetric. We refer to these as the *summability* and *symmetry* restrictions. In addition, the value shares must be *non-negative*, since the price function is non-decreasing and the price function must be *concave* to guarantee the appropriate curvature.

To generate an econometric model for the allocation of full consumption we add a vector of random disturbances ε_{Dt} to the equations for the value shares (10.16), obtaining:

$$v_{Dt} = \alpha_{PD} + B_{PD} \ \ln PD_t + \varepsilon_{Dt}, \quad t = 1, 2, \ldots, T, \tag{10.56}$$

where the parameters α_{PD} and B_{PD} are the same as in (10.16), the variables v_{Dt} and $\ln PD_t$ now have time subscripts, and the vector of disturbances ε_{Dt} takes the form:

$$\varepsilon_{Dt} = \begin{bmatrix} \varepsilon_{Ct} \\ \varepsilon_{LJt} \\ \varepsilon_{HDt} \end{bmatrix}. \tag{10.57}$$

The disturbance vector corresponds to random deviations from the optimal allocation of full consumption within each time period and errors in measuring the value shares. We assume that the expected value of this vector is zero:

$$E(\varepsilon_{Dt}) = 0, \quad t = 1, 2, \ldots, T, \tag{10.58}$$

and the covariance matrix:

$$V\left(\varepsilon_{Dt}\right) = \textstyle\sum, t = 1, 2, \ldots, T, \tag{10.59}$$

is constant. We also assume that the disturbances of any two distinct time periods are distributed independently.

The summability restrictions imply that the value shares sum to unity, so that the sum of the corresponding disturbance terms must be zero:

$$i'\varepsilon_{Dt} = 0, t = 1, 2, \ldots, T \tag{10.60}$$

and the covariance matrix $\sum$ must be singular. We assume that this third-order matrix has rank two.

We incorporate symmetry and summability restrictions into our model of consumer behavior by imposing these restrictions on the parameter estimates for the share equations. To impose the concavity restrictions, we first consider the following transformation of the Hessian of the price function:

$$\frac{1}{PF}P'HP = B_{PD} + v_D v_D' - V_D, \tag{10.61}$$

where H is the Hessian, P is a diagonal matrix with prices of the three commodity groups along the main diagonal:

$$P = \begin{bmatrix} PC & 0 & 0 \\ 0 & PHD & 0 \\ 0 & 0 & PLJ \end{bmatrix},$$

v_{D} is the vector of value shares of full consumption and V_{D} is a diagonal matrix with these value shares along the main diagonal:

$$V_D = \begin{bmatrix} v_C & 0 & 0 \\ 0 & v_{HD} & 0 \\ 0 & 0 & v_{LJ} \end{bmatrix}.$$

Since the prices are non-negative, the Hessian H is negative semidefinite if, and only if, the expression on the right-hand side of equation (10.61) is negative semidefinite.[28]

Our strategy is to estimate the share equations with the parameters constrained so that concavity holds at all data points. We require that the transformation of the Hessian of the price function given in equation (10.61) must be negative semidefinite for each data point. We represent this transformation of the Hessian in terms of its Cholesky factorization:

$$B_{PD} + v_D v_D' - V_D = LDL', \tag{10.62}$$

where L is a lower triangular matrix and D is a diagonal matrix.

Given the prices of consumption goods, leisure, and household capital services, estimates of the parameters α_{PD} and B_{PD} are sufficient to determine the value shares, but the price level of full consumption is indeterminate. To fix the price level we add a constant term α_0^{PD} to the logarithmic price function and set its value at the average of:

$$\ln PF^* - \ln PD^{*'}\alpha_{PD}^* - \frac{1}{2}\ln PD^{*'}B_{PD}\ln PD^*,$$

[28] Further details are given by Jorgenson (2000).

for our sample period 1970–2010, where $\ln PF^*$ and $\ln PD^*$ are based on the price system consistent with our model. This assures that the fitted full consumption price tracks the historical path.[29]

To generate an econometric model for the allocation of household capital services we add a vector of random disturbances ε_{Ht} to the equations for the value shares (10.16), obtaining:

$$v_{Ht} = \alpha_{PH} + B_{PH} \ln PH_t + \varepsilon_{H_t}, \quad t = 1, 2, \ldots, T, \tag{10.63}$$

where the parameters α_{PH} and B_{PH} are the same as in (10.16), the variables v_{Ht} and $\ln PH_t$ have time subscripts, and the vector of disturbances ε_{Ht} takes the form:

$$\varepsilon_{Ht} = \begin{bmatrix} \varepsilon_{HLt} \\ \varepsilon_{HSt} \end{bmatrix}. \tag{10.64}$$

The disturbance vector corresponds to random deviations from the optimal allocation of household capital services within each time period, as well as errors in measuring the value shares. We assume that the expected value of this vector is zero, the covariance matrix is constant and the disturbances from distinct time periods are distributed independently. Summability implies that the value shares must sum to one, so that the disturbances must sum to zero and the covariance matrix is singular; we assume that this second-order matrix must have rank one.

We estimate all three components of our econometric model of consumer behavior simultaneously. The complete system of equations consists of the transition equation (10.55), two of the three equations for the allocation of full consumption (10.56) and one of the two equations for the allocation of household capital services (10.63). We estimate a total of 20 parameters – two in the transition equation, 12 in the allocation of full consumption and six in the allocation of household capital services. The symmetry and summability restrictions reduce the number of parameters in the four estimating equations to only nine.

In our model of the US economy these prices are endogenously determined by the interaction of supply and demand. The method of non-linear three-stage least squares (NL3SLS) is consistent and asymptotically efficient in the class of minimum distance estimators that employ the same set of instruments.[30] The NL3SLS estimator is invariant with respect to the choice of an equation to be dropped under the summability conditions.

We estimate our econometric model of consumer behavior by the method of NL3SLS, using the instrumental variables. The results are summarized in Table 10.1. The price function for household capital services satisfies the conditions for local concavity without imposing restrictions on the parameters. Cholesky values at each data point in the sample

29 We similarly determine the levels of estimated logarithmic price functions for capital services of the household, corporate and non-corporate sectors, and labor requirement in the business sector.

30 See Jorgenson and Laffont (2000).

Table 10.1 Allocation of lifetime wealth, full consumption and household capital services: parameter estimates

Parameter	Estimate	Standard error	*t*-Statistic
α_C	0.292687	1.84E-03	159.112
α_L	0.626518	1.36E-03	459.697
α_H	0.080796	1.20E-03	67.3279
β_{CC}	0.126598	4.91E-03	25.7708
β_{CL}	−0.149088	2.00E-03	−74.5344
β_{CH}	0.02249	2.96E-03	7.5919
β_{LC}	−0.149088	2.00E-03	−74.5344
β_{LL}	0.214793	3.45E-04	622.842
β_{LH}	−0.065705	1.86E-03	−35.3796
β_{HC}	0.02249	2.96E-03	7.5919
β_{HL}	−0.065705	1.86E-03	−35.3796
β_{HH}	0.043215	1.35E-03	32.0026
δ_L	−0.0192	0	0
λ_{LH}	0.785695	0.062624	12.5462
δ_H	−0.0192	0	0
α_o^{PD}	0.18315		
α_C^*	0.25077		
α_L^*	0.6869		
α_H^*	0.062325		
α_S^H	0.554599	4.21E-03	131.657
α_L^H	0.445401	4.21E-03	105.734
β_{SS}^H	0.054014	4.62E-03	11.6893
β_{SL}^H	−0.054014	4.62E+03	−11.6893
β_{LL}^H	0.054014	4.62E-03	11.6893
δ_S^H	−0.193005	4.41E+03	−43.7455
α_0^{PH}	−0.0025794		
σ	2.24146	0.370072	6.05682
γ	0.025545	6.82E-03	3.74696
SSR	5.55175		

δ_L and δ_H are constrained at −0.0192.

are given in Table 10.2. The non-negativity conditions hold at every data point in the sample. To interpret the implications of our estimates for consumer behavior we present price elasticities of demand and elasticities of substitution for this model in Section 10.3.3.

10.3.2 Producer behavior

There are many similarities between our models of the business sector and the household sector. We describe technology in terms of the labor requirements for producing outputs

Table 10.2 Allocation of lifetime wealth, full consumption and household capital services: local Cholesky values

Year	δ_L	δ_H	δ_S^H
1970	−0.0057291	−0.0045918	−0.18416
1971	−0.006374	−0.0080258	−0.18411
1972	−0.0097633	−0.023913	−0.18528
1973	−0.01124	−0.025123	−0.18567
1974	−0.0073066	−0.0010157	−0.18439
1975	−0.0083358	−0.00462	−0.18351
1976	−0.013836	−0.03007	−0.18627
1977	−0.016158	−0.034712	−0.18686
1978	−0.016819	−0.035911	−0.18746
1979	−0.015738	−0.031542	−0.18716
1980	−0.013559	−0.023004	−0.1863
1981	−0.015616	−0.029485	−0.18741
1982	−0.010566	−0.021383	−0.18856
1983	−0.01367	−0.030232	−0.18929
1984	−0.018305	−0.039538	−0.19018
1985	−0.018049	−0.037974	−0.19035
1986	−0.017541	−0.035397	−0.19019
1987	−0.012517	−0.027235	−0.19057
1988	−0.013113	−0.02767	−0.19072
1989	−0.014155	−0.028227	−0.19077
1990	−0.012881	−0.023753	−0.19089
1991	−0.010276	−0.014999	−0.19081
1992	−0.011373	−0.017586	−0.19088
1993	−0.012257	−0.017702	−0.19045
1994	−0.01288	−0.021883	−0.19095
1995	−0.012854	−0.021402	−0.19093
1996	−0.01594	−0.029309	−0.19155
1997	−0.016894	−0.030674	−0.19186
1998	−0.016711	−0.028402	−0.19186
1999	−0.018661	−0.030702	−0.19217
2000	−0.019045	−0.028468	−0.19207
2001	−0.018381	−0.02411	−0.19196
2002	−0.018896	−0.025672	−0.19262
2003	−0.018652	−0.022468	−0.19275
2004	−0.018556	−0.017872	−0.19245
2005	−0.0192	−0.0192	−0.193
2006	−0.02038	−0.021011	−0.1934
2007	−0.021479	−0.025349	−0.19421
2008	−0.020602	−0.024391	−0.19462
2009	−0.020534	−0.029333	−0.19512
2010	−0.022557	−0.03295	−0.19517

of consumption and investment goods, given inputs of corporate and non-corporate capital services. Our description of technology also expresses inputs of corporate and non-corporate capital services as functions of their long-lived and short-lived components. Finally, we impose conditions on the description of technology that imply the existence of balanced growth equilibrium for our dynamic general equilibrium model.

Under constant returns to scale we can describe the technology of the business sector through the price function for labor input (10.1). The value shares (10.2) derived from this price function sum to unity, since the function is homogeneous of degree one. The interpretation of this condition is that the value of the products is exhausted by the value of the factors of production. In addition, the matrix of share elasticities B_{PP} must be symmetric. We refer to these as the product *exhaustion* and *symmetry* restrictions.

The theory of producer behavior implies two additional sets of restrictions on our description of technology. First, the value shares of outputs of consumption and investment goods must be non-negative and the shares of inputs of corporate and non-corporate capital services must be non-positive, since the price function is non-decreasing in the prices of outputs and non-increasing in the prices of inputs. Second, the price function must be *convex* in order to guarantee the appropriate curvature.

To generate an econometric model for the outputs of consumption and investment goods, and inputs of corporate and non-corporate capital services, we add a vector of random disturbances ε_t to the equations for the value shares (10.2), obtaining:

$$v_t = \alpha_p + \mathrm{B}_{pp} \ln P_t + \beta_{PT} T + \varepsilon_t, \tag{10.65}$$

where the parameters α_{p}, B_{PP} and β_{PT} are the same as in (10.2), the variables v_t and $\ln P_t$ now have time subscripts, and the vector of disturbances ε_t takes the form:

$$\varepsilon_t = \begin{bmatrix} \varepsilon_{CSt} \\ \varepsilon_{ISt} \\ \varepsilon_{MDt} \\ \varepsilon_{QDt} \end{bmatrix}, \tag{10.66}$$

The disturbance vector corresponds to random deviations from the optimal allocation of outputs and inputs and errors in measuring the value shares. We assume that the expected value of this vector is zero, the covariance matrix is constant and the disturbances corresponding to any two distinct time periods are distributed independently. The product exhaustion condition implies that the value shares sum to unity, so that the sum of the corresponding disturbance terms must be zero and the covariance matrix must be singular. We assume that this fourth-order matrix has rank three.

The rate of productivity growth v_T is the negative of the growth rate of the price of labor input, holding the prices of the two outputs and the two capital inputs constant. To generate an econometric model for the rate of productivity growth we add a random disturbance ε_{Tt} to Equation (10.3):

$$-v_{Tt} = \alpha_{T} + \beta_{PT} \ln P_t + \beta_{TT} T + \varepsilon_{Tt}, \tag{10.67}$$

where the parameters α_T, β_{PT} and β_{TT} are the same as in (10.3) and the variables v_{Tt} and $\ln P_t$ have time subscripts. The disturbance ε_{Tt} corresponds to random shocks in the rate of productivity growth and errors in measurement in this growth rate.

