THE INTERNATIONAL SPILLOVER EFFECTS OF U.S. TAX REFORM: A COMPUTATIONAL GENERAL EQUILIBRIUM APPROACH WITH A GLOBAL TRADE MODEL

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ABSTRACT

THE INTERNATIONAL SPILLOVER EFFECTS OF U.S. TAX REFORM: A COMPUTATIONAL GENERAL EQUILIBRIUM APPROACH WITH A GLOBAL TRADE MODEL

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I integrate trade modeling and tax modeling, by evaluating the international spillover effects of changes in U.S. tax policy. I use both static and dynamic computational general-equilibrium models that divide the world into four regions. The data are from Global Trade Analysis Project for 1995. My model incorporates a labor/leisure choice and international cross-ownership of assets. My simulations suggest that unilateral elimination of U.S. capital taxes generates capital inflows. This policy change encourages more efficient use of the capital stock, but it will also generate negative effects on the terms of trade. Overall, the policy change generates welfare gains for the United States. If the other regions do not respond to the U.S. policy change, they suffer welfare losses. However, if all regions eliminate capital taxes, welfare gains accrue for the entire world. The analysis of welfare gains for the United States indicates that unilateral elimination of U.S. capital taxes yields an annual static welfare gain of around $98 billion in 1995 dollars (which amounts to 1.4 percent of GDP), while it yields dynamic gains, whose present values are around $4.0~$4.1 trillion (which amount to 2.2 percent of GDP stream).

Dedicated to

My father, Dong-Hyuk Kang
My mother, Young-Nam Kim

My mother-in-law, Myung-Ja Jung

My wife, Chooyoung Lee
My daughter, Michelle Kang

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CHAPTER 1

INTRODUCTION

The current tax-reform debate in the United States has focused attention on proposals that would lead to reform of the taxation of capital income. In the current debates, three proposals have received the most attention; the "flat tax" proposal, which suggests cutting income-tax rates to a single rate, the "unlimited saving allowance" proposal, which suggests providing deductions for all savings, and the "consumption-tax-only" proposal, which asserts complete replacement of the federal income tax with a value-added tax.[1] Although they differ in some important details, each of these proposals points toward reduced taxation of capital income generally (and corporate capital income in particular), and toward increased consumption taxation.

Much of the discussion has focused on the effect of tax reforms on labor supply and capital accumulation within the domestic economy. A number of authors have simulated the effects of moving toward consumption taxation in closed-economy models, and have generally found that heavier reliance on consumption taxation will lead to welfare gains in the long run.[2]

International issues have been given relatively little attention. However, as the world economy becomes increasingly integrated, it becomes increasingly appropriate to focus on international issues. Recently, some researchers have begun to study the

[1] See the papers in Mieszkowski and Zodrow (forthcoming, 2002), which discuss the effects of various proposals that would move in the direction of greater reliance on consumption taxation.

[2] These papers include Auerbach and Kotlikoff (1983), Fullerton, Shoven, and Whalley (1983), Ballard (1990a), Auerbach, Kotlikoff, Smetters, and Walliser (1997), Engen and Gale (1997), Jorgenson and Wilcoxen (1997), Rogers (1997), and Altig, Auerbach, Kotlikoff, Smetters, and Walliser (2001).

international implications of major tax reforms. In the early 1980s, Whalley (1980) and Goulder, Shoven, and Whalley (1983) analyze the effects of tax-policy changes, using open-economy simulation models. More recently, in the 1990s, Grubert and Newlon (1995), Hines (1996), Thalmann, Goulder, and DeLorme (1996), and Mendoza and Tesar (1998) deal with the international considerations of tax reform.

Multi-region models, in which international trade is the key inter-regional link, have been developed for analyzing global issues, especially multilateral trade policy issues such as trade liberalization, other trade policies, or fiscal policies that may be changed simultaneously in a number of countries.[3] With an integrated world market for goods, the effects of tax policies undertaken by a single country spill over to other countries. Recognition of such international economic interdependence stimulates interest in the international coordination of fiscal policies, in general, and of tax reforms, in particular.

My study aims to integrate tax and trade issues, by evaluating the international spillover effects of U.S. fundamental tax reform, and examining the key elements determining the magnitude of its effects, using a multi-region trade model. In this study, international spillover effects, through both changes in commodity flows and changes in capital flows, are considered. This paper begins with a description of previous studies, which are summarized in Chapter 2. Chapter 3 describes the static simulation model, which is mainly used for the analyses. Chapter 4 provides the model calibration. The

[3] In the middle of the 1990s, Hertel and Tsigas (1996) developed the standard GTAP, which is well suited for analyzing the effects of trade policies. There have been a lot of studies that deal with trade issues, with multi-region trade models. However, there are only a few papers that analyze the effects of fiscal-policy changes, using multi-region trade models. Only a few works deal with both tax and trade issues simultaneously: Whalley (1980) focuses on the global effects of domestic factor-tax systems, and Whalley (1982) partly deals with tax policy, in addition to trade issues.

data and simulation method are discussed in Chapter 5. Chapter 6 presents and interprets the simulation results in the static case. The issues on dynamic simulations are discussed in Chapter 7. Lastly, Chapter 8 concludes.

CHAPTER 2

RELEVANT STUDIES

2.1. The Incidence of the Corporate Tax

Harberger (1962) constructs a perfectly competitive, static, closed-economy model with two sectors and two factors of production. When a tax is levied on capital income in the corporate sector, competitive forces lead to a re-allocation of the capital stock. This re-allocation continues until the net-of-tax return to capital is the same in each sector. This leads to the result that the burden of the tax is borne by all capital, including capital that is not located in the corporate sector. The results of Harberger's model depend on the elasticities of substitution between capital and labor in the two sectors, the elasticities of demand for the two outputs, and the factor intensities in production. However, Harberger finds that his basic result is quite robust with respect to changes in the parameters of the model.

Shoven (1976) extends the Harberger model to include 12 production sectors. Shoven's model is more elaborate than that of Harberger, but it retains the basic character of the Harberger model by assuming perfect competition in a static context. Consequently, it is not surprising that Shoven's results are broadly supportive of Harberger's. However, the efficiency effects estimated by Shoven are larger than those estimated by Harberger. In effect, the assumption that there are only two sectors leads to an understatement of the intersectoral distortions caused by differential capital taxation. When Shoven moves to a 12-sector model, the simulated efficiency effects increase substantially.

Fullerton, King, Shoven, and Whalley (FKSW, 1981) continue to assume perfect competition, and they continue to assume that there are no international capital flows. However, they extend the model to 19 production sectors, and they make the model dynamic. In the short to medium run, the results of FKSW are similar to those of Harberger (1962) and Shoven (1976): When the corporate and personal income taxes are integrated, the returns to capital increase throughout the economy. This implies that the burden of the corporate tax is borne by capital. However, when FKSW trace out the dynamic development of the economy, the incidence picture changes in dramatic fashion. When the rate of return to capital is increased by the integration of the corporate tax, the rate of capital accumulation is increased. Consequently, in the very long run, the capital stock is substantially larger when there is no corporate tax than it would have been in the presence of the corporate tax. This increased capital stock leads to higher real wage rates for workers, which means that labor bears a substantial portion of the burden of the corporate tax in the long run.

All of the studies described above have assumed a closed economy.[4] When international flows of goods and capital are allowed, the results can change significantly. Harberger (1995) considers a static, perfectly competitive model in which there are international flows of goods and capital. Harberger assumes that the world capital market functions perfectly, in spite of the evidence of substantial international capital immobility.[5] For a small, open economy, the net-of-tax rate of return to capital is fixed in

[4] There have been many other studies of the quantitative effects of tax policy changes, using closed-economy models. These include Shoven and Whalley (1972), Whalley (1975), Keller (1980), Slemrod (1983), Piggott and Whalley (1985), and Ballard, Fullerton, Shoven, and Whalley (1985).