The parameters β_{PT} and β_{TT} must be equal to zero in (10.65) and (10.67). These are the balanced growth restrictions. There are 21 parameters to be estimated in the equations for the value shares and the rate of productivity growth. Symmetry of the matrix B_{PP} reduces this number to 15 and product exhaustion reduces the number to 10. These restrictions also imply that the contemporaneous disturbances are linearly dependent and the covariance matrix is singular. Therefore, we drop the share equation for the output of consumption goods and estimate the parameters of the remaining four equations. As before, we employ the method of NL3SLS to obtain consistent estimates, using the instrumental variables.

The non-negativity and non-positivity restrictions on the share equations must be checked at each data point. To impose convexity restrictions on the price function for labor input, we consider the following transformation of the Hessian of the price function:

$$\left(\frac{1}{PLD}\right) P'HP = B_{PP} + vv' - V, \tag{10.68}$$

where H is the Hessian and P is a diagonal matrix with prices of the four inputs and outputs along the main diagonal:

$$P = \begin{bmatrix} PCS & 0 & 0 & 0 \\ 0 & PIS & 0 & 0 \\ 0 & 0 & PMD & 0 \\ 0 & 0 & 0 & PQD \end{bmatrix},$$

v is the vector of value shares of the outputs and inputs and V is a diagonal matrix with these value shares along the main diagonal:

$$V = \begin{bmatrix} v_{CS} & 0 & 0 & 0 \\ 0 & v_{IS} & 0 & 0 \\ 0 & 0 & v_{MD} & 0 \\ 0 & 0 & 0 & v_{QD} \end{bmatrix}.$$

Our strategy for imposing convexity on the price function for labor input is similar to the approach we have employed in our model of consumer behavior. We constrain the parameters of the share equations so that convexity holds at all data points in the sample. To impose convexity we require that the Hessian of the price function is positive semidefinite. We represent the transformation of the Hessian (10.68) in terms of its Cholesky factorization:

$$B_{PP} + v\,v' - V = LDL', \tag{10.69}$$

where L is a lower triangular matrix and D is a diagonal matrix.

Under convexity the diagonal elements of the matrix D, the Cholesky values, must be greater than or equal to zero. Since one of the Cholesky values is zero by product exhaustion, we impose inequality constraints on the three remaining values. The convexity restrictions are satisfied at all data points.

The rate of productivity growth cannot be measured directly. However, the translog price function (10.1) implies that the rate of productivity growth in any two periods can be expressed as *an exact index number*:[31]

$$\bar{v}_{Tt} = \Delta \ln PLD_t - \bar{v}_{Ct}\Delta \ln PCS_t - \bar{v}_{It} \ln PIS_t - \bar{v}_{Qt}\Delta \ln PQD_t - \bar{v}_{Mt}\Delta \ln PMD_t. \tag{10.70}$$

Under the balanced growth restrictions the negative of the average rate of productivity growth (10.70) in any two periods can be expressed as a constant plus the average of the disturbance terms in the two periods:

$$-\bar{v}_{Tt} = \alpha_T + \bar{\varepsilon}_{Tt}, \tag{10.71}$$

The covariance matrix of the transformed disturbances is the Laurent matrix:

$$\Omega = \begin{bmatrix} \frac{1}{2} & \frac{1}{4} & 0 & \dots & 0 \\ \frac{1}{4} & \frac{1}{2} & \frac{1}{4} & \dots & 0 \\ 0 & \frac{1}{4} & \frac{1}{2} & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \dots & \frac{1}{2} \end{bmatrix}.$$

31 See Jorgenson (2000) for further details.

The subdiagonals above and below the main diagonal of the matrix Ω reflect the serial correlation induced by averaging the rate of productivity growth. To eliminate this serial correlation we express the matrix Ω^{-1} in terms of the Cholesky factorization:

$$\Omega^{-1} = LDL',$$

where L is a lower triangular matrix and D is a diagonal matrix.

We transform the matrix Ω by premultiplying this matrix by the matrix square root of Ω^{-1}:

$$D^{\frac{1}{2}}L'\Omega LD^{\frac{1}{2}} = I,$$

where I is an identity matrix of order $T-1$. We can transform the vector of observations in the equation for the average rate of productivity growth (10.71) by means of this matrix square root to eliminate serial correlation.

We treat the share equations (10.65) symmetrically with the average rate of productivity growth (10.71) by expressing the average of the value shares in any two periods as a function of the average of the logarithm of the prices in the two periods:

$$\bar{v}_t = \alpha_P + \beta_{PP}\overline{\ln P_t} + \bar{\varepsilon}_t.$$

This transformation induces serial correlation that can be eliminated by multiplying the vector of observations by the matrix square root of the matrix Ω^{-1}.

Our strategy for estimation of the model of producer behavior is similar to the one we have used for the model of consumer behavior. However, we require that the price function for labor input is convex. We must also take account of serial correlation induced by construction of the exact index number for productivity growth. (i) We construct the variables by calculating 2-year averages of the value shares, the rate of productivity growth and the logarithms of prices. (ii) We transform the vector of dependent and independent variables by the matrix square root given above. (iii) We drop the share equation for consumption goods in order to incorporate the product exhaustion restrictions.

In estimating the parameters of producer behavior, α_P, α_T and B_{PP}, we normalize the producer prices of consumption goods, investment goods, corporate and non-corporate capital services at unity in 2005, and simplify representation of the convexity restrictions. The estimate of B_{PP} is not affected by the choice of the base year. To fix the level of producer price of labor services, we add a constant term α_0^P to the logarithmic producer price function of labor services, and set its value at the average of:

$$\ln PLD^* - \ln P^{*\prime}\alpha_P^* - \alpha_T T - \frac{1}{2}\ln P^{*\prime}, B_{PP}\ln P^*,$$

for 1970–2010, where $\ln PLD^*$ and $\ln P^*$ are based on the price system used in our dynamic general equilibrium model. This assures that the fitted value of labor price tracks the historical path.

In estimating models for the allocation of capital services between long-lived and short-lived assets in the corporate and non-corporate sectors, we follow the procedure employed for household capital services in Section 10.3.1. We pool the three components of our model of producer behavior by estimating the parameters simultaneously. By pooling observations we exploit the information in all three components of the model and take account of non-zero covariances among the disturbances.

In order to take account of the serial correlation induced by averaging the rate of productivity growth, we employ 2-year averages of both dependent and independent variables in all equations and eliminate the resulting serial correlation by transforming these averaged observations. Table 10.3 summarizes the estimates, which are used in our dynamic general equilibrium model. Table 10.4 gives the Cholesky values at each data point. As before, the fitted value shares satisfy appropriate non-negativity conditions for all data points.

10.3.3 Elasticities of demand and supply

The estimated values of the parameters in our models of consumer and producer behavior provide important information on the responses of consumers and producers to changes in tax policy. We supplement this information by deriving price elasticities of demand and supply implied by our parameter estimates, including the compensated price elasticity of supply for labor services. We also provide elasticities of substitution in consumption, including the intertemporal elasticity of substitution — a constant parameter in our model of consumer behavior.

We present own-price and cross-price elasticities of demand for consumption goods, leisure and household capital services, using pooled estimates for our model of consumer behavior and average shares for the period 1970—2010, in panel 2 of Table 10.5.

The average share of leisure is more than 64% of full consumption, while the share of consumption goods and services is slightly more than 27% and the share of household capital services is around 8.6%. The own-price elasticity of demand for consumption goods and services is 26%, while the own-price elasticity of demand for leisure is only 2.4% and the elasticity of demand for capital services is 41%.

The compensated elasticity of labor supply is, perhaps, a more familiar concept than the elasticity of demand for leisure. We employ the average ratio of the values of leisure and labor supply for the period 1970—2010 in estimating this elasticity; the result, given at the bottom of panel 2, Table 10.5, is 6.2%. The elasticity of intertemporal substitution in consumption is the inverse of σ, estimated from the transition equation for full consumption:

$$\ln \frac{F_t}{F_{t-1}} = \frac{1}{\sigma}\left[\ln\left(1 + r_t\right) - \ln\left(1 + \tilde{r}\right)\right] + \varepsilon_{Ft}, \quad t = 1, 2, \ldots, T.$$

This describes the rate of adjustment of full consumption to the difference between the real private rate of return and its long-run equilibrium value. The estimate of this elasticity reported in panel 3 of Table 10.5, is 44.6%.

Table 10.3 Production Frontier and the allocation of corporate and non-corporate capital services: parameter estimates

Parameter	Estimate	Standard error	*t*-statistic
α_C	1.08299	0.00700537	154.594
α_I	0.426091	0.00365921	116.444
α_Q	−0.368551	0.0055957	−65.8633
α_M	−0.14053	0.00203508	−69.0537
α_T	0.014622	0.013054	1.12008
β_{CC}	0.580427	0.086049	6.74531
β_{CI}	−0.429505	0.016886	−25.4353
β_{CQ}	−0.130724	0.069699	−1.87555
β_{CM}	−0.020199	0.023259	−0.868429
β_{IC}	−0.429505	0.016886	−25.4353
β_{II}	0.264538	0.000540894	489.075
β_{IQ}	0.138956	0.015006	9.2603
β_{IM}	0.026012	0.00237318	10.9607
β_{QC}	−0.130724	0.069699	−1.87555
β_{QI}	0.138956	0.015006	9.2603
β_{QQ}	−0.02263	0.059596	−0.379722
β_{QM}	0.014398	0.018498	0.778363
β_{MC}	−0.020199	0.023259	−0.868429
β_{MI}	0.026012	0.00237318	10.9607
β_{MQ}	0.014398	0.018498	0.778363
β_{MM}	−0.020211	0.00718281	−2.8138
δ_I	0.02	0	0
λ_{IQ}	−0.904055	0.727653	−1.24243
λ_{IM}	−1.69335	0.11627	−14.5639
δ_Q	0.465406	0.048976	9.5028
λ_{QM}	0.076434	0.050949	1.50022
δ_M	0.08	0	0
α_0^P	0.04412		
α_C^*	−0.14024		
α_I^*	1.09059		
α_Q^*	0.41778		
α_M^*	−0.36814		
α_S^Q	0.459123	0.00705052	65.119
α_L^Q	0.540877	0.00705052	76.7145
β_{SS}^Q	−0.02923	8.977486E−02	−2.99117
β_{SL}^Q	0.029238	0.00977486	2.99117
β_{LL}^Q	−0.02923	8.977486E−02	−2.99117
δ_S^Q	−0.27756	7.010253	−27.0712
α_0^{PQ}	0.010036		
α_S^M	0.173957	0.0031578	55.0879
α_L^M	0.826043	0.0031578	261.588
β_{SS}^M	0.069115	0.00398289	17.3531
β_{SL}^M	−0.06911	5.398289E−02	−17.3531
β_{LL}^M	0.069115	0.00398289	17.3531
δ_S^M	−0.07458	0.574420E−02	−12.9836
α_0^{PM}	−0.0045680		
SSR	8.90669		

δ_I and δ_M are constrained at 0.02 and 0.08, respectively.