[5] The evidence on international capital immobility is extensive. Feldstein and Horioka (1980) report empirical evidence suggesting that capital is quite immobile internationally. Frankel (1990) and Obstfeld (1993) provide a review of the literature that was spawned by Feldstein and Horioka. Several possible

the world capital market. Consequently, there is no way for domestic capital to bear the burden of the tax. Instead, capital will flow out of the domestic economy, raising the domestic gross-of-tax rate of return to capital, until the net rate of return to domestic capital is once again equal to the net rate of return to capital in the rest of the world. When the international flow of goods is also perfectly competitive, the brunt of the corporate tax must be borne by domestic labor.[6]

Gravelle and Smetters (1998) build a model with imperfect substitutability between domestic and foreign products, and imperfect portfolio substitution between domestic and foreign capital. Gravelle and Smetters find that these imperfections play an important role in limiting the amount of the corporate tax that is borne by domestic labor. In some cases, the burden on labor is eliminated entirely. Gravelle and Smetters perform a number of sensitivity analyses. Their results show a mild amount of sensitivity to changes in the parameters. However, for the parameter combinations that seem most reasonable, capital bears at least half of the burden of the tax, and often significantly more.

2.2. Efficiency Results from Simulation Models

2.2.1. Closed-Economy Simulation Models

Among the many econometric studies of consumption functions, only a few suggest that saving is highly responsive with respect to the net-of-tax rate of return.[7]

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explanations have been discussed in Gordon and Bovenberg (1996). Especially, Gordon and Bovenberg attribute international capital immobility to asymmetric information across countries.

[6] Feldstein (1994) gives a similar argument.

[7] One of the very few studies to find a really large elasticity is that of Taylor (1971). He finds elasticities in the vicinity of 0.8 to 0.9 in some cases. Another study is that of Heien (1972).

Most studies find that the savings elasticity is not far from zero, and some find that it is negative. Thus, if a simulation model implies that the savings elasticity is enormous, the results of the simulation study must be viewed with considerable caution.

Unfortunately, many simulation models do imply very large savings elasticities. In a model that lacks uncertainty, or borrowing constraints, or any other rigidities, model consumers find it very easy to re-allocate their consumption across time, even though such re-allocations may be more difficult for real people in the real world. This problem is especially severe in models with very long time horizons. In the extreme case, a large number of researchers assume that consumers live forever. These infinite-horizon models often imply savings responses that are extremely unrealistic. Even in an overlapping-generations model, in which consumers live for a finite period, the problem can still be severe. For example, Auerbach and Kotlikoff (1983) show that simulations of the switch to a consumption tax involve an increase in the savings rate from 10 percent to 42 percent.

This extreme result is driven by a feature that is common to the infinite-horizon models.[8] In models of this type, the first step in the consumer's decision-making process is to calculate his full wealth. This involves calculating the present discounted value of the infinite stream of the consumer's labor time. For a fundamental tax reform, the net rate of return will usually increase. This means that the consumer's full wealth will be smaller under the policy change than it was in the "base case". Since the consumer is poorer, and since consumption in every period is a normal good, the consumer will want to reduce this first-period consumption. This can lead to a very large increase in saving,

[8] See Ballard (1990a, 2001) for details.

even if labor supply does not change. However, if the single-period utility function is a composite of consumption and leisure, the consumer will want to consume less leisure, in addition to consuming fewer goods. Therefore, the consumer will work more. When the consumer works more and consumes less, it is possible to have truly enormous increases in savings. Unfortunately, the workings of this type of model can tell us very little about what would actually happen in the real world, in response to a tax-policy change.

In recent years, researchers have made promising developments in the specification of simulation models. Engen and Gale (1996, 1997) have developed overlapping-generations simulation models in which consumers are uncertain about their path of future earnings and their length of life. To a great extent, this uncertainty reduces the excessive sensitivity of savings. For example, Engen and Gale (1996) suggest that, if modeled within the context of a closed economy, fundamental tax reform would increase the U.S. saving rate by 0.3 to 0.8 percentage points.

In these models, consumption is typically reduced in the first several years after the move to a consumption tax. However, the additional saving leads to a higher rate of capital accumulation, so that consumption is eventually higher under a consumption tax than an income tax. The present value of the gain in consumption in the future is usually large enough to outweigh the loss of consumption in the near term. Thus, virtually all of the closed-economy simulation studies find that movements toward consumption taxation would yield welfare improvements.

Even though some of the simulation models imply that saving is extremely, unrealistically responsive, it does not necessarily follow that these models imply welfare improvements that are dramatically different from the welfare improvements that are simulated by models with more modest savings elasticities. As shown in Ballard (1990a), very large increases in the savings elasticity are often only associated with small increases in the simulated welfare gains from moving toward a consumption tax. With a small saving elasticity, consumption drops when a consumption tax is instituted, and then recovers. Consumption eventually approaches a new steady state, in which the level of consumption is higher than in the base case, but the rate of growth is the same. With a larger savings elasticity, consumption drops farther when a consumption tax is instituted, and it recovers more quickly. However, consumption will approach the same steady state for either value of the savings elasticity. Thus, the consumption profiles for the large-elasticity case and the small-elasticity case are really quite similar. For the large-elasticity case, consumption is lower at first, and then higher, and finally the levels of consumption in the two cases will converge to the same steady state. Consequently, the long-run welfare calculations may not be dramatically different.

2.2.2. Open-Economy Simulation Models

Whalley (1980) evaluates the effects of removing domestic factor taxes, using a static trade model in which goods are mobile, but factors are immobile across regions, and suggests that the current factor tax structure can produce significant terms-of-trade gains. The result shows that significant welfare losses occur as a result of the elimination of domestic factor taxes. This result, which contrasts with the result of conventional closed-economy analysis, is explained by the fact that national terms-of-trade losses outweigh the gains from removal of domestic distortions.

Goulder, Shoven, and Whalley (GSW, 1983) begin with the GEMTAP model, which they developed over a period of years, along with Ballard, Fullerton, and others.[9] The standard version of the GEMTAP model has a very cursory treatment of the foreign sector, but GSW modify the GEMTAP model of the U.S. economy and tax system, to include international capital flows.

Their results depend critically on whether a particular reform leads to an increase or a decrease in the net rate of return to capital in the United States, as perceived by foreign investors. For reforms that lead to an increase in this rate of return (such as corporate tax integration), the model suggests that the U.S. will receive capital inflows. As a result of these inflows of capital from abroad, the U.S. experiences significant welfare gains. The welfare gains are driven partly by international capital flows, which were ruled out by assumption in Whalley (1980). On the other hand, for reforms that lead to a decrease in the rate of return in the long run (such as an increase in the percentage of domestic saving that is taxed on a consumption-tax basis), the model usually finds that capital will flow out of the U.S., and these capital outflows lead to welfare losses. Even though the results are highly sensitive with respect to the values of elasticity parameters that control the degree of international capital flows, they demonstrate that our understanding of the effects of tax-policy changes may be altered when we introduce international capital flows.

Thalmann, Goulder, and DeLorme (1996) assess the effects on the U.S. economy of tax-policy changes in foreign countries. They use an infinite-horizon model that

[9] For a detailed description of a standard version of the GEMTAP model, see Ballard, Fullerton, Shoven, and Whalley (1985). This model has the advantage that it can be calibrated to any desired savings elasticity so that it avoids some of the problems of excessive intertemporal responsiveness.

displays a larger degree of intertemporal sensitivity than does the model of GSW. However, their results are of some interest. For one thing, they explicitly incorporate imperfect substitutability between foreign and domestic assets, which is consistent with the econometric evidence on international capital mobility. Even for a fairly modest policy change (an increase in depreciation allowances in the rest of the world), the model of Thalmann, *et al.*, calculates a welfare improvement of 0.3 percent of GDP for the rest of the world.

Mendoza and Tesar (1998) use a simulation model to assess the difference between the effects of fundamental tax reform in a closed economy and in an open economy. Mendoza and Tesar employ some extreme assumptions. First, they use a model with an infinitely-lived consumer. As mentioned above, a model of this type is likely to produce simulated consumer behavior that is unrealistically responsive to changes in rates of return. Indeed, when Mendoza and Tesar simulate the effects of replacing the U.S. capital-income tax with a consumption tax in a closed-economy setting, they find that the impact effect is for consumption to decline by 8.3 percent, which seems extremely large and unrealistic. An infinite-horizon formulation tends to overstate intertemporal effects. The second extreme assumption is that they consider a world in which international capital markets are "fully integrated"; that is, capital is assumed to be perfectly mobile, in spite of the evidence of substantial international capital immobility. Thus, their simulations are likely to overstate the extent of the international capital flow that would be caused by fundamental tax reform in the United States.

Mendoza and Tesar suggest that the simulated welfare gains from replacing the U.S. capital-income tax with a consumption tax are greater when the simulations are carried out in an open-economy than in a closed-economy model. In the open-economy model, the U.S. gains by 2.89 percent, which is about one-third larger than in the closed-economy model.

Although these earlier studies shed some light, they can be improved upon in several dimensions: (1) The papers mentioned above are based on models with only two regions. (2) The model of Mendoza and Tesar has a fully integrated world capital market, which greatly overstates the degree of international capital mobility. (3) The models of Thalmann, *et al.*, and Mendoza and Tesar employ infinite-horizon formulation, which tend to overstate the intertemporal effects of tax-policy changes. In this paper, I address some of these issues. The model described in the next section is a static model with four regions, in which capital is internationally mobile, but with incomplete adjustment in the world capital market. The model is extended later to the dynamic structure, which incorporates sequences of single-period equilibria.

CHAPTER 3

DESCRIPTION OF THE SIMULATION MODEL

3.1. Overview

The basic framework for my research originates with the Global Trade Analysis Project (GTAP).[10] The standard version of the GTAP model is a static, multi-sectoral, and multi-regional model, in which each region's final demand is determined by a representative agent, who allocates expenditure across goods so as to maximize welfare. The model described here is based primarily on Rutherford's (1998) GTAP-data-based CGE model.[11]

In some respects, the core model used here is essentially identical to the standard GTAP model. First, the model is static.[12] There is no capital accumulation in the model. Consequently, in this version of the model, I may understate the distorting effects of capital taxes, since the effects on saving decisions are not captured.[13] Second, perfect competition is assumed in all sectors and all regions. The production technology is

[10] The Global Trade Analysis Project (GTAP) is a research program initiated in 1992 to provide the economic research community with a global economic data set for use in quantitative analyses of international economic issues.

[11] The standard programming language for GTAP data and modeling work has been GEMPACK. In the GEMPACK framework (see Harrison and Pearson (1996)), the model is solved as a system of linearized equations. Rutherford (1998) develops a GTAP-data-based model that is implemented as a nonlinear complementarity problem in the GAMS programming language, and calls it the "GTAPinGAMS" model. The database represents global production and trade for 45 countries, 50 commodities, and five primary factors. This database characterizes all transactions in 1995, and measures them in 1995 dollars.

[12] The model described here has the same time frame as the well-known model of Harberger (1962), which is sometimes called a "medium-run" model. Since there is no capital accumulation, it is not a long-run model. However, it allows reallocation of the existing world capital stock among all sectors in the world. Thus, it is not a short-run model, either.

[13] The dynamic version of the model, in which consumers make a saving decision in each period, is required to capture intertemporal distortions. The model is extended later to the dynamic setting, along lines of the model of Ballard, *et al.* (1985).

characterized as constant returns to scale (CRTS).[14] Third, trade is based on the Armington assumption: Commodities are distinguished by their place or country of origin.[15] The assumption of national product differentiation is particularly convenient, because it allows us to use a very simple formulation to incorporate crosshauling (*i.e.*, the simultaneous export and import of goods in the same commodity category), which is an important empirical feature of international trade. However, it should be noted that the Armington assumption has weaknesses. Brown (1987) criticizes this approach to product differentiation. She suggests that strong terms-of-trade effects can arise from the monopoly power implicit in national product differentiation. Therefore, she suggests that the Armington-type model may be fundamentally flawed for commercial policy analysis. An alternative approach is firm-level product differentiation, in which products are differentiated by firm, rather than by country of origin.[16] (Firm-level product differentiation implies imperfect competition. See footnote 14.)

However, the core model differs from the standard GTAP or GTAPinGAMS model in some important ways. The model is modified in the following ways:

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[14] The assumptions of perfect competition and CRTS have been criticized on grounds that they tend to underestimate the welfare gains of trade liberalization. Recent work in international trade has focused on imperfect competition and scale economies. Imperfect competition and scale economies are important subjects for my future work.

[15] The products are nationally differentiated; for example, Japanese cars that are produced in Japan are distinct from American cars. Refer to Armington (1969). Most empirical evidences support national product differentiation: Jomini, Zeitsch, McDougall, Welsh, Brown, Hambley, and Kelly (1991) review the literature on estimation of the elasticities of substitution between domestic and imported goods, and conclude that those elasticities are low for almost all products. Reinert and Roland-Holst (1992) also estimate Armington elasticities ranging a low of 0.14 and a high of 3.49, which implies that commodities are far from perfect substitutes.

[16] This approach is based on the work of Spence (1976) and Dixit and Stiglitz (1977). Brown and Stern (1989) demonstrate that if the appropriate formulation is one of oligopoly with firm-level product differentiation, the approach of national product differentiation will provide a poor approximation of the welfare changes.

(1) Final demand in the standard GTAP is represented by the constant-difference-elasticity demand system. In the GTAPinGAMS model, final demand is of the Cobb-Douglas functional form. However, the utility function of the nested constant elasticity of substitution (CES) form is incorporated in the core model here. The elasticity of substitution is allowed to vary between different groups of goods: the elasticity of substitution is large for close substitutes, and small otherwise. As shown in Shoven and Whalley (1992), the specific form chosen typically depends upon how elasticities are to be used in the model. The demands derived from the Cobb-Douglas utility function have the restrictions of unitary income and uncompensated own-price elasticities, and zero uncompensated cross-price elasticities. These restrictions are typically implausible, given empirical estimates of elasticities applicable to any particular model. However, these can be relaxed by using a more general functional form, such as the CES form.

(2) The model incorporates a labor/leisure choice, by having leisure as an argument of the utility function. Among many simulation studies, Auerbach and Kotlikoff (1987), Ballard, Fullerton, Shoven, and Whalley (1985), Fullerton and Rogers (1993), and Jorgenson and Wilcoxen (1998) have adopted this approach. It is not possible to capture fully the distortionary effects of income taxes in a model with exogenous labor supply (such as the standard GTAP model or the GTAPinGAMS model). Since the model incorporates an endogenous labor-supply decision, the results reflect the fact that the income tax is distortionary. In addition, consumption taxes have an effect on the real wage rate, even if the net-of-tax nominal wage rate is unaffected. The model also captures the fact that this effect on the real wage rate will lead to changes in labor supply.