Table 10.4 Production Frontier and the allocation of corporate and non-corporate capital services: local Cholesky values

Year	δ_I	δ_Q	δ_M	δ_S^Q	δ_S^M
1970	0.022576	0.30062	0.025622	−0.2741	−0.12085
1971	0.02135	0.3047	0.024552	−0.2738	−0.12229
1972	0.021915	0.3022	0.024074	−0.27412	−0.11996
1973	0.021229	0.30304	0.021604	−0.27461	−0.11585
1974	0.019102	0.31108	0.019989	−0.27476	−0.11514
1975	0.018589	0.31428	0.023622	−0.27463	−0.12007
1976	0.020112	0.30821	0.024832	−0.2746	−0.12055
1977	0.021592	0.30343	0.023615	−0.27477	−0.11647
1978	0.022133	0.30132	0.023535	−0.27502	−0.11475
1979	0.021092	0.30481	0.022115	−0.27508	−0.11372
1980	0.01916	0.31323	0.021056	−0.27492	−0.11489
1981	0.018827	0.31514	0.02028	−0.27486	−0.11483
1982	0.018941	0.3152	0.018593	−0.275	−0.11248
1983	0.01809	0.31927	0.015847	−0.27518	−0.11055
1984	0.018215	0.31648	0.012395	−0.27536	−0.10807
1985	0.018055	0.31586	0.009426	−0.2755	−0.10493
1986	0.016734	0.32488	0.008492	−0.27558	−0.10302
1987	0.015963	0.33196	0.0078281	−0.27534	−0.10339
1988	0.01564	0.33443	0.0059678	−0.27517	−0.10328
1989	0.015171	0.34098	0.0069308	−0.27532	−0.10174
1990	0.014689	0.3549	0.012434	−0.27536	−0.1008
1991	0.014542	0.3718	0.021896	−0.27532	−0.10106
1992	0.014734	0.38608	0.031102	−0.27532	−0.10153
1993	0.014947	0.39378	0.036093	−0.27539	−0.10119
1994	0.014839	0.3904	0.032846	−0.27557	−0.099776
1995	0.014737	0.38601	0.029015	−0.27576	−0.098399
1996	0.014775	0.38744	0.029308	−0.27592	−0.097097
1997	0.014855	0.39033	0.0303	−0.27613	−0.094962
1998	0.015229	0.40255	0.038323	−0.2763	−0.093688
1999	0.015979	0.41909	0.049579	−0.27644	−0.092055
2000	0.017021	0.43425	0.060449	−0.27654	−0.090273
2001	0.018913	0.45057	0.073976	−0.27658	−0.089185
2002	0.020562	0.45953	0.08213	−0.2767	−0.08665
2003	0.021418	0.46592	0.0859	−0.27693	−0.083543
2004	0.021406	0.47018	0.086233	−0.27723	−0.080016
2005	0.02	0.46541	0.08	−0.27757	−0.07458
2006	0.018655	0.4562	0.07159	−0.27786	−0.067841
2007	0.019428	0.46231	0.076328	−0.27796	−0.065103
2008	0.02271	0.47975	0.091671	−0.27784	−0.068882
2009	0.026121	0.49207	0.10159	−0.27767	−0.075016
2010	0.026036	0.49881	0.10184	−0.27772	−0.077245

Table 10.5 Elasticities of consumer behavior

1. Basic information	
Average shares (1970–2010)	
v_C	0.27325
v_{LJ}	0.64069
v_{HD}	0.08605
v_{HS}	0.57058
Second-order coefficients	
β_{CC}	0.1266
β_{CL}	−0.14909
β_{CH}	0.02249
β_{LL}	0.21479
β_{LH}	−0.065705
β_{HH}	0.043215
β_{SS}^{H}	0.054014
2. Compensated elasticities (with constant full consumption)	
Elasticities of demand	
ε_{CC}	−0.26344
ε_{CL}	0.095086
ε_{CH}	0.16836
ε_{LC}	0.040554
ε_{LL}	−0.02406
ε_{LH}	−0.016502
ε_{HC}	0.53461
ε_{HL}	−0.12286
ε_{HH}	−0.41175
Elasticity of labor supply	
ε_{LL}^{S}	0.06248
3. Elasticity of intertemporal substitution	
σ^{-1}	0.44614
4. Elasticities of intratemporal substitution	
e_{CL}	−0.24873
e_{CH}	−0.6323
e_{LH}	−0.33675
e_{HD}	−0.77955

The elasticity of substitution between two consumption goods is defined as the ratio of the proportional change in the ratio of the quantities consumed relative to the proportional change in the corresponding price ratio. The prices of other components are held constant, while the quantities are allowed to adjust to relative price changes. Our estimates of elasticities of substitution are based on parameter values from the pooled estimation of the model of consumer behavior, using average shares for 1970–2010. We report estimates of these elasticities in panel 4 of Table 10.5. The elasticity of substitution between the services of the long-lived and short-lived household assets is presented at the bottom of panel 4, Table 10.5. All of these elasticities are considerably less than one in absolute value, so that the corresponding value shares rise with an increase in price.

As in our model of consumer behavior, we define elasticities of substitution in production by allowing the relative quantities to adjust to changes in relative prices, while holding the prices of other inputs and outputs constant. We derive these elasticities from the pooled estimation of our model of producer behavior and the average value shares for 1970–2010. We report the results in panel 2 of Table 10.6.

Table 10.6 Elasticities of producer behavior

1. Basic information	
Average shares (1970–2010)	
v_{CS}	0.95513
v_{IS}	0.50823
v_{QD}	−0.3342
v_{MD}	−0.12913
v_{QS}	0.44533
v_{MS}	0.21496
Second-order coefficients	
β_{CC}	0.58043
β_{CI}	−0.4295
β_{CQ}	−0.13072
β_{CM}	−0.0202
β_{II}	0.26454
β_{IQ}	0.13896
β_{IM}	0.026012
β_{QQ}	−0.02263
β_{QM}	0.014398
β_{MM}	−0.02021
β_{SS}^{Q}	−0.02924
β_{SS}^{M}	0.069115
2. Elasticities of substitution	
e_{CL}	12.54486
e_{IL}	0.058447
e_{QL}	−0.94925
e_{ML}	−0.86138
e_{CI}	0.13778
e_{CQ}	−0.80182
e_{CM}	−0.86509
e_{IQ}	−3.39865
e_{IM}	−1.10465
e_{QM}	−0.8061
e_{QD}	−1.11837
e_{MD}	−0.59043

We also give the elasticities of substitution between the capital services from the short-lived and long-lived assets in the corporate and non-corporate sectors. The relative value shares of labor and the two capital inputs rise with a price increase if the elasticities of substitution are less than unity in absolute value and fall with a price increase if the elasticities are greater than unity in absolute value. The elasticities of substitution among inputs are less than unity in absolute value. However, the elasticities of substitution between labor and corporate capital, labor and non-corporate capital, and the two types of capital are only slightly less than one.

10.3.4 Non-tax parameters

We conclude this section by assigning values to the parameters of our model of the US economy that cannot be estimated econometrically. These include the ratio of government expenditures to GDP, *SGOV*, and the shares of government expenditures, net of interest payments on government debt, *SCG*, *SIG*, *SLG*, *SEL* and *SER*. These parameters are given in the first three panels of Table 10.7.

The next group of parameters includes the proportions of labor employed by government enterprises and net exports of labor services to the total labor supply, *SLE* and *SLR*. It also includes the production of consumption goods by government enterprises as a proportion of the total consumption goods produced by the business sector *SCE*. Finally, this group includes net exports of consumption goods as a proportion of the total domestic demand for consumption goods, *SCR*, and net exports of investment goods as a proportion of the total domestic production of investment goods, *SIR*. The parameters are given in panels 4 and 5 of Table 10.7.

The third group of parameters includes the dividend pay-out ratio of the corporate sector, α, the debt–asset ratios of the corporate, non-corporate and household sectors, β_q, β_m and β_h, and the real interest rate. This group of parameters is given in the sixth panel of Table 10.7. The parameters – *SGOV*, *SCR* and *SIR* – are used to calibrate the size of the government debt and claims on the rest of the world in the steady state of our model of the US economy. All other parameter values are set at the averages for the sample period, 1970–2010.

The fourth group of parameters is given in panels 7 and 8 of Table 10.7. This group includes the steady-state values of government debt and claims on the rest of the world, relative to the US GDP. The time endowment, *LH*, is set at the historical value in 2011. The growth of this time endowment reflects the growth of population as well as changes in the quality of labor.

Our population projections are based on the official projections by the Bureau of the Census for 2009.[32] Population growth and changes in labor quality will decline in the

[32] See: http://www.census.gov/population/www/projections/2009projections.html.

Table 10.7 Non-tax parameters

1. Size of government	
$SGOV = 0.20168$	government expenditure including debt service/GDP
2. Unemployment	
$SLU = 0.0$	share of unemployed time in total labor supply
3. Allocation of government expenditure, net of interest payments (1970–2010 averages)	
$SCG = 0.16883$	share of consumption goods
$SIG = 0.17814$	share of investment goods
$SLG = 0.47807$	share of labor services
$SEL = 0.16208$	share of transfer payments
$SER = 0.012887$	share of transfer to foreigners
4. Government enterprises (1970–2010 averages)	
$SLE = 0.018781$	share of labor used by government enterprises
$SCE = 0.028954$	ratio of consumption goods produced by government enterprises and the private sector
5. Export–import	
$SCR = -0.0007$	net export of consumption goods as a fraction of total domestic demand for consumption goods
$SIR = -0.0022$	net export of investment goods as a fraction of total production of investment goods
$SLR = -0.00048489$ (1970–2010 average)	share of exported labor
6. Financial variables (1970–2010 averages)	
$\alpha = 0.47855$	dividend pay-out ratio
$\beta_q = 0.098245$	debt–capital ratio in the corporate sector
$\beta_m = 0.22618$	debt–capital ratio in the noncorporate sector
$\beta_h = 0.33152$	debt–capital ratio in the household sector
$i_o = 0.046576$	real interest rate
7. Other parameters	
$LH_{2011} = 27820$	total time endowment in efficiency units of 2011
8. Wealth composition (steady state of the Base Case)	
Government debt/GDP $= 0.40$	
Claims on the rest of the world/GDP $= 0.05$	
9. Rates of economic depreciation	
$\delta_q^S = 0.1554$	short-lived corporate asset
$\delta_q^L = 0.0186$	long-lived corporate asset
$\delta_m^S = 0.1578$	short-lived noncorporate asset

(*Continued*)

Table 10.7 Non-tax parameters—cont'd

$\delta_m^L = 0.0122$	long-lived noncorporate asset
$\delta_h^S = 0.1895$	short-lived household asset
$\delta_h^L = 0.0132$	long-lived household asset
10. Prices of asset and investment goods (2011 values)	
$PK_q^S = 4.410$	short-lived corporate asset
$PK_q^L = 8.665$	long-lived corporate asset
$PK_m^S = 5.006$	short-lived noncorporate asset
$PK_m^L = 9.773$	long-lived noncorporate asset
$PK_h^S = 4.386$	short-lived household asset
$PK_h^L = 23.867$	long-lived household asset
$PI = 1.0473$	investment goods
11. Relative prices of labor	
$A_{LH} = 1.04411$ (1970–2010 average)	time endowment (before tax)
$A_{LJ} = 1.06406$ (1970–2010 average)	leisure (before tax)
$A_{LG} = 0.93698$ (1970–2010 average)	labor employed in general government
$A_{LE} = 0.97045$ (1970–2010 average)	labor employed in government enterprises
$A_{LR} = 1.0$	exported labor (assumption)
$A_{LU} = 1.0$	unemployed time (assumption)

future. The initial values of the quantity indexes of the capital stock, government debt and claims on the rest of the world are set at their historical values in 2011. This procedure guarantees that the size of our simulated economy is equal to that of the US economy in 2011.

The ratio of government debt to the US GDP has shown a distinct downward trend after the two World Wars. In view of the recent rise of the government debt/GDP ratio, we set the ratio at 65% of the GDP in 2011. In the same spirit, we set its steady-state value at 0.4. We set the steady-state ratio of the US claims on the rest of the world to the GDP at 0.05. We treat the paths of government debt and claims on the rest of the world as exogenous.

Our fifth group of parameters includes the rates of economic depreciation. We distinguish among corporate, non-corporate and household sectors and two types of assets, short-lived and long-lived, within each sector. For the corporate and non-corporate sectors the short-lived asset includes producers' durable equipment, while the long-lived asset includes structures, inventories, and land. For the household sector the short-lived asset includes 28 types of consumers' durables, while the long-lived asset includes structures and land.

The rates of economic depreciation of the six classes of assets, two classes within each of the three sectors, are weighted averages of their components with capital stocks at the end of 2010 as weights. For example, the rate of economic depreciation of the long-lived corporate asset is the average depreciation rate of 29 categories of non-residential structures, residential structures, non-farm inventories and land employed in the corporate sector. Economic depreciation rates for the six categories of assets are shown in panels 9 of Table 10.7.

Finally, we present two sets of relative prices in panels 10 and 11 of Table 10.7. The relative prices of the six categories of assets in the corporate, non-corporate and household sectors and the price of investment goods are the first of these. We set the relative prices of the six categories of assets and investment goods at their 2011 values, adjusted for the inflation of 2011. The relative prices of the time endowment, leisure, and labor employed in the various sectors of the economy and the rest of the world are set at historical averages for the period 1970–2010.

10.4 ECONOMIC IMPACT OF TAX REFORM

The objective of this section is to develop a methodology for evaluating the welfare effects of tax reform. For this purpose we design a computational algorithm for determining the time path of the economy following the reform. This algorithm is composed of two parts. First, we solve for the unique steady state of the economy corresponding to any tax policy. We then determine the unique transition path that is consistent with both the steady-state and the initial conditions. We describe the dynamics of our dynamic general equilibrium model of the US economy in terms of the saddle-point configuration of this transition path.

The plan of this section is as follows. In Section 10.4.1 we describe the dynamics of our model of the US economy. In Section 10.4.2 we present a methodology for comparing welfare levels for alternative tax policies. In Section 10.4.3 we outline our computational algorithm for determining the transition path to a new balanced growth equilibrium following tax reform. In the following section we evaluate the economic impact of alternative tax reform proposals.