(3) The model incorporates a new method for calibrating the international capital flows. In our model, investors hold internationally diversified portfolios.[17] Consumers choose the portfolio shares of domestic and foreign assets, which are assumed to be imperfect substitutes in portfolios. As a result of changes in the relative rates of return, consumers are induced to alter the fractions of their financial wealth held in assets from different countries.

(4) Various *ad-valorem* taxes are incorporated in the model, as in the GTAPinGAMS model; these include output taxes, taxes levied on intermediate inputs, export taxes, import tariff, and taxes levied on private demand.[18] Since there are no data for factor taxes in either the GTAP or the GTAPinGAMS database, the data for capital taxes and labor taxes, which are calculated on the basis of some statistics, are newly incorporated in the dataset.[19] The corporate income taxes and the property taxes are treated as taxes on capital use by industry. The payroll taxes are treated as taxes on labor use by industry. The commodity taxes and the selective excise taxes are treated as consumer taxes on goods purchased.

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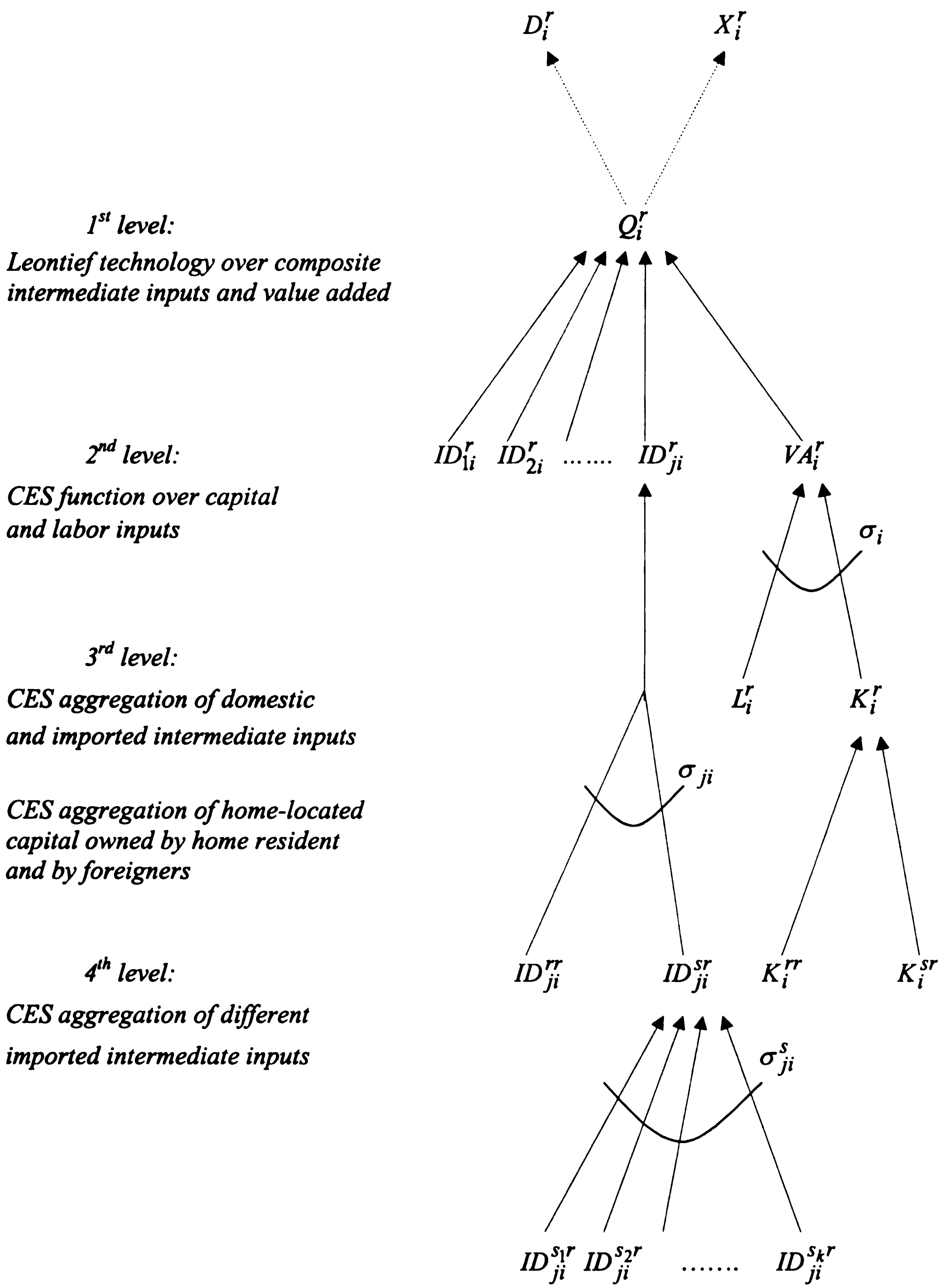
[17] The standard GTAP model assumes that international capital flows are allocated in response to changes in regional rates of return. The GTAPinGAMS model assumes exogenous international capital flows: it ignores the significant phenomenon of the expansion of international capital flows, so that it does not account for the spillover effects of the tax policy initiated by a country.

[18] Since the GTAP database has no direct data for taxation, each tax rate is imputed, in the GTAPinGAMS database, using the corresponding values that are measured at both the tax-free price and the tax-inclusive price.

[19] I deal with the method of calculating factor-tax rates, in Chapter 5.

Figure 3-1. The Structure of the Production



3.2. Structure of the Static Model

3.2.1. Production Sector

A "tree", as shown in figure 3-1, represents the structure of the production side of the model. There are two types of produced commodities, domestic outputs and exports, which are assumed to be prefect substitutes. The assumption of perfect substitution is based on the fact that the goods produced for domestic consumption are nearly the same as those produced for exports: Toyota cars consumed in Japan are nearly the same as those consumed in the United States. Thus, the production activity levels, Q_i^r, are represented as just the sums of domestic outputs and exports:

$$Q_i^r = D_i^r + X_i^r, \qquad (3.1)$$

where the D_i^r are domestic outputs for good *i* produced in region *r*, and the X_i^r are exports for good *i* produced in region *r*.

Composite intermediate inputs and value added are combined by a fixed-coefficient technology to generate these outputs, Q_i^r:

$$Q_i^r = \min\left\{ID_{1i}^r, ID_{2i}^r, \ldots\ldots., ID_{ji}^r, VA_i^r\left(L_i^r, K_i^r\right)\right\}, \qquad (3.2)$$

where the ID_{ji}^r are the intermediate demands for good *j* used in producing good *i* in region *r*, the VA_i^r are the value-added functions, the L_i^r are the labor inputs used in the production of good *i* in region *r*, and the K_i^r are the capital inputs used in the production of good *i* in region *r*.

The primary factors, labor and capital, are combined according to a value-added function. Labor inputs are assumed to be mobile between production sectors, but not internationally. Capital inputs are assumed to be mobile across sectors *and* regions. For each sector in each region, a CES function is employed to describe the functional relationship between the two primary factors:

$$VA_i^r(L_i^r, K_i^r) = \psi_i \left\{ \alpha_i^{r\,VA} L_i^{r\,\frac{\sigma_i - 1}{\sigma_i}} + \left(1 - \alpha_i^{r\,VA}\right) K_i^{r\,\frac{\sigma_i - 1}{\sigma_i}} \right\}^{\frac{\sigma_i}{\sigma_i - 1}}, \qquad (3.3)$$

where the ψ_i are scale parameters, the $\alpha_i^{r\,VA}$ are share parameters, and the σ_i are the elasticities of substitution between labor and capital in sector *i*.