10.4.1 Perfect foresight dynamics

In a world of perfect foresight the transition path of the economy from an initial state to the steady state is unique. It is also self-validating in the sense that expectations on the future course of the economy are actually realized. Suppose that the economy is initially at a steady state, indicated by point A in Figure 10.1. At the

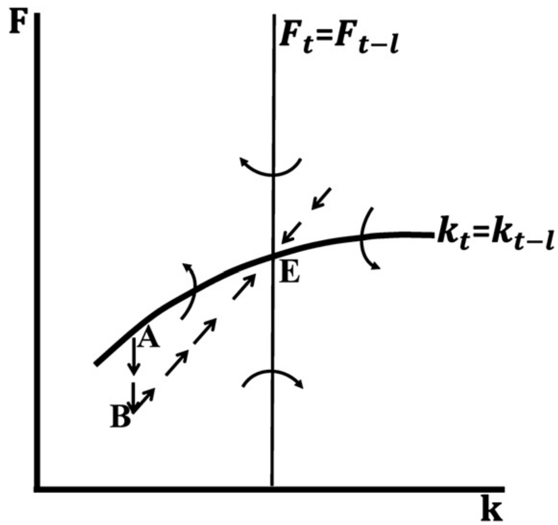

Figure 10.1 Transition path under perfect foresight.

steady state, the real private rate of return on capital is constant at the value determined by (10.12):

$$\tilde{r} = (1+\gamma)(1-\alpha_T)^{\sigma} - 1, \tag{10.72}$$

where γ is the rate of time preference, $-\alpha_T$ is the rate of labor-augmenting productivity growth and σ is the inverse of intertemporal elasticity of substitution. The steady-state value of the rate of return is independent of tax policy.

For expository purposes we first assume that the supply of labor is fixed and that full consumption includes only a single homogeneous good, measured in the same units as capital. We also assume that government rebates all the tax revenues to the household sector and that net exports are zero. We suppose that a new tax policy is introduced in order to improve the efficiency of capital allocation. The short run impact of this policy is that the nominal rate of return ρ rises above the steady-state level $\tilde{\rho}$.The transition path for full consumption is described by equation (10.9), so that:

$$F_t = F_{t-1}\left[\frac{PF_{t-1}}{PF_t}\,\frac{1+\rho_t}{(1+\gamma)(1-\alpha_T)^{\sigma}}\right]^{\frac{1}{\sigma}}, \tag{10.73}$$

where F is full consumption *per capita* with population expressed in efficiency units and PF is the price of full consumption. Immediately after the introduction of the new policy the level of full consumption rises over time. The intuition is that with a higher rate of return future consumption is cheaper relative to current consumption, so that the consumer can attain a higher level of welfare by saving more now in order to consume more in the future.

When the rate of return exceeds its long-run equilibrium level, capital intensity in the new steady state is higher than in the initial state. As the economy moves along the transition path, capital intensity rises and the rate of return is brought down, gradually, to the steady-state level. In the new steady state, represented by point E in Figure 10.1, both the level of full consumption and capital intensity are higher than at the starting point of the transition path, given by point B.

In order to understand the dynamics of the transition to a new steady state, it is useful to examine changes in the level of full consumption and capital intensity. At the beginning of period t the capital stock is the sum of capital stock at the beginning of period $t-1$ and investment during period $t-1$. In period t, this capital stock must be allocated among the total labor force. As a consequence, *capital intensity*, defined as the ratio of capital stock to labor in efficiency units, grows according to the equation:

$$k_t = \frac{[k_{t-1} + h(k_{t-1}) - F_t]}{(1-\alpha_T)(1+n_t)}, \tag{10.74}$$

where k_{t-1} is the capital intensity at the end of period $t-1$, h is the production function in intensive form, representing output *per capita* as a function of capital intensity, and n is the rate of population growth.

The locus of points at which capital intensity remains constant is characterized by $k_t = k_{t-1}$. In the steady state $n_t = n$. By substituting these conditions into (10.74), we obtain:

$$F_t = h(k_{t-1}) - ((1-\alpha_T)(1+n)-1)k_{t-1}. \tag{10.75}$$

Similarly, the locus of the points at which full consumption *per capita* remains constant is obtained by substituting $F_t = F_{t-1}$ into (10.73):

$$\tilde{\rho} = \rho_t. \tag{10.76}$$

Making use of Equations (10.73)–(10.76), we can illustrate the dynamics of our model of the US economy. In Figure 10.1 the arrows indicate directions of movement. If the new policy improves efficiency of the economy, the locus of $k_t = k_{t-1}$ shifts upward and the initial steady state at point A lies below the curve along which capital intensity is constant under the new policy. At the beginning of the transition the economy has to jump to point B by adjusting the level of full consumption downward. After this level of full consumption is known, we can describe the entire transition path of the economy with Equations (10.73) and (10.74). The only path that leads to the new steady state is $\overline{\text{BE}}$. Along this transition path the markets for goods and for labor and capital services clear in each period.

10.4.2 Comparison of welfare levels

In order to evaluate alternative tax policies, we compare the levels of social welfare associated with each of these policies. We can translate welfare comparisons into monetary terms by introducing the equivalent variation in wealth. We express the full wealth required to achieve a given level of welfare in terms of the time path of all future prices of full consumption and rates of return. We refer to this expression as *the intertemporal expenditure function*. Using the expenditure function, we can express differences in welfare in terms of differences in wealth.

To derive the intertemporal expenditure function we first express the time path of full consumption in terms of the initial level and future real private rates of return:

$$\frac{F_t}{F_0} = \prod_{s=0}^{t}\left[\frac{1+r_s}{(1+\gamma)(1-\alpha_T)^{\sigma}}\right]^{\frac{1}{\sigma}}, (t = 1, 2, \ldots), \tag{10.77}$$

Using this expression, we can write the intertemporal welfare function as:

$$V = \frac{F_0^{1-\sigma}}{1-\sigma}D, \tag{10.78}$$

where:

$$D = \sum_{t=0}^{\infty}\left[\frac{1}{(1+\gamma)^{\frac{1}{\sigma}}}\right]^{t}\prod_{s=0}^{t}(1+n_s)(1+r_s)^{\frac{1-\sigma}{\sigma}}.$$

The function D summarizes the effect of all future prices and rates of return on the initial level of full consumption F_0 associated with a given level of welfare V.

Since the optimal time path for full consumption must satisfy the intertemporal budget constraint, we can express the initial level of full consumption in terms of full wealth and all future real private rates of return:

$$F_0 = \frac{W}{PF_0}\,\frac{1}{D}.$$

Combining this expression with (10.78) and solving for full wealth, we obtain the intertemporal expenditure function, say $W(PF_0, D, V)$, where:

$$W\left(PF_0, D, V\right) = PF_0\left[\frac{(1-\sigma)V}{D^{\sigma}}\right]^{\frac{1}{1-\sigma}}. \tag{10.79}$$

We employ the intertemporal expenditure function to provide a money measure of differences in levels of welfare associated with alternative tax policies. For this purpose we first calculate the solution to our dynamic general equilibrium model of the US economy for the base case. We denote the resulting prices and discount rates by PF_0 and D_0 and the corresponding level of welfare by V_0. We then solve the model for a policy case and denote the resulting level of welfare by V_1. Finally, we calculate the *equivalent variation in full wealth*, say ΔW, where:

$$\begin{aligned}\Delta W &= W(PF_0, D_0, V_1) - W(PF_0, D_0, V_0) \\ &= W(PF_0, D_0, V_1) - W_0.\end{aligned} \tag{10.80}$$

The equivalent variation in full wealth (10.80) is the difference between the wealth required to attain the level of welfare associated with the policy case at prices of the base case, $W(PF_0, D_0, V_1)$, less the wealth required for the base case W_0. If the equivalent variation is positive, a change in policy produces a gain in welfare; otherwise, the policy change results in a welfare loss. The equivalent variations in full wealth enable us to rank the base case and any number of policy cases in terms of a money metric of the corresponding welfare levels.[33]

10.4.3 Computational algorithm

The computational algorithm for determining the solution of our dynamic general equilibrium model of the US economy has two stages. In the first stage we determine the steady state consistent with a given tax policy. In the second stage we find the transition path that is consistent with this steady state and the initial conditions at the time the tax policy is introduced.

The evolution of the economy from one period to the next is determined by the transition equation for full consumption and the accumulation equations for capital stock, government debt and claims on the rest of the world. The paths of government debt and claims on the rest of the world are predetermined and the initial value of capital stock is given. The second stage reduces to finding the initial level of full consumption that is consistent with convergence to the steady state of the economy.

Along the transition path, as well as in the steady state, the time endowment in efficiency units grows at the rate $(1-\alpha_T)(1+n_t)-1$. We find it convenient to use the property of constant returns in order to scale the solution of the model to the time endowment. When the economy moves from one period to the next, we rescale the economy by dividing the three stock variables − capital stock, government debt and claims on the rest of the world − at the end of the period by the factor $(1-\alpha_T)(1+n_t)$ in order to obtain the stocks available at the beginning of the next period.

With a rate of inflation different from zero we set the prices of the six categories of assets and the price of investment goods at the values shown in panel 10 of Table 10.7. For capital stock, government debt and claims on the rest of the world, we set the current prices at unity and the lagged prices at $1/(1+\pi)$. After the normalized equilibrium of the economy is determined, conversion to the actual size of the economy with the absolute price level is straightforward.

[33] The approach proposed by Ballard *et al.* (1985, Chapter 7) is based on the difference between present values of time paths of full consumption associated with alternative tax policies, rather than the equivalent variation in full wealth. Although there are important similarities between comparisons of present values of full consumption and the equivalent variation, the two approaches do not coincide.

We next describe the algorithm for computing market equilibrium for our model of the US economy. The model is in balanced growth equilibrium when all the quantities grow at the same rate $(1-\alpha_T)(1+n)$ and relative prices are constant. This is a steady state in the sense that the relative prices and quantities per unit of labor expressed in efficiency units are constant. In each period the relative prices and the allocation of the capital stock and the time endowment are determined so that all the markets clear, producers maximize profit and consumers maximize utility.

We can characterize the steady state of the economy by three conditions. (i) Capital stock, government debt and claims on the rest of the world grow at the same rate as the time endowment in efficiency unit:

$$VK = VKL - D + V + (S - DG - GR) = VKL(1-\alpha_T)(1+n)(1+\pi) \tag{10.81a}$$

$$VG = VGL + DG = VGL(1-\alpha_T)(1+n)(1+\pi) \tag{10.81b}$$

$$VR = VRL(1+\pi) + DR = VRL(1-\alpha_T)(1+n)(1+\pi). \tag{10.81c}$$

Equation (10.81a) shows that the nominal value of private capital decreases by the value of depreciation (D) and increases by revaluation of the capital remaining (V) and gross investment. Investment equals gross private saving (S), net of the accumulation of government debt (DG) and claims on the rest of the world (DR). Equation (10.81b) shows that the outstanding government debt grows at the rate of government budget deficit (DG). Equation (10.81c) shows that growth of the claims on the rest of the world is the sum of the trade deficit (DR) and the revaluation of the outstanding claims. In a steady state with a constant rate of inflation, the nominal value of private capital (VKL), government debt (VGL) and claims on the rest of the world (VRL) all grow at the same rate and the quantities of these variables per unit of labor in efficiency units remain constant. (ii) Full consumption per unit of labor in efficiency units remains constant:

$$F_t = F_{t-1}. \tag{10.82}$$

Together with (10.72) and (10.73), Equation (10.82) implies that that the nominal rate of return ρ is equal to its steady-state value $\tilde{\rho}$. (iii) Every market must clear in the steady state. By invoking Walras' law we can ignore the labor market, and consider clearing of markets for consumption goods, investment goods and capital services.

In the steady state all the endogenous variables can be expressed in terms of the seven variables: F, KL, GL, RL, PC, PLD and LD, where KL, GL and RL are quantity indexes of capital stock, government debt, and claims on the rest of the world, respectively.[34]

[34] The quantity indexes are implicitly defined by $VKL = KL \cdot PKL$, $VGL = GL \cdot PGL$ and $VRL = RL \cdot PRL$.