Cross-ownership of capital is allowed in the model: both home residents and foreigners may own domestic capital. Therefore, producers make decisions about choosing capital owned by home residents and capital owned by foreigners. In the analysis, home-located capital owned by home residents and home-located capital owned by foreigners are assumed to be perfect substitutes, which means that producers are indifferent regarding whether their capital is owned by domestic residents or by foreigners. With infinite elasticities of substitution, the capital inputs are just the sums of capital owned by home residents and capital owned by foreigners:

$$K_i^r(K_i^{rr}, K_i^{sr}) = K_i^{rr} + K_i^{sr}, \tag{3.4}$$

where the K_i^{rr} are home-located capital owned by home resident and used in sector *i*, and the K_i^{sr} are home-located capital owned by foreigners and used in sector *i*.

The cost functions are represented as:

$$C_i^r\left(L_i^r, K_i^r\right) = wL_i^r + rK_i^r, \tag{3.5}$$

where the w are wage rates and the r are rental rates in region *r*.

Minimizing the cost function (3.5) subject to a given technology (3.3), and manipulating some equations, gives us the unit cost functions, $c_i^r(w,r)$:

$$c_i^r(w,r) = \frac{1}{\psi_i}\left\{\left(\alpha_i^{r\,VA}\right)^{\sigma_i} w^{1-\sigma_i} + \left(1-\alpha_i^{r\,VA}\right)^{\sigma_i} r^{1-\sigma_i}\right\}^{\frac{1}{1-\sigma_i}}, \tag{3.6}$$

and the factor-demand functions, $L_i^r(w,r)$ and $K_i^r(w,r)$:[20]

$$L_i^r(w,r) = \frac{Q_i^r}{\psi_i}\left\{\alpha_i^{r\,VA} + \left(1-\alpha_i^{r\,VA}\right)\left[\frac{\alpha_i^{r\,VA}\, r}{\left(1-\alpha_i^{r\,VA}\right)w}\right]^{1-\sigma_i}\right\}^{\frac{\sigma_i}{1-\sigma_i}} \tag{3.7}$$

and

$$K_i^r(w,r) = \frac{Q_i^r}{\psi_i}\left\{\left(1-\alpha_i^{r\,VA}\right) + \alpha_i^{r\,VA}\left[\frac{\left(1-\alpha_i^{r\,VA}\right)w}{\alpha_i^{r\,VA}\,r}\right]^{1-\sigma_i}\right\}^{\frac{\sigma_i}{1-\sigma_i}} . \qquad (3.8)$$

Under the Armington assumption, which treats products in different regions as qualitatively different across countries, intermediate input demands, ID_{ji}^r, are represented by a CES aggregation of domestic and imported intermediate inputs.

$$ID_{ji}^r = \xi_{ji}\left\{\alpha_{ji}^{r\,ID}\, ID_{ji}^{rr\,\frac{\sigma_{ji}-1}{\sigma_{ji}}} + \left(1-\alpha_{ji}^{r\,ID}\right) ID_{ji}^{sr\,\frac{\sigma_{ji}-1}{\sigma_{ji}}}\right\}^{\frac{\sigma_{ji}}{\sigma_{ji}-1}}, \qquad (3.9)$$

where the ξ_{ji} are scale parameters, the $\alpha_{ji}^{r\,ID}$ are share parameters, the ID_{ji}^{rr} are domestically supplied intermediate input demands for good *j* used in producing good *i* in region *r*, the ID_{ji}^{sr} are imported (from all foreign regions s) intermediate input demands for good *j* used in producing good *i* in region *r*, and the σ_{ji} are the elasticities of substitution between domestic and imported intermediate inputs.

The intermediate input demand functions, ID_{ji}^{rr} and ID_{ji}^{sr}, have the same form as the factor-demand functions, (3.7) and (3.8):

[20] See section 1 in the appendix for details.

$$ID_{ji}^{rr} = \frac{ID_{ji}^{r}}{\xi_{ji}} \left\{ \alpha_{ji}^{r\ ID} + \left(1 - \alpha_{ji}^{r\ ID}\right) \left[\frac{\alpha_{ji}^{r\ ID} q_{ji}^{s}}{\left(1 - \alpha_{ji}^{r\ ID}\right) q_{ji}^{r}} \right]^{1-\sigma_{ji}} \right\}^{\frac{\sigma_{ji}}{1-\sigma_{ji}}} \tag{3.10}$$

and

$$ID_{ji}^{sr} = \frac{ID_{ji}^{r}}{\xi_{ji}} \left\{ \left(1 - \alpha_{ji}^{r\ ID}\right) + \alpha_{ji}^{r\ ID} \left[\frac{\left(1 - \alpha_{ji}^{r\ ID}\right) q_{ji}^{r}}{\alpha_{ji}^{r\ ID} q_{ji}^{s}} \right]^{1-\sigma_{ji}} \right\}^{\frac{\sigma_{ji}}{1-\sigma_{ji}}}, \tag{3.11}$$

where the q_{ji}^{r} are the producer prices of the domestically produced intermediate inputs, and the q_{ji}^{s} are the after-tariff producer prices of the foreign inputs.

Imported intermediate input demands, ID_{ji}^{sr}, are also represented by a CES aggregation of the imported intermediate inputs from different regions:

$$ID_{ji}^{sr} = \zeta_{ji} \left\{ \sum_{s_k} \alpha_{ji}^{s\ ID} \left(ID_{ji}^{s_k r} \right)^{\frac{\sigma_{ji}^{s}-1}{\sigma_{ji}^{s}}} \right\}^{\frac{\sigma_{ji}^{s}}{\sigma_{ji}^{s}-1}}, \tag{3.12}$$

where the $ID_{ji}^{s_k r}$ are imported (from region s_k) intermediate input demands for good *j* used in producing good *i* in region *r*, and the σ_{ji}^{s} are the elasticities of substitution among imported intermediate inputs from different regions.

As in the case of intermediate input demands, imported intermediate input demands, $ID_{ji}^{s_k r}$, are represented by the formula:

$$ID_{ji}^{s_k r} = \frac{ID_{ji}^{sr}}{\zeta_{ji}} \left(\frac{\alpha_{ji}^{s\ ID}}{q_{ji}^{s_k}} \right) \left\{ \sum_{s_k} \left(\alpha_{ji}^{s\ ID} \right)^{\sigma_{ji}^{s}} \left(q_{ji}^{s_k} \right)^{1-\sigma_{ji}^{s}} \right\}^{\frac{\sigma_{ji}^{s}}{1-\sigma_{ji}^{s}}}, \tag{3.13}$$

where the $q_{ji}^{s_k}$ are the after-tariff produce prices of foreign country s_k.

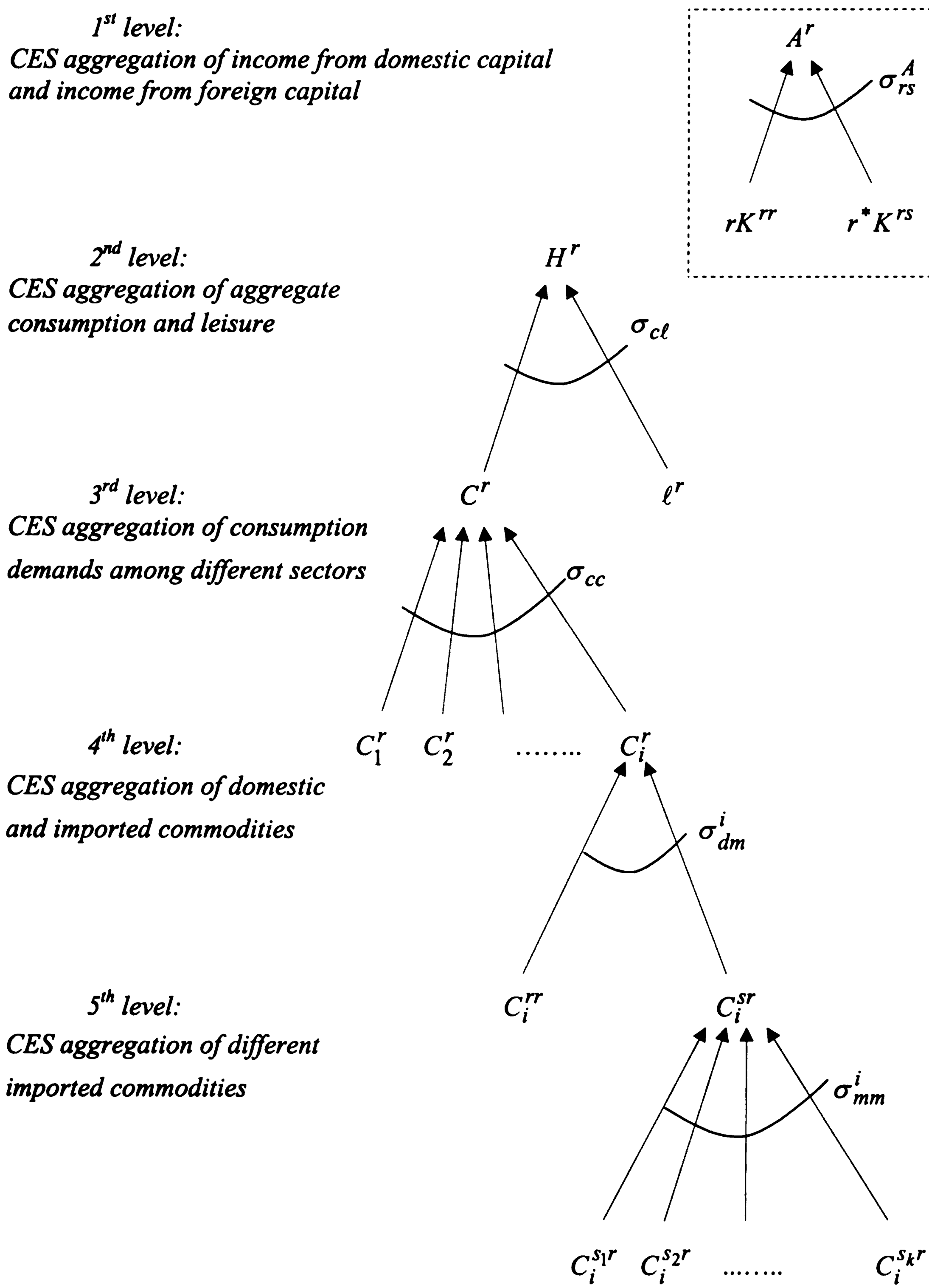
3.2.2. Demand Sector

A representative agent determines final demand in each region. Figure 3-2 shows the structure of the decision-making process of the representative agent as a "tree".

I introduce the asset-holding function, to allow the consumer's internationally diversified portfolio. On the first level, the consumer chooses the shares of domestic and foreign assets, which are assumed to be imperfect substitutes in financial wealth.[21] The consumer's asset holdings in region *r*, A^r, are represented by a CES function:

[21] The assumption that domestic and foreign assets are imperfect substitutes in the consumer's portfolio is consistent with observed home-country preference; home-country assets typically make up the bulk of portfolios, even when rates of return on foreign assets are comparable or higher. See Thalmann, Goulder, and DeLorme (1996). French and Poterba (1991) empirically examine the international asset-ownership patterns, and find that most investors hold nearly all of their wealth in domestic assets.

Figure 3-2. The Structure of Utility



$$A^r\left(rK^{rr}, r^*K^{rs}\right) = \left\{\alpha^{rA}\left(rK^{rr}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}} + \left(1-\alpha^{rA}\right)\left(r^*K^{rs}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}}\right\}^{\frac{\sigma_{rs}^A}{\sigma_{rs}^A - 1}}, \tag{3.14}$$

where the α^{rA} are share parameters, the σ_{rs}^A are the elasticities of substitution between domestic and foreign capital assets, the rK^{rr} are income from domestic assets (home-located capital invested by home resident) in region *r*, and the r^*K^{rs} are income from foreign assets (foreign-located capital invested by home resident) in region *r*.[22]

The consumer maximizes the asset-holding function, A^r, subject to the constraints, $\overline{K} = K^{rr} + K^{rs}$, where $\overline{K}$ is fixed. The assumption of fixed number of capital invested by domestic residents is consistent with Harberger-type assumptions.[23] These asset-holding functions can be represented by $\widetilde{A}^r$, which is a monotonic transformation of A^r:

---

[22] In the model, the $rK's$, not the $K's$ themselves, are used as the arguments of the function, in a sense that the consumer cares about flows of income he gets from capital, not the capital itself. The r^*K^{rs} are also the result of a CES aggregation.

[23] In the standard Harberger model of a closed economy, the total capital stock is fixed, but capital is mobile across sectors. It is as though owners of capital have a certain number of machines and rent them out to whichever sector offers the highest after-tax return. In that spirit, I assume that U.S. citizens own a fixed number of machines: $\overline{K} = K^{rr} + K^{rs}$, and have some allocation between K^{rr} and K^{rs} in the base case. When a policy change changes the after-tax returns on domestic and foreign investments, they may want to reallocate. Literally, this means that if the after-tax return goes up domestically, they will take some of the machines they were renting to firm in Europe and bring them back to the U.S. to rent them to firms here. This seems a little unrealistic, but it is consistent with Harberger-type assumptions.

$$\widetilde{A}^r = \left\{ \alpha^{rA}\left(\frac{r}{r^*}\right)^{\frac{\sigma_{rs}^A-1}{\sigma_{rs}^A}} \left(K^{rr}\right)^{\frac{\sigma_{rs}^A-1}{\sigma_{rs}^A}} + \left(1-\alpha^{rA}\right)\left(\overline{K}-K^{rr}\right)^{\frac{\sigma_{rs}^A-1}{\sigma_{rs}^A}} \right\}^{\frac{\sigma_{rs}^A}{\sigma_{rs}^A-1}} . \tag{3.15}$$

Differentiating $\widetilde{A}^r$ with respect to the choice variable K^{rr} yields the first-order condition:

$$\left\{ \alpha^{rA}\left(\frac{r}{r^*}\right)^{\frac{\sigma_{rs}^A-1}{\sigma_{rs}^A}} \left(K^{rr}\right)^{\frac{\sigma_{rs}^A-1}{\sigma_{rs}^A}} + \left(1-\alpha^{rA}\right)\left(\overline{K}-K^{rr}\right)^{\frac{\sigma_{rs}^A-1}{\sigma_{rs}^A}} \right\}^{\frac{1}{\sigma_{rs}^A-1}}$$

$$\times \left\{ \alpha^{rA}\left(\frac{r}{r^*}\right)^{\frac{\sigma_{rs}^A-1}{\sigma_{rs}^A}} \left(K^{rr}\right)^{\frac{-1}{\sigma_{rs}^A}} - \left(1-\alpha^{rA}\right)\left(\overline{K}-K^{rr}\right)^{\frac{-1}{\sigma_{rs}^A}} \right\} = 0. \tag{3.16}$$