Thus, we have seven unknowns and six equations. The system is closed by the price possibility frontier (10.1) of the business sector:

$$\ln PLD = \ln P'\alpha_p + \alpha_T \cdot T + \frac{1}{2}\ln P' B_{PP} \ln P. \tag{10.83}$$

This form of the price possibility frontier is consistent with the existence of balanced growth equilibrium. We solve the equation system by Newton's method.[35]

To solve for the steady state, we set the prices of investment goods, capital stock, government debt and claims on the rest of the world exogenously. The prices of aggregate capital stock, government debt and claims on the rest of the world are set at unity. The producers' price of investment goods is obtained from:

$$PIS = \frac{PI}{1+t_{\mathrm{I}}}.$$

Since the real private rate of return r is equal to the value $\tilde{r}$ in the steady state, the nominal private rate of return is defined as:

$$\rho = (1+\tilde{r})(1+\pi) - 1, \tag{10.84}$$

and the nominal private rate of return on equity, say ρ^{e}, is obtained from the definition of ρ:

$$\rho\left(VKL + VGL + VRL\right) = \left((1-\beta)\rho^{\mathrm{e}} + \beta i_{\mathrm{k}}\right)\left(VKL + VRL\right) + i_{\mathrm{g}} \cdot VGL, \tag{10.85}$$

where β is the average debt-asset ratio of private national wealth, including private assets and claims on the rest of the world, i_{k} is the average after-tax nominal interest rate on private national wealth, and i_{g} is the after-tax nominal interest rate on government debt, defined as:

$$i_g = \left[1 - (1 - D1)t_g^d\right].i.$$

The nominal interest rate i is determined according to the strict version of Fisher's law:

$$i = i_0 + \pi,$$

where i_0 is the real interest rate, given exogenously. Given the nominal private rate of return to equity, the real rates of return for investments in the corporate, non-corporate and household sectors (r^{q}, r^{m} and r^{h}) can be calculated from the equations:

$$\begin{aligned} r^{\mathrm{q}} - \pi = {} & (1-\beta_{\mathrm{q}})\frac{\left[\rho^{\mathrm{e}} - \pi\left(1 - (1-DC)t_{\mathrm{q}}^{\mathrm{g}}\right)\right]\left(1 - \alpha DDt_{\mathrm{q}}\right)}{1 - \left[\alpha t_{\mathrm{q}}^{\mathrm{e}} + (1-\alpha)t_{\mathrm{q}}^{\mathrm{g}}\right]} \\ & + \beta_{\mathrm{q}}\left[\left(1 - (1-DI)t_{\mathrm{q}}\right)i - \pi\right] \end{aligned} \tag{10.86a}$$

35 More details on the computational procedure for applying Newton's method to our seven equation system for the steady state under the Base Case are presented in Chapter 7 of Jorgenson and Yun (2001).

$$r^{\mathrm{m}} - \pi = \left(1 - \beta_{\mathrm{m}}\right)\left[\rho^{\mathrm{e}} - \pi\left(1 - \left(1 - DC\right)t_{\mathrm{m}}^{\mathrm{g}}\right)\right] + \beta_{\mathrm{m}}\left[\left(1 - \left(1 - DI\right)t_{\mathrm{m}}^{\mathrm{e}}\right)i - \pi\right] \tag{10.86b}$$

$$r^{\mathrm{h}} - \pi = (1 - \beta_{\mathrm{h}})\left[\rho^{\mathrm{e}} - \pi\left(1 - (1 - DC)t_{\mathrm{h}}^{\mathrm{g}}\right)\right] + \beta_{\mathrm{h}}\left[\left(1 - DHI(1 - HDI)t_{\mathrm{h}}^{\mathrm{e}}\right)i - \pi\right]. \tag{10.86c}$$

The nominal private rate of return on equity ρ^{e} can be calculated from (10.85) if the average debt-asset ratio of private national wealth β and the average after-tax nominal interest rate i_{k} are known. However, β and i_{k} depend on the allocation of capital among the corporate, non-corporate and household sectors, which in turn depends on ρ^{e} through the discount rates for investment in the three private sectors as defined in (10.86a)—(10.86c). In order to simplify the algorithm, we include the nominal private rate of return to equity ρ^{e} in the list of unknowns and Equation (10.85) to the simultaneous equation system to be solved.

The remaining problem is to find the transition path consistent with the steady-state and the initial conditions of the economy. After the steady state of the economy is determined, the paths of government debt and claims on the rest of the world are also determined, so that capital stock and full consumption remain the essential determinants of the dynamics of the economy along the transition path. Given the level of full consumption in the first year on the transition path, the complete time path of full consumption is determined by the model. For this purpose we employ the method of multiple shooting.[36] It is convenient to assume that the economy has been under a new policy regime in period 0, one period before the policy is actually introduced. The computational procedures are similar to those of the steady-state solution except that we now take FS_0 as one of the unknowns and K_0, G_0 and R_0 as given where $FS_0 = F_0 \cdot PF_0{}^{1/\sigma}$. The current and lagged prices of assets, and the producer and purchaser's price of investment goods are determined as before.

We have assumed that the allocation of total government expenditure, net of the interest payments on government debt, among consumption goods (CG), investment goods (IG), labor (LG), and transfer payments to US citizens (EL) and to foreigners (ER) can be represented by a Cobb—Douglas price function (10.31):

$$\ln PGS = SCG \ln PC + SIG \ln PI + SLG \ln PLG + SEL \ln PEL + SER \ln PER,$$

where PGS is the price index of aggregate government spending, and SCG, SIG, SLG, SEL and SER are the exogenously given shares of government expenditure. Under an appropriate normalization of the indirect utility function of the government, the benefits derived from government spending are equal to the quantity of government spending (GS).

36 For a systematic treatment of the multiple shooting technique, see Lipton *et al.* (1982).

In the base case, we set the steady-state level of government spending equal to a fixed proportion *SGOV* of the GDP. Along the transition path the level of government spending is determined as the sum of the tax revenue and budget deficit. When we solve the model under the policy cases, we control the level of welfare derived from government spending by setting the quantity of government spending in each period at the value in the base case.

In a dynamic setting the budget constraint of the government requires that the present value of government spending equals the present value of government receipts plus the net worth of the government. Under this budget constraint, the government can finance a given amount of spending either by taxation or by issuing debt, followed by a tax increase to service and eventually repay the debt. However, this is not to say that tax financing and debt financing are equivalent in terms of their economic impact.

We require that the budget deficit of the government and government tax revenue must follow the same path under all the policies being compared. We assume that the level of government debt reaches its steady-state value in 39 years after the introduction of the new policy. We close the gap between the initial and the steady-state levels of the government debts at the annual rate of 1/34 during the first 29 years and then at the annual rate of 1/68 for the remaining 10 years. The steady-state value is reached in year 40. We apply the same procedure to determine the path of claims on the rest of the world.

Since the time paths of real government spending and the government budget deficit are predetermined, the level of tax revenue under an alternative tax policy must be adjusted to meet the budget constraint. In order to adjust the tax revenues, we consider four alternative approaches. These include the adjustments of a hypothetical lump-sum tax, sales taxes, the labor income tax and the individual income tax. In each period we have to find the size of tax adjustment along with other endogenous variables. When the lump-sum tax is adjusted to meet the government budget constraint, R_{lum} is added to government tax revenue and is subtracted from private national income.

Under the labor income tax adjustment we adjust the average and marginal tax rates on labor income either by the same percentage points or by the same proportion. These adjustment methods are referred to the *additive adjustment* and *proportional adjustment*, respectively. Under the sales tax adjustment, we adjust the tax rates on consumption goods and investment goods by the same percentage points. When the sales taxes are flat and the tax rates are identical, additive and proportional adjustments are equivalent. Finally, when the individual income tax is adjusted, we adjust the average and marginal tax rates on labor income either by the same percentage points or by the same proportion.

If the average and marginal tax rates on labor income are adjusted by the same percentage points, the average tax rate on capital income is also adjusted by the same percentage points, but the marginal tax rates on capital income are adjusted in the same proportion as the marginal tax rate on labor income. If the average and marginal tax rates on labor income are adjusted in the same proportion, the average and marginal tax rates on capital income are also adjusted in this proportion. We represent the size of tax adjustment by *ADJ* and to close the equation system for the equilibrium of the economy, we add the budget constraint of the government (10.35) as one of the balancing equations. The algorithm used to solve for the steady state for a policy case is similar to the one used for the base case.

In our model of the US economy trade with the rest of the world need not be balanced. However, capital employed abroad does not generate corporate tax revenues. Second, this capital is not combined with domestic labor in production, so that domestic labor productivity is unaffected. Therefore, we control the path of the claims on the rest of the world in the same way as government debt. In order to keep the trade deficit on a path implied by claims on the rest of the world, we adjust net exports of consumption and investment goods and labor services.

10.5 INCOME TAX REFORM

We next employ our dynamic general equilibrium model to evaluate the economic impact of alternative tax reform proposals. The economy is characterized by a price system that clears markets for labor and capital services and for consumption and investment goods. These prices link past and future through markets for investment goods and capital services. Assets are accumulated through past investments, while asset prices equal the present values of future capital services.

In this section we evaluate tax reforms that remove barriers to efficiency of the existing income tax system. In Section 10.5.1 we present the base case for our tax policy evaluations, based on the tax laws of 2010. We then consider policy cases involving the elimination of tax wedges among streams of capital income received from different classes of assets and different legal forms of organization. Finally, we consider Efficient Taxation of Income, which involves the elimination of all tax wedges among different forms of capital income and substitutes a proportional tax on labor income from a graduated or "progressive" tax on labor income.

10.5.1 Tax law of 2010

In order to evaluate the economic impact of alternative tax reforms we require a reference economy to serve as a base case. We take the US economy under the tax laws effective in 2010 as the point of reference. We take 1 January 2011 as the starting point for our simulations we consider. This takes place after the end of the Great Recession of 2007–2009. The simulated growth path of the US economy is the base case for our analysis of the economic impact of alternative tax reforms.

The growth of the population determines the time endowment available for work and leisure. We assume that the distribution of individuals by age, sex and education will evolve in accord with demographic projections. Hence, the quality of the time endowment, leisure and the labor employed in the various sectors of the economy will also change. We also assume that the efficiency of a given quality of labor improves at the rate of productivity growth.

In Table 10.8 we present the tax rates that describe the US tax system in 2010. These include: the marginal tax rates on individual capital income, the corporate income tax rate, the marginal tax rate on labor income and the average tax rate on personal income. The tax rates also include sales and property taxes, personal non-taxes, and wealth taxes.

Table 10.8 Tax rates (2010)

1. Marginal tax rates on individual income			
Inflation rate	0	0.04	0.08
t_q^e	0.19124	0.19185	0.19224
t_m^e	0.29027	0.29027	0.29027
t_h^e	0.29027	0.29027	0.29027
t_q^g	0.053	0.053	0.053
t_m^g	0.07257	0.07257	0.07257
t_h^g	0	0	0
t_q^d	0.16589	0.17681	0.18397
t_m^d	0.24493	0.24882	0.25138
t_h^d	0.27575	0.27589	0.27598
t_g^d	0.19384	0.19678	0.19871
2. Corporate income tax rate			
	t_q		0.38765
3. Marginal tax rate on labor income			
	t_L^m		0.25094
4. Average tax rates on personal income			
	t_L^a		0.095
	t_e^a		0.15218
	t_d^a		0.15218
5. Sales tax rates			
	t_C		0.0537
	t_I		0.0537
6. Property tax rates			
	t_q^p		0.01295
	t_m^p		0.01705
	t_h^p		0.00731
7. Others			
	t_t		0.0111
	t_w		0.00034

(*Continued*)

Table 10.8 Tax rates (2010)—cont'd

Notations:	
t_q^e, t_m^e, t_h^e :	Average marginal tax rates of individual income accruing to corporate, noncorporate and household equities, respectively
t_q^g, t_m^g, t_h^g :	Average marginal tax rates of capital gains accruing to corporate, noncorporate and household equities, respectively
$t_q^d, t_m^d, t_h^d, t_g^d$:	Average marginal tax rates of interest income accruing to corporate, noncorporate, household, and government debts, respectively
t_q :	Corporate income tax rate (federal + state and local)
t_L^m :	Average marginal tax rate of labor income
t_L^a :	Average tax rate of labor income
t_e^a, t_d^a :	Average tax rates of personal capital income from equity and debt
t_c, t_I :	Sales tax rates of consumption and investment goods
t_q^p, t_m^p, t_h^p :	Property tax rates of corporate, noncorporate and household assets, respectively
t_t :	Rate of personal non-taxes
t_w :	Effective rate of wealth taxation

Note: We set $t_h^e = t_m^e$ and $t_h^g = 0$.

Non-taxes are payments to the government sector that do not take the form of taxes, e.g. fees for government services provided to the private sector. Capital consumption allowances are permitted only for corporate and non-corporate business sectors.

In Table 10.9 we give the present values of the capital consumption allowances for short-lived and long-lived assets in 2010 under alternative rates of inflation. We calculate present values of the capital consumption allowances from the statutory depreciation schedules. We employ the after-tax nominal interest rate for discounting these allowances to the present.

Inflation is exogenous to our model. Under the 2010 tax law inflation increases the tax burden of corporate assets faster than that of non-corporate assets and the burden of non-corporate assets faster than that of household assets. Table 10.10 shows the impact of inflation on the performance of the US economy under a lump-sum tax adjustment, labor income tax, sales tax and individual income tax adjustments.

Table 10.9 Present value of capital consumption allowances (2010)

	Corporate		Non-corporate	
Inflation rate	**Short**	**Long**	**Short**	**Long**
0.00	0.9364	0.5907	0.9408	0.4914
0.04	0.8887	0.4811	0.896	0.3819
0.08	0.8465	0.4054	0.8558	0.3091

Table 10.10 Welfare effects of inflation under the 2010 law (billions of 2011 US$)

Rate of inflation	Revenue adjustment	Welfare effect
0.00	Lump-sum tax	1473.0
	Labor income tax	1092.2
	Sales tax	809.8
	Individual income tax	953
0.04	Lump-sum tax	0
	Labor income tax	0
	Sales tax	0
	Individual income tax	0
0.08	Lump-sum tax	−1339.7
	Labor income tax	−1061.8
	Sales tax	−813.3
	Individual income tax	−860.3

In 2011, GDP and the private national wealth (i.e., the sum of the real private assets in the corporate, non-corporate, and household sectors and the claims on the rest of the world at the beginning of the year) were $15,094 and 50,767 billion dollars, respectively.

10.5.2 Elimination of tax wedges

The economic impact of tax distortions can be measured by the improvement in economic welfare when the tax wedges are eliminated. We first analyze the impact of distortions resulting from the taxation of income from capital. We consider the elimination of tax wedges among assets and among sectors. We also consider the elimination of wedges between rates of return before and after taxes. Specifically, we measure the gains from the following changes in the 2010 tax system:

(i) Eliminate tax wedges between short-lived and long-lived assets within each sector.
(ii) Eliminate tax wedges between short-lived and long-lived assets in the business sector — corporate and non-corporate.
(iii) Eliminate tax wedges for short-lived and long-lived assets among all sectors — corporate, non-corporate and household.
(iv) Eliminate all tax wedges in the business sector.
(v) Eliminate all tax wedges in the private sector.
(vi) Corporate tax integration.
(vii) Eliminate taxation of income from capital
(viii) Eliminate capital income taxes and sales tax on investment goods.
(ix) Eliminate capital income taxes and property taxes.
(x) Eliminate capital income taxes, sales tax on investment goods and property taxes.

The social rate of return is the rate of return before all taxes, adjusted for inflation. This is calculated by subtracting the rate of depreciation from the price of capital services. The

Table 10.11 Steady state of the base case (rate of inflation: 4%)

	Corporate		Non-corporate		Household	
	Short	Long	Short	Long	Short	Long
w	0.1062	0.2325	0.0169	0.1683	0.1157	0.3603
z	0.8887	0.4811	0.896	0.3819	0	0
δ	0.1554	0.0186	0.1578	0.0122	0.1895	0.0132
PKS	0.2722	0.1457	0.2562	0.1148	0.2597	0.0764

w: Share of capital stock.
z: Present value of capital consumption allowances.
δ: Economic depreciation rate.
PKS: Price of capital services.

social rate of return includes the inflation-adjusted rate of return after all taxes, together with the tax burdens due to corporate income taxes, individual income taxes and property taxes. The tax burdens are partly offset by capital consumption allowances. In order to eliminate tax wedges among asset categories, we equalize the social rates to return by assigning an appropriate investment tax credit to each category of assets.

Table 10.11 shows the present values of capital consumption allowances z and the rates of economic depreciation δ. Capital consumption allowances are deductions from income for tax purposes and must be distinguished from tax credits, which are deductions from tax liabilities. Table 10.11 also shows the steady-state allocation of capital stock ω and prices of capital services PKS for the base case corresponding to the 2010 tax system. The tax credits required for the first six sets of changes in the 2010 tax system are presented in panel 2 of Table 10.12, along with the corresponding social rates of return and effective tax rates. For comparison base case figures are presented in panel 1.

The welfare effects of the 10 tax reform proposals are summarized in Table 10.13. We begin with simulations based on a lump-sum tax adjustment to achieve revenue neutrality. This provides a standard of comparison for more realistic policies that achieve revenue neutrality by adjusting distorting taxes, such as labor income taxes, sales taxes and individual income taxes. We find that the welfare gain from the elimination of the tax wedges within the three sectors is $479.0 billion (2011 US$). Under lump-sum tax adjustment, elimination of tax wedges between the corporate and non-corporate sectors yields a welfare gain of only $40.7 billion.

The economic impact of our third tax reform proposal illustrates the substantial welfare gains from eliminating tax wedges between the business and household sectors. This is intuitively plausible, given the size of the tax wedges between these sectors. The estimated gain is $5347.8 billion. By contrast, the welfare gain from eliminating all tax wedges among business assets alone is only $303.9 billion. The fifth simulation eliminates all the tax wedges among sectors and assets, leading to efficient allocation of capital

Table 10.12 Elimination of interasset and intertemporal tax wedges (rate of inflation: 4%)

	Corporate		Non-corporate		Household	
	Short	Long	Short	Long	Short	Long
1. Base case						
$\sigma - \pi$	0.1106	0.1264	0.0921	0.1021	0.0626	0.0626
e	0.3584	0.4384	0.3061	0.3738	0.0761	0.0761
k	0	0	0	0	0	0
2. Alternative policies						
(i) No interasset wedges: corporate and non-corporate						
$\sigma - \pi$	0.1214	0.1214	0.1012	0.1012	0.0626	0.0626
e	0.4155	0.4155	0.3682	0.3682	0.0761	0.0761
k	−0.0273	0.0303	−0.028	0.0083	0	0
(ii) No intersector wedges: corporate and non-corporate						
$\sigma - \pi$	0.1081	0.1162	0.1081	0.1162	0.0626	0.0626
e	0.3433	0.3891	0.4085	0.4497	0.0761	0.0761
k	0.0064	0.0625	−0.0493	−0.128	0	0
(iii) No intersector wedges: all sectors						
$\sigma - \pi$	0.0861	0.0908	0.0861	0.0908	0.0861	0.0908
e	0.1753	0.2186	0.2571	0.2961	0.3277	0.363
k	0.0621	0.2179	0.0188	0.1025	−0.0921	−0.3962
(iv) No interasset and intersector wedges: all assets, corporate and non-corporate						
$\sigma - \pi$	0.1143	0.1143	0.1143	0.1143	0.0626	0.0626
e	0.3789	0.3789	0.4406	0.4406	0.0761	0.0761
k	−0.0092	0.0741	−0.0685	−0.1107	0	0
(v) No interasset and intersector wedges: all assets, all sectors						
$\sigma - \pi$	0.0897	0.0897	0.0897	0.0897	0.0897	0.0897
e	0.2086	0.2086	0.2872	0.2872	0.3549	0.3549
k	0.0529	0.2249	0.0075	0.1129	−0.1063	−0.3802
(vi) Corporate tax integration						
$\sigma - \pi$	0.0921	0.1021	0.0921	0.1021	0.0626	0.0626
e	0.2296	0.3048	0.3061	0.3738	0.0761	0.0761
k	0.0468	0.1488	0	0	0	0

$\sigma - \pi$: Social rate of return.
e: Effective tax rate.
k: Investment tax credit.
π: Inflation rate.

within each time period. The welfare gain is estimated to be \$5567.0 billion. Most of this can be attributed to the elimination of tax wedges between business and household sectors, as in the third simulation.

The sixth simulation, corporate tax integration, is the key to President Bush's Advisory Panel's Simplified Income Tax Plan. In this simulation we eliminate tax wedges between the assets in the corporate and non-corporate assets by setting the

Table 10.13 Welfare effects of tax distortion: 2010 tax law (billions of 2011 US$)[a]

Eliminated wedges and method of revenue adjustment	Welfare effect	
	Additive[b]	Proportional[c]
(i) Within sector interasset distortion		
Lump-sum tax adjustment	479.0	479.0
Labor income tax adjustment	473.7	551.6
Sales tax adjustment	483.2	483.2
Individual income tax adjustment	474.3	570.0
(ii) Intersector distortion: corporate and non-corporate sectors		
Lump-sum tax adjustment	40.7	40.7
Labor income tax adjustment	−27.4	−62.8
Sales tax adjustment	−70.5	−70.5
Individual income tax adjustment	−63.4	−100.9
(iii) Intersector distortion: all sectors		
Lump-sum tax adjustment	5347.8	5347.8
Labor income tax adjustment	5326.2	5367.5
Sales tax adjustment	5313.2	5313.2
Individual income tax adjustment	5313.0	5364.2
(iv) Interasset and intersector distortion: corporate and non-corporate sectors, all assets		
Lump-sum tax adjustment	303.9	303.9
Labor income tax adjustment	253.9	248.1
Sales tax adjustment	223.0	223.0
Individual income tax adjustment	227.6	226.9
(v) Interasset and intersector distortion: all sectors, all assets		
Lump-sum tax adjustment	5567.0	5567.0
Labor income tax adjustment	5558.1	5619.4
Sales tax adjustment	5550.3	5550.3
Individual income tax adjustment	5545.4	5612.6
(vi) Corporate tax integration (set $\sigma^q = \sigma^m$)		
Lump-sum tax adjustment	2320.2	2320.2
Labor income tax adjustment	1715.4	398.3
Sales tax adjustment	1237.6	1237.6
Individual income tax adjustment	1422.4	100.0
(vii) Capital income taxes (business and personal)		
Lump-sum tax adjustment	5176.7	5177.0
Labor income tax adjustment	3858.5	−1104.7
Sales tax adjustment	3138.3	3138.3
Individual income tax adjustment	3858.5	−1104.7
(viii) Capital income taxes and sales tax on investment goods		
Lump-sum tax adjustment	5628.2	5628.4
Labor income tax adjustment	3997.9	−3799.3

(*Continued*)

Table 10.13 Welfare effects of tax distortion: 2010 tax law (billions of 2011 US$)[a]—cont'd

Eliminated wedges and method of revenue adjustment	Welfare effect	
	Additive[b]	Proportional[c]
Sales tax adjustment	2996.1	2995.5
Individual income tax adjustment	3997.9	−3799.3
(ix) Capital income taxes and property taxes		
Lump-sum tax adjustment	6054.0	6054.0
Labor income tax adjustment	3490.1	−18738.7
Sales tax adjustment	2557.6	2557.8
Individual income tax adjustment	3490.1	−18738.7
(x) Capital income taxes, sales tax on investment goods, and property taxes		
Lump-sum tax adjustment	6421.8	6422.1
Labor income tax adjustment	3543.4	−25441.2
Sales tax adjustment	2280.6	2280.4
Individual income tax adjustment	3543.4	−25441.2

[a]Inflation is fixed at 4% per year.
[b]Under the additive tax adjustment, the average and marginal tax rates of labor income and the average tax rates of individual capital income are adjusted in the same percentage points. The marginal tax rates of individual capital income are adjusted in the same proportion as the marginal tax rate of labor income.
[c]Under the proportional tax adjustment, average and marginal tax rates are adjusted in the same proportion.

social rates of return of corporate assets equal to the corresponding rates on noncorporate assets. The tax burdens on the corporate assets are unambiguously reduced without an offsetting increase in other marginal tax rates. The estimated welfare gains are $2320.2 billion, less than half the gains from eliminating all tax wedges among sectors and assets.

In the first six simulations we have focused on the distorting impact of tax wedges among sectors and assets. In the following four simulations, we estimate the welfare cost of tax distortions resulting from wedges between before- and after-tax rates of return. We eliminate the distortions caused by the taxes on capital income, including property taxes and sales taxes on investment goods. In the seventh simulation we set the effective tax rates on all forms of capital equal to be zero.

We find that elimination of capital income taxes at both individual and corporate levels generates a welfare gain of $5176.7 billion. Eliminating sales taxes on investment goods as well increases this gain to $5628.2 billion. Eliminating capital income taxes and property taxes produces a gain of $6054.0 billion, while eliminating taxes on investment goods as well generates a gain of $6421.8 billion.

Table 10.13 also shows that the magnitudes of welfare gains under alternative tax adjustments. Since the elimination of tax wedges is not revenue-neutral, changes in tax rates to generate the missing revenue can produce significant distortions. For this reason the welfare effects are very sensitive to the method for revenue adjustment. These effects are most sensitive to the choice between lump-sum tax adjustment and the distorting tax adjustments. The results are also somewhat sensitive to choices among the distorting tax adjustments, especially when the required revenue is large.

10.5.3 Efficient Taxation of Income

Our final simulation is intended to measure the distortions associated with progressivity of the tax on labor income. A progressive tax on labor income produces marginal tax rates far in excess of average tax rates. Our point of departure is the elimination of all tax distortions in panel (v) of Table 10.13. In Table 10.14 we replace the progressive labor income tax by a proportional labor income tax. Under a lump-sum tax adjustment this generates a welfare gain of $6963.6 billion – a substantial increase over the gain from eliminating all capital income distortions.

We conclude that a tax reform that would combine elimination of tax wedges among all sectors and assets with substitution of a proportional tax on labor income for a graduated tax would produce the greatest gain in consumer welfare. Elimination of the tax wedges would remove barriers to efficient allocation of capital. The lower marginal tax rate on labor income would substantially reduce distortions from labor income taxes.

Table 10.14 describes the new approach to tax reform that we call Efficient Taxation of Income. This would avoid a drastic shift in tax burdens by introducing different tax rates for property-type income and earned income from work – a distinction that existed in the US tax code between 1969 and 1982. An important advantage of Efficient Taxation of Income is that the tax bases would be defined exactly as in the existing tax code, so that no cumbersome transition rules would be required.

The key to Efficient Taxation of Income is the system of investment tax credits presented in Table 10.12. These credits would equalize the tax burdens on all sources of business income. The average tax credits for corporations would be 5.3% on equipment and 22.5% on structures. Non-corporate business would receive smaller credits of 0.8% on equipment and 11.3% on structures. In order to equalize tax burdens on business and

Table 10.14 Welfare cost of labor tax progressivity under efficient capital allocation (billions of 2011 US$)

	Revenue adjustment		
	Progressive		Proportional
	Additive	Proportional	Additive
Lump-sum tax	5567	5567	6963.6
Labor income tax	5558.1	5619.4	6961.1
Sales tax	5550.3	5550.3	6988.2
Individual income tax	5545.4	5612.6	6980.7

1. Inflation is fixed at 4% per year.
2. The figures for the progressive labor income tax are the same as in Panel (v) of Table 10.13.

household assets, prepayments of taxes on new investments by households would be required. The prepayment rates given in Table 10.12 would be 10.6% on new durables and 38% on new housing. The additional revenue from these prepayments would precisely offset the tax credits for business investment, preserving revenue neutrality.