Totally differentiating with respect to $\left(r/r^*\right)$ and K^{rr}, and manipulating it, I get the elasticity of demand for domestic capital with respect to the ratio of domestic and foreign rental rates, η_{KD}:

$$\eta_{KD} \equiv \frac{\partial K^{rr}}{\partial\left(\frac{r}{r^*}\right)} \frac{\left(\frac{r}{r^*}\right)}{K^{rr}} = \frac{\alpha^{r^A} K^{rr \frac{-1}{\sigma_{rs}^A}} \left(\frac{r}{r^*}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}} \left(D + \frac{\left(\sigma_{rs}^A - 1\right)B}{K^{rr}}\right)}{BF - D^2}, \quad (3.17)$$

where

$$B \equiv \left\{\alpha^{r^A}\left(\frac{r}{r^*}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}} \left(K^{rr}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}} + \left(1 - \alpha^{r^A}\right)\left(\overline{K} - K^{rr}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}}\right\},$$

$$D \equiv \left\{\alpha^{r^A}\left(\frac{r}{r^*}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}} K^{rr \frac{-1}{\sigma_{rs}^A}} - \left(1 - \alpha^{r^A}\right)\left(\overline{K} - K^{rr}\right)^{\frac{-1}{\sigma_{rs}^A}}\right\},$$

$$\text{and } F \equiv \left\{\alpha^{r^A}\left(\frac{r}{r^*}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}} K^{rr \frac{-1}{\sigma_{rs}^A} - 1} + \left(1 - \alpha^{r^A}\right)\left(\overline{K} - K^{rr}\right)^{\frac{-1}{\sigma_{rs}^A} - 1}\right\}.$$

The elasticity of demand for domestic capital, η_{KD}, has a positive sign, under the assumption of home asset preference.[24] The formulation of (3.17) has the property that as $\left(r / r^*\right)$ increases, the consumer chooses a larger K^{rr}. By the units convention, $r = r^* = 1$, equation (3.17) can be written as:

[24] B and F have positive signs, but D is undetermined. In addition, the numerator and denominator are also undetermined. However, for the analysis, home residents are assumed to prefer to invest more money on home-country assets. In the benchmark, the share parameters for domestic assets are set to 0.92~0.96. With the assumption of home-asset preference, D and the denominator have positive signs. If σ_{rs}^A is greater than 1.0, the numerator is definitely positive. Even though σ_{rs}^A is less than 1.0, the numerator can be positive, under the assumption of home asset preference. Consequently, the sign of η_{KD} is positive.

$$\eta_{KD} = \frac{\alpha^{r^A} K^{rr^{\frac{-1}{\sigma_{rs}^A}}} \left(D + \frac{\left(\sigma_{rs}^A - 1\right)B}{K^{rr}} \right)}{BF - D^2}. \tag{3.18}$$

Using equation (3.18), the asset-substitution elasticities, σ_{rs}^A, are calibrated to match with desired levels of the elasticity of demand for domestic capital with respect to the ratio of domestic and foreign rental rate.

On the second level, the consumer maximizes the utility function, H^r, subject to a budget constraint that takes K^{rr} and K^{rr}, which were deriving from maximization of A^r, *as given.* He maximizes the utility function, which is a CES aggregation of consumption and leisure:

$$H^r\left(C^r, \ell^r\right) = \left\{ \beta^{r^C} C^{r^{\frac{\sigma_{c\ell}-1}{\sigma_{c\ell}}}} + \left(1 - \beta^{r^C}\right) \ell^{r^{\frac{\sigma_{c\ell}-1}{\sigma_{c\ell}}}} \right\}^{\frac{\sigma_{c\ell}}{\sigma_{c\ell}-1}}, \tag{3.19}$$

where the β^{r^C} are share parameters, the $\sigma_{c\ell}$ are the elasticities of substitution between consumption and leisure, the P_c^r are the prices of the composite consumption goods in region *r*, the P_ℓ^r are the prices of leisure in region *r*, the C^r are the composite consumption goods in region *r*, the ℓ^r are the values of leisure in region *r*.

The consumer's budget constraints are given by:

$$P_c^r C^r + P_\ell^r \ell^r = wE^r + \bar{r}\bar{K}^{rr} + \bar{r}^* \bar{K}^{rs} + TR^r \equiv Y_1^r \, , \qquad (3.20)$$

where the Y_1^r are region r's expanded income, which includes the value of the consumer's labor endowments, the value of the consumer's capital income from domestic capital, the value of the consumer's capital income from foreign capital, and transfer payments (TR^r).[25] The government collects taxes and tariffs, and all tax and tariff revenues are assumed to be transferred to the agent in each region, in lump-sum fashion.[26] The $\sigma_{c\ell}$ parameters are calibrated to match with desired levels of the labor-supply elasticities.

Constrained maximization of the sub-utility functions H^r provides the demand functions:

$$C^r = \left(\frac{\beta^{rC}}{P_c^r} \right)^{\sigma_{c\ell}} \frac{Y_1^r}{\beta^{rC^{\sigma_{c\ell}}} P_c^{r^{1-\sigma_{c\ell}}} + \left(1 - \beta^{rC} \right)^{\sigma_{c\ell}} P_\ell^{r^{1-\sigma_{c\ell}}}} \qquad (3.21)$$

and

[25] Shoven and Whalley (1992) distinguish "expanded income" (which includes the value of the total endowment of time) from observed money income. On this level, rK^{rr} and $r^* K^{rs}$ are taken as given. Of course, in general equilibrium, r and r^* are endogenous, but they are exogenous from the consumer's point of view.

[26] In the closed-economy model, as Ballard (1990b) points out, when taxes are rebated to the consumer in lump-sum fashion, taxes in the model do not have any income effects. However, there is still a possibility of income effects, to a small degree, if taxes are collected from both domestic and foreign agents, but the revenues are rebated only to domestic consumers.

$$\ell^r = \left(\frac{1-\beta^{r^C}}{P_\ell^r}\right)^{\sigma_{c\ell}} \frac{Y_1^r}{\beta^{r^{C^{\sigma_{c\ell}}}} P_c^{r^{1-\sigma_{c\ell}}} + \left(1-\beta^{r^C}\right)^{\sigma_{c\ell}} P_\ell^{r^{1-\sigma_{c\ell}}}} . \tag{3.22}$$

On the third level, the consumer maximizes the utility from aggregate consumption, which is represented by a CES aggregation of consumption demands among the different sectors:

$$C^r\left(C_1^r,\ldots\ldots,C_i^r\right)=\left\{\sum_i \beta_i^{r^C} C_i^{r^{\frac{\sigma_{cc}-1}{\sigma_{cc}}}}\right\}^{\frac{\sigma_{cc}}{\sigma_{cc}-1}}, \tag{3.23}$$

subject to the constraint:

$$\sum_i P_i^r C_i^r = Y_1^r - P_\ell \ell^r \equiv Y_2^r , \tag{3.24}$$

where the $\beta_i^{r^C}$ are share parameters, the σ_{cc} are the elasticities of substitution among different commodities, the P_i^r are the prices of the consumption goods *i* in region *r*, and the C_i^r are the levels of consumption of good *i* in region *r*.