Under Efficient Taxation of Income individuals would continue to file the familiar Form 1040 for individual income, while corporations would file corporate income tax returns. Deductions from taxable income, as well as tax credits and exemptions, would be unaffected. Businesses would continue to claim depreciation on past investments, as well as tax deductions for interest paid on debt. Mortgage interest and property taxes would be deductible from individual income for tax purposes. The tax treatment of Social Security and Medicare would remain the same, and the private pension fund industry would not be eviscerated.

It is important to emphasize that prepayments would apply only to new investments in owner-occupied housing and consumers' durables. Owners of existing homes and consumer durables would be deemed to have prepaid all taxes at the time of their original purchase. No additional taxes would be imposed on housing or durables already in the hands of households. This is essential for enactment, since 65% of households own their homes. Home owners are also voters who can express their concerns about maintaining the value of their property and new taxes on existing homes at the ballot box.

The prepayments under Efficient Taxation of Income are essential to protect property values after tax reform is enacted. The cost of new housing reflects the cost of capital to businesses, including the taxes paid on capital income. These taxes would be reduced sharply for corporations and substantially for non-corporate businesses. Without tax prepayments in place, the price of new housing would plummet. This price decline would erode the price structure for existing housing, leading to capital losses for home owners. After introduction of Efficient Taxation of Income most existing home owners would enjoy a modest capital gain.

A second point to emphasize is that tax credits for new investments in structures by corporations and non-corporate businesses would apply to new rental housing. These credits would provide incentives for real estate developers to expand the construction of rental housing. The added supply of rental housing would provide existing renters with more attractive and affordable options. It would also substantially reduce housing costs for newly formed households.

In summary, Efficient Taxation of Income would preserve all the features of the existing tax code that have been carefully crafted by generations of lawmakers since adoption of the Federal income tax in 1912. At the same time this new approach to tax reform would remedy the conspicuous deficiencies in our income tax system. These arise from differential taxation of corporate income and exclusion of owner-occupied housing, as well as consumers' durables, from the income tax base. In addition, substantial gains would arise from replacing the progressive taxation of labor income by a proportional labor income tax. We turn next to tax reforms that would shift the tax base from income to consumption.

10.6 CONSUMPTION TAX REFORM

A useful starting point for the definition of consumption for tax purposes is personal consumption expenditures (PCE), as defined in the US NIPA.[37] However, the taxation of the services of household capital poses significant administrative problems, reviewed in the US Department of the Treasury (1984) monograph on tax reform. The services of owner-occupied housing and consumers' durables could be taxed by the "prepayment method" described by Bradford (1986). Taxes on these capital services would be prepaid by including investment rather than consumption in the tax base, as in Efficient Taxation of Income.

Proposals to replace income by consumption as a tax base in the US were revived during the 1990s. We compare the economic impact of consumption tax proposals, taking the 2010 Tax Law as a point of departure. In Section 10.6.1 we consider impact of the Hall—Rabushka proposal and the closely related Armey—Shelby Proposal. These are similar to the Growth and Investment Plan of President Bush's Advisory Panel (2005). In Section 10.6.2 we analyze the economic impact of replacing the existing tax system by a National Retail Sales Tax (NRST). We consider combinations of consumption and labor income taxes and evaluate the cost of progressivity by comparing proportional or "flat" taxes with graduated or "progressive" taxes.

10.6.1 Alternative proposals

The "subtraction method" for implementing a consumption tax is the basis for the ingenious Flat Tax proposed by Hall and Rabushka (1983, 1995). The Hall—Rabushka proposal divides tax collections between firms and households. Firms would expense or "subtract" the cost of all purchases from other businesses, including investment goods. Firms would also deduct purchases of labor services, so that labor compensation — wages and salaries, health insurance, pension contributions, and other supplements — could be taxed at the individual level. This facilitates the introduction of personal allowances for low-income taxpayers in order to achieve progressivity.

Taxation of business firms under the Hall—Rabushka proposal is different from the current income tax system in three ways. (i) A constant tax rate would be applied to the tax base, hence the identification of this proposal as a Flat Tax. (ii) Interest paid by the firm would no longer be tax deductible. (iii) Investment spending would be recovered through immediate write-offs, so that the effective tax rate on new investments would be zero. The inclusion of interest payments in the tax base eliminates the differential tax

37 See Bureau of Economic Analysis (2011).

treatment of debt and equity, insuring financial neutrality of the tax system. These features of the Flat Tax have been incorporated into President Bush's Advisory Panel's Growth and Investment Plan.

The Armey—Shelby proposal, introduced in the 104th Congress by former Representative Richard Armey and Senator Dick Shelby, is a variant of the Hall—Rabushka Flat Tax proposal.[38] The Armey—Shelby proposal is more generous to the taxpayer than the Hall—Rabushka proposal, since the tax rate is lower after the first two years and the family allowances are higher. The natural question is, would the Armey—Shelby proposal achieve revenue neutrality? Since Hall and Rabushka have set the Flat Tax rate to make the Hall—Rabushka proposal revenue-neutral, it is clear that tax revenue under the Armey—Shelby would fall short of neutrality. We will show, however, that neither proposal would achieve revenue neutrality.

A proposal for replacing the income tax system with a NRST has been introduced by former Representatives Dan Schaefer, Bill Tauzin and others.[39] The Schaefer—Tauzin proposal replaces personal and corporate income taxes, estate and gift taxes, and some excise taxes with a 15% national retail sales tax on a tax-inclusive consumption base. On this definition the tax base would include sales tax revenues as well as the value of retail sales to consumers. The Schaefer—Tauzin proposal allows for a family consumption refund in order to achieve progressivity.

To achieve revenue neutrality through a NRST, we consider a number of alternatives to the Schaefer—Tauzin proposal. In all of these alternatives, new investment would be excluded from the tax base. We first construct a prototype NRST, and then develop alternative proposals by varying the degree of progressivity and the division of revenues between the sales tax and a labor income tax. The labor tax may be flat or proportional to the tax base, or may be graduated by introducing a system of family allowances.

10.6.2 Modeling the tax reform proposals

We maintain the role of the property tax in the existing US tax system in all of our simulations. However, we consider alternative treatments of existing sales taxes on consumption and investment goods. The key tax parameter of the Hall—Rabushka and Armey—Shelby proposals is the Flat Tax rate. If investment is expensed, the effective tax rate on new investment is zero, whatever the Flat Tax rate, so that the choice of this rate does not affect intertemporal resource allocation. However, the Flat Tax rate plays a very important role in the labor—leisure choice by households. It also affects the tax burden on capital assets already accumulated at the time of the reform.

38 Armey and Shelby (1995).

39 The Schaefer—Tauzin proposal was first introduced in the 104th Congress of 1996 and again in the 105th Congress in 1997. See Schaefer (1997). An alternative national sales tax proposal was introduced by former Representative John Linder (2005).

Since compensation for labor input would be excluded from a business firm's tax base, the marginal and average tax rates are the same as the statutory flat rate, unless value added by the firm falls short of the compensation for labor input. However, a substantial proportion of households are exempt from taxation due to personal allowances, so that marginal and average tax rates on labor income are very different.

Under the Hall–Rabushka proposal the statutory Flat Tax rate is 19%. Under the Armey–Shelby proposal a Flat Tax rate of 20% applies in the first two years after the tax reform, followed by a lower rate of 17% thereafter. These rates are chosen in order to replace federal tax revenues. In our model all three levels of government – federal, state and local – are combined into a single government sector. If the federal income tax is replaced by a Flat Tax, we assume that the state and local income taxes are also replaced by a Flat Tax. In addition, we assume that the state and local Flat Tax is deductible at the federal level. In order to determine the federal and state and local Flat Tax rates for corporations, we calibrate the Flat Tax rates to the 2010 federal and state and local corporate income tax revenues.

The average marginal tax rate for labor income is defined as a weighted average of the marginal tax rates of individual taxpayers, where the share of labor income for each taxpayer in total labor income is used as the weight. The average tax rate is simply the total tax revenue divided by total labor income. Using the same NIPA for 1993 as Hall and Rabushka,[40] we estimate that the average labor income tax rate is 0.0855 for the Hall–Rabushka Flat Tax proposal.

In order to determine the average marginal tax rates for the Hall–Rabushka and Armey–Shelby proposals on a consistent basis, we require the distribution of labor income by the marginal tax rate of the individual taxpayer. We use the Current Population Survey to estimate the average and the average marginal federal tax rates on labor income for both the Hall–Rabushka and Armey–Shelby Flat Tax proposals.[41]

In order to determine the average marginal tax rate on labor income for the government sector as a whole, we follow the same procedure as in calculating the federal and state and local Flat Tax rates for corporations. In place of the corporate income tax revenues, we use the individual income tax revenues for 2010. The results are that the average marginal tax rate is 0.2214 for Hall–Rabushka and 0.1924 for Armey–Shelby. The corresponding figure for the Tax Law of 2010 is 0.2509. Our estimate of the average tax rate is 0.0902 for Hall–Rabushka and 0.0704 for Armey–Shelby. These figures may be compared with the corresponding figure of 0.0950 for the 2010 Tax Law, or with the federal tax rate of 0.0855 estimated by Hall and Rabushka.

We can summarize the tax rates as follows:

- Hall–Rabushka:
  - Business tax rate, average and marginal: 0.2162

40 Hall and Rabushka (1995, p. 57, Table 3.1).
41 We are indebted to M. S. Ho for these calculations. For more details, see Ho and Stiroh (1998).

  - Labor income tax rate, marginal: 0.2214
  - Labor income tax rate, average: 0.0902
- Armey–Shelby:
  - Business tax rate, average and marginal: 0.1941
  - Labor income tax rate, marginal: 0.1924
  - Labor income tax rate, average: 0.0704
- Tax Law of 2010:
  - Corporate income tax rate: 0.3877
  - Labor income tax rate, marginal: 0.2509
  - Labor income tax rate, average: 0.0950

We develop alternative plans for the NRST by combining a sales tax on consumption and a labor income tax. Taxation of capital income is eliminated in all these plans. Although the existing sales taxes on investment may or may not be abolished as part of tax reform, we prefer the policies with no sales taxes on investment. As before, property taxes are left unchanged in our simulations. The alternative proposals differ in progressivity. They also differ in the revenue-raising roles of the sales tax and the labor income tax. This has the effect of altering the relative tax burden between labor income and capital accumulated prior to reform.

We first construct prototype sales tax and labor income taxes. The labor income tax is based on the Hall–Rabushka Flat Tax proposal. The sales tax is a Flat Tax rate with personal exemptions. We set the proportion of total exemptions in retail sales equal to the proportion of total exemptions in Hall–Rabushka, which is 0.3516. Assuming that the federal sales tax rate is 17%, as in Aaron and Gale (1996, Table 1.1), we estimate that the corresponding average tax rate is 11.02%. In order to represent the current sales taxes, used mainly by the state and local government, we add a Flat Tax of 5.37% to the progressive tax system we have derived.

We construct eight alternative NRST plans. Each plan consists of two parts – a sales tax and a labor income tax. The first two plans are limited to a sales tax, while the last two consist of a labor income tax alone.[42] Although these two plans are not sales taxes in the usual sense, they provide benchmarks for analyzing the economic impacts of the NRST plans. We evaluate the impacts on efficiency of resource allocation for all eight plans.

In Plan 1, a progressive NRST replaces the capital and labor income taxes. Since the revenue requirement is very large in relation to the sales tax base, we start with marginal and average tax rates twice as high as those of the prototype consumption tax. These sales tax rates serve as the starting values of our simulations, but are adjusted to achieve revenue neutrality. In Plan 2, we remove the progressivity from the sales tax of Plan 1 and set the marginal tax rate equal to the average tax rate.

42 We discuss the equivalence of consumption and labor income taxes in Jorgenson and Yun (2001, section 8.4, pp. 353–364).

In Plan 3, we introduce a prototype labor income tax from the Hall–Rabushka Flat Tax proposal and combine this with a prototype sales tax with the progressivity removed. As a consequence, the sales tax is flat or proportional while the labor income tax has the same progressivity as Hall–Rabushka. Compared with Plan 1, the role of the sales tax as an instrument for tax collection and redistribution is substantially reduced.

In Plan 4, we replace the current income tax system with the combination of a flat sales tax and a flat labor income tax. Since no attempt is made to achieve progressivity, this plan would be politically unpopular. On the other hand, the efficiency loss is minimal, so that Plan 4 provides a useful benchmark for evaluation of the potential cost of trading off efficiency against equity.

Plan 5 combines a progressive sales tax with a flat labor income tax. The sales tax rates are the same as in the prototype sales tax plan and the rate of the labor income tax is set at the average tax rate of the Hall–Rabushka proposal. Plan 6 combines the prototype sales tax with the labor income tax of the Hall–Rabushka proposal. Since both segments of the plan are progressive, the sacrifice of efficiency could be substantial.