Constrained maximization of the sub-utility functions C^r gives the demand functions:

$$C_i^r = \left(\frac{\beta_i^{r\,C}}{P_i^r} \right)^{\sigma_{cc}} \frac{Y_2^r}{\sum_i \beta_i^{r\,C\,\sigma_{cc}} P_i^{r\,1-\sigma_{cc}}}. \tag{3.25}$$

On the fourth level, the consumer decides whether to buy a commodity at home or abroad. According to the Armington assumption, commodities are distinguished by their place of origin. Under this assumption, the consumption of good i is represented by a CES aggregation of domestic and imported goods. The consumer maximizes the utility functions:

$$C_i^r\left(C_i^{rr}, C_i^{sr}\right) = \left\{ \beta_i^{r\,D} C_i^{rr\,\frac{\sigma_{dm}^i - 1}{\sigma_{dm}^i}} + \left(1 - \beta_i^{r\,D}\right) C_i^{sr\,\frac{\sigma_{dm}^i - 1}{\sigma_{dm}^i}} \right\}^{\frac{\sigma_{dm}^i}{\sigma_{dm}^i - 1}}, \tag{3.26}$$

subject to the constraint:

$$P_i^{rr} C_i^{rr} + P_i^{sr} C_i^{sr} = Y_2^r - \sum_{j \neq i} P_j^r C_j^r \equiv Y_3^r, \tag{3.27}$$

where the $\beta_i^{r\,D}$ are share parameters, the σ_{dm}^i are the Armington elasticities of substitution between domestic goods and imported goods in sector i, the P_i^{rr} are the consumer prices of domestically produced goods in sector i and region r, the P_i^{sr} are the consumer prices of imported goods in sector *i* and region *r*, the C_i^{rr} are the levels of consumption of domestically supplied goods in sector *i* and region *r*, and the C_i^{sr} are the levels of consumption of imported (from all foreign regions *s*) goods in sector *i* and region *r*.[27]

Constrained maximization of the sub-utility functions C_i^r provides the demand functions:

$$C_i^{rr} = \left(\frac{\beta_i^{r\,D}}{P_i^{rr}} \right)^{\sigma_{dm}^i} \frac{Y_3^r}{\beta_i^{r\,D\,\sigma_{dm}^i} P_i^{rr\,1-\sigma_{dm}^i} + \left(1-\beta_i^{r\,D}\right)^{\sigma_{dm}^i} P_i^{sr\,1-\sigma_{dm}^i}} \qquad (3.28)$$

and

$$C_i^{sr} = \left(\frac{1-\beta_i^{r\,D}}{P_i^{sr}} \right)^{\sigma_{dm}^i} \frac{Y_3^r}{\beta_i^{r\,D\,\sigma_{dm}^i} P_i^{rr\,1-\sigma_{dm}^i} + \left(1-\beta_i^{r\,D}\right)^{\sigma_{dm}^i} P_i^{sr\,1-\sigma_{dm}^i}}. \qquad (3.29)$$

Finally, on the fifth level, the consumer maximizes aggregate consumption of imported goods, which are represented by a CES aggregation of different imported commodities:

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[27] In equation (3.27), the constraint states that the consumer's expenditure on the goods in sector *i* cannot exceed Y_3^r. The $\sum_{j \neq i} P_j^r C_j^r$ indicate the value of the consumption for the commodities in sector *j*, and must be substracted from Y_2^r to determine the amount of income available for the commodities in sector *i*.

$$C_i^{sr}\left(C_1^{s_1 r},\ldots\ldots,C_i^{s_k r}\right)=\left\{\sum_k \beta_i^{r^S} C_i^{s_k r \frac{\sigma_{mm}^i-1}{\sigma_{mm}^i}}\right\}^{\frac{\sigma_{mm}^i}{\sigma_{mm}^i-1}}, \tag{3.30}$$

subject to the constraint:

$$\sum_k P_i^{s_k r} C_i^{s_k r} = Y_3^r - P_i^{rr} C_i^{rr} \equiv Y_4^r, \tag{3.31}$$

where the β_i^S are share parameters, the σ_{mm}^i are the Armington elasticities of substitution among imported goods in sector *i* from different regions, the $P_i^{s_k r}$ are the consumer prices of imported (from s_k) goods in sector *i* and region *r*, and the $C_i^{s_k r}$ are the levels of consumption of imported (from s_k) goods in sector *i* and region *r*.[28]

Constrained maximization of the sub-utility functions C_i^{sr} gives the demand functions:

[28] In equation (3.31), the constraint states that the consumer's expenditure on imported goods cannot exceed Y_4^r. The $P_i^{rr} C_i^{rr}$ represent the value of consumption of domestically supplied commodities, and must be subtracted from Y_3^r to determine the amount of income available for imported goods.

$$C_i^{s_k r} = \left(\frac{\beta_i^{rS}}{P_i^{s_k r}} \right)^{\sigma_{mm}} \frac{Y_4^r}{\sum_i \beta_i^{rS^{\sigma_{mm}}} P_i^{s_k r^{1-\sigma_{mm}}}}. \qquad (3.32)$$

3.2.3. Zero-Profit Conditions

In this model, competitive producers operate according to constant-returns technology, and earn zero profit. For the producer, the market value of a unit of output equals the unit cost of production. The market value of a unit of output is the value of sales in the domestic and export markets, net of indirect taxes. The unit cost of production includes the cost of primary factor inputs and intermediate inputs with taxes:

$$\left(q_i^{rD} a_i^{rD} + q_i^{rX} a_i^{rX} \right)\left(1 - t_i^{rQ} \right)$$

$$= \sum_F a_i^{rF} q_i^{rF} \left(1 + t_i^{rF} \right) + \sum_j a_{ji}^{r\,ID} q_{ji}^r \left(1 + t_{ji}^{r\,ID} \right), \qquad (3.33)$$

where the a_i^{rD} are the unit supply functions of domestic outputs, the a_i^{rX} are the unit supply functions of exports, the a_i^{rF} are the unit factor-demand functions for labor and capital, the $a_{ji}^{r\,ID}$ are the coefficients of intermediate inputs, the t_i^{rQ} are the output tax rates, the $t_i^{r\,F}$ are the factor tax rates, and the $t_{ji}^{r\,ID}$ are the tax rates for intermediate inputs.[29]

In equilibrium, the value of a unit of imports equals the F.O.B. price, gross of export tax, the transportation margin, and the applicable tariff:[30]

$$p_i^{r\,M} = \sum_s a_i^{rs\,M} \left\{ p_i^{s\,X} \left(1 + t_i^{sr\,X} \right) + \tau_i^{rs} p^T \right\} \left(1 + t_i^{sr\,M} \right), \tag{3.34}$$

where the $p_i^{r\,M}$ are the domestic C.I.F. prices in region *r*, the $p_i^{s\,X}$ are the F.O.B. export prices from region *s*, the $a_i^{rs\,M}$ are the unit import-demand functions, the $t_i^{sr\,X}$ are the export tax rates, the $t_i^{sr\,M}$ are the import tariff rates, the τ_i^{rs} are the unit transport cost coefficients, and the p^T are the unit costs of transportation on all commodity trade flows.[31]

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[29] $q_i^{r\,L} = w$, and $q_i^{r\,K} = r$. See the appendix for unit-supply and unit-demand functions in detail.

[30] The import aggregation activity, which defines the aggregation of imports by trading partner, is the most complex component of the model. The import activity applies export taxes and import tariffs on all bilateral trades, and it also applies transportation margins on all bilateral trades. In this sense, in the model, two types of inputs are set to be applied to the import activity: one is F.O.B. payments to producers in different regions, and the other is inputs of transportation services. Many multi-region CGE models have neglected the presence of international transportation costs, due to difficulty in data availability. However, Tsigas, Hertel, and Binkley (1992) estimate these margins from pooled time-series/cross-section bilateral trade data. This is further refined in Gehlhar, Gray, Hertel, Huff, Ianchovichina, MacDonald, McDougall, Tsigas, and Wigle (1996), where a trade-margins function, depending on distance and volume, is explicitly estimated. The resulting margins are incorporated in the GTAP database. In the dataset, the values of transportation cost in the manufacturing sectors are about 3~5 percent of the values of commodity trades, and those in the primary-material and agriculture sectors are about 7~8 percent of the values of commodity trades. See Hertel, Ianchovichina, and MacDonald (1997).

[31] The model assumes that export tax applies on the F.O.B. prices, net of transport margins, while the import tariff applies on the C.I.F. prices, gross of export tax and transport margins. See Rutherford (1998).

Armington aggregation functions transform domestic and imported goods into composite goods for private demand and intermediate input demand. Zero profit for the private goods provides the following equilibrium identities:

$$P_i^r = \left\{ \beta