Plan 7, the labor income tax is flat or proportional and there is no sales tax. The average and marginal tax rates of labor income are equal. Since all the tax revenue is raised by the tax on labor, we start with a labor income tax rate twice that of the Hall–Rabushka Flat Tax proposal. Finally, in Plan 8, we introduce an element of progressivity into Plan 7 by setting the average and the average marginal tax rate of labor income at twice the level in the Hall–Rabushka proposal.

We preserve revenue neutrality by requiring the government sector to follow the same time paths of real spending and government debt under all tax reform proposals. We also fix the time paths of the claims on the rest of the world. These assumptions are necessary to separate the economic impacts of alternative tax policies from the effects of changes in the government budget and the balance of payments. Government revenues must be adjusted through changes in the tax policy instruments in order to satisfy the government budget constraints in every period along the transition path to a steady state.

Investment spending on household assets is included in the sales tax base under the Schaefer–Tauzin proposal. The most important type of investment spending is the purchase of owner-occupied housing. We model the sales tax on household investment by imposing taxes on sales to the household sector. At the same time we increase the price of capital services by the amount of the sales tax. This is equivalent to prepayment of the consumption tax on household capital services.

10.6.3 Welfare impact of consumption taxation

In Table 10.15 we present two sets of welfare impacts. In the first set of simulations the corporate and individual income taxes of 2010 are replaced by the Hall–Rabushka

Table 10.15 Welfare effects of fundamental tax reform—flat tax (billions of 2011 US$)[a]

Tax reform proposal and revenue adjustment	Welfare effect $t_C = t_C^a = t_I = 0.0537$	Welfare effect $t_C = t_C^a = t_I = 0.0$
1. Hall—Rabushka		
Lump-sum tax	5111.8	6308.2
Flat tax	3789.8	2819.6
Sales taxes	4064.6	—
Flat tax and sales taxes	3912.0	—
2. Armey—Shelby		
Lump-sum tax	5444.3	6541.5
Flat tax	3299	1806.7
Sales taxes	3912.1	—
Flat tax and sales taxes	3626.8	—

[a]Inflation is fixed at 4% per year.
t_C: Marginal sales tax rate on consumption goods.
t_C^a: Average sales tax rate on consumption goods.
t_I: Sales tax rate on investment goods.

or Armey—Shelby Flat Tax, while sales taxes on consumption and investment goods remain unchanged Column (2). In the second set of simulations we replace the sales taxes as well, so that marginal and average consumption taxes, as well as taxes on investment are zero. In these simulations, all tax distortions, except for the property tax, are eliminated.

If both income taxes and sales taxes are replaced by a Flat Tax, and a lump-sum tax is used to compensate for the revenue shortfall, the welfare gains are very substantial, $5111.8 billion US dollars of 2011 for Hall—Rabushka and $5444.3 billion for Armey—Shelby. If sales taxes, as well as a corporate and individual income taxes, are replaced with a Flat Tax and a lump-sum tax is used to raise the additional revenue, the gains are even larger — $6308.2 billion for Hall—Rabushka and $6541.5 billion for Armey—Shelby.

The welfare gains from the Flat Tax proposals are lower when distorting taxes are increased to meet the revenue requirement. If the Flat Tax rate is adjusted to make up the revenue shortfall, substitution of the Hall—Rabushka Flat Tax for corporate and individual income taxes would produce a welfare gain of only $3789.8 billion. If sales taxes are also replaced the gain falls to $2819.6 billion. The corresponding welfare gains for the Armey—Shelby Flat Tax are $3299.0 billion for replacement of income taxes and $1806.7 billion for replacement of sales taxes as well. These results imply that the distortions resulting from the Flat Tax are worse than those from sales taxes.[43]

[43] A high Flat Tax rate implies a heavy lump-sum tax on "old" capital, offsetting the distorting effects of the tax on labor.

President Bush's Advisory Panel has proposed a Growth and Investment Tax Plan that would permit the expensing of business investment and disallow interest deductions from corporate income. However, the Growth and Investment Tax Plan would retain mortgage interest tax deductions at the individual level, introducing a substantial subsidy for owner-occupied housing.[44] This has the advantage of preserving incentives for home ownership, as requested by President Bush. However, it undercuts the equalization of tax burdens on business assets and owner-occupied housing associated with consumption taxes, such as the Hall–Rabushka and Armey–Shelby Flat Tax proposals.

Table 10.16 reports the welfare effects of the six plans for replacing the corporate and individual income taxes with an NRST and the two additional plans for replacing income taxes with a labor income tax. We present two sets of simulations – one with the sales tax on investment goods and the other without. First, note that the case without a sales tax on investment goods is more in the spirit of the NRST, which exempts sales taxes on investment goods from taxation.

Second, in Plans 1–6 a sales tax is included as a part of the replacement tax policy. These sales taxes on consumption goods together with sales taxes on investment goods generate revenue surpluses and require either a negative lump-sum tax adjustment or a decrease in tax rates. This explains the fact that welfare gains under the lump-sum tax adjustment are lower than under other tax adjustments.[45] Plan 4 with flat sales and labor income taxes and no tax on investment goods attains a welfare gain of $6574.9 billion. However, Plan 2 and Plan 7 are not far behind in terms of gains in welfare. Finally, the welfare gains attainable with the progressive Plans 1, 3 and 5 are also quite high.

A second set of comparisons highly relevant to deliberations about tax reform is the cost of progressivity. One of the most attractive features of the Hall–Rabushka and Armey–Shelby Flat Tax proposals is the possibility of introducing a system of family allowances in order to preserve the progressivity of the existing US tax system. Plan 1 for the NRST retains this feature, but generates welfare gains of $6090.8 billion with a distorting sales tax adjustment, more than doubling the gains of the Hall–Rabushka Flat Tax proposal with a distorting flat tax adjustment. The NRST is clearly superior to the Flat Tax as an approach to tax reform.

The costs of progressivity can be ascertained by comparing the welfare gains between Plan 1, a progressive sales tax, with Plan 2, a flat sales tax. With no sales tax on investment goods and adjustment of the sales tax on consumption goods to achieve revenue neutrality, the gain in welfare from eliminating progressivity is $530 billion. When this is added to the welfare gain of a progressive sales tax of $6090.8 billion, the overall gain is $6620.8 billion. Other comparisons between progressive and flat tax versions on the

44 See President's Advisory Panel (2005, Figure 7.3, p. 165).
45 Revenue shortfalls occur in Plan 7.

Table 10.16 Welfare effects of fundamental tax reform—national retail sales tax (billions of 2011 US$)[a]

Tax reform proposal and revenue adjustment	Welfare effect	
	$t_l = 0.0537$	$t_l = 0.0$
1. Progressive sales, no labor income tax		
Lump-sum tax	4807.7	5332.4
Labor income tax	—	—
Sales taxes	5959.2	6090.8
Labor income tax and sales taxes	—	—
2. Flat sales, no labor income tax		
Lump-sum tax	5748.7	6180.8
Labor income tax	—	—
Sales taxes	6460.0	6620.8
Labor income tax and sales taxes	—	—
3. Flat sales tax, progressive labor income tax		
Lump-sum tax	4880.1	5395.0
Labor income tax	5817.3	5633.8
Sales taxes	5256.4	5471.4
Labor income tax and sales taxes	5465.7	5531.2
4. Flat sales, flat labor income tax		
Lump-sum tax	6196.8	6574.9
Labor income tax	6408.3	6639.8
Sales taxes	6450.4	6638.6
Labor income tax and sales taxes	6437.7	6639.3
5. Progressive sales tax, flat labor income tax		
Lump-sum tax	5799.3	6226.9
Labor income tax	6053.4	6297.0
Sales taxes	6163.8	6317.8
Labor income tax and sales taxes	6128.0	6309.8
6. Progressive sales tax, progressive labor income tax		
Lump-sum tax	4215.3	4790.1
Labor income tax	5272.4	4995.5
Sales taxes	4726.3	4875.7
Labor income tax and sales taxes	4927.6	4919.8
7. No sales, flat labor income tax		
Lump-sum tax	6499.9	6814.5
Labor income tax	6288.9	6489.4
Sales taxes	—	—
Labor income tax and sales taxes	—	—
8. No sales, progressive labor tax		
Lump-sum tax	2248.2	2918.4

(Continued)

Table 10.16 Welfare effects of fundamental tax reform—national retail sales tax (billions of 2011 US$)[a]—cont'd

Tax reform proposal and revenue adjustment	Welfare effect	
	$t_I = 0.0537$	$t_I = 0.0$
Labor income tax	−3343.5	−6564.4
Sales taxes	—	—
Labor income tax and sales taxes	—	—

[a]Inflation is fixed at 4% per year.
t_I: Sales tax rate on investment goods.

NRST given in Table 10.16 generate estimates of the cost of progressivity that are similar in magnitude.

Since tax wedges distort resource allocation, a critical requirement for comparisons among alternative tax reform proposals is that all proposals must raise the same amount of revenue. The authors of the Hall–Rabushka Flat Tax proposal have calibrated their tax rates to the NIPA for 1993 so that the resulting tax regime is revenue-neutral. It is clear that the Armey–Shelby proposal falls short of revenue neutrality because it is more generous in personal allowances and applies a lower tax rate than the Hall–Rabushka proposal. However, the Hall–Rabushka proposal also fails the test of revenue neutrality.

The need for a major upward adjustment in the Flat Tax rate conflicts with the claim by Hall and Rabushka that their proposal is designed to be revenue-neutral. The explanation is that the dataset employed by Hall and Rabushka, the US NIPA of 1993, was generated under a tax system with a significant tax burden on capital.[46] Although the Flat Tax imposed a lump-sum tax on "old" capital accumulated before the tax reform, the Flat Tax does not impose any tax burden on "new" capital accumulated through investment after the reform. The tax base of the business portion of the tax shrinks dramatically and a large revenue shortfall emerges, requiring an increase in the Flat Tax rate.

From the point of view of efficiency the most attractive approach to tax reform we have considered is Plan 4 for the NRST, which combines a flat sales tax with a flat labor income tax and eliminates sales taxes on investment goods. The welfare gain would be diminished relatively little by shifting the burden toward the labor income tax, as in Plan 7. The combination of an NRST collected at the retail level and a labor income tax collected as at present would also be administratively attractive.

46 In 1993, the corporate income taxes were $138.3 billion for the Federal Government and $26.9 billion for the state and local governments. In the same year, the Federal Government collected $508.1 billion of income tax from individuals, and the state and local governments collected $124.2 billion.

10.7 CONCLUSIONS

Our overall conclusion is that the most substantial gains from tax reform are associated with equalizing tax burdens on all assets and all sectors and eliminating the progressive taxation of labor income. Efficient Taxation of Income produces the largest welfare gains of any proposal that we consider. Since the definitions of individual and corporate income would be unchanged, no cumbersome transition rules would be required. Efficient Taxation of Income could be enacted today and implemented tomorrow.

Integration of corporate and individual taxes is a key objective of President Bush's Advisory Panel's Simplified Income Tax Plan. The purpose of this proposal is to eliminate the double taxation of corporate income. The Advisory Panel's plan would leave a substantial tax wedge between corporate and non-corporate income, and would actually increase the wedge between business income and owner-occupied housing.

We have shown that the most popular Flat Tax proposals would generate substantial welfare gains. President Bush's Advisory Panel's Growth and Investment Plan would follow the subtraction approach to consumption taxation for business income employed by Hall and Rabushka. However, this Plan would introduce a substantial tax subsidy for owner-occupied housing and would fail to achieve the benefits of equalizing the tax burdens on business assets and owner-occupied housing.

A NRST with the same progressivity as the Hall–Rabushka Flat Tax would produce welfare gains that are 50% higher. This would require a marginal sales tax rate of around 34% and an average sales tax rate of more than 25% for revenue neutrality. These rates would provide substantial incentives for tax evasion and erosion of the tax base, boosting the required marginal and average tax rates even further. The Advisory Panel's selection of the subtraction method of the Flat Tax for its consumption tax proposal undoubtedly reflects these administrative issues associated with a progressive NRST.

The cost of maintaining a progressive rate structure within the framework of the NRST is substantial. This is due to the increase in the marginal tax rate on consumption required to compensate for the loss of portions of the tax base that are required to achieve progressivity. However, the benefits of a NRST with a flat rate structure are double those of a Flat Tax. These welfare gains are nearly comparable with the largest gains from Efficient Taxation of Income. However, gains from combining Efficient Taxation of Income with a proportional tax on labor income would be much greater.

We conclude that the frontier for economic analysis of tax and spending programs is to combine estimates of social rates of return for alternative tax policies with estimates of substitution possibilities by businesses and households. This can be done by means of a dynamic general equilibrium model like the one that we have presented in this chapter. This model also facilitates the evaluation of alternative tax reforms programs in terms of their impact on economic welfare.

We have illustrated the dynamic general equilibrium methodology for evaluating alternative proposals for a variety of tax reforms. These are based on two broad approaches to reform. (i) Reform the existing income tax, as in Efficient Taxation of Income. (ii) Replace income by consumption as a tax base. Our detailed illustrations can serve as a guide for policy makers who share our goal of making the allocation of capital and labor inputs within a market economy more efficient.

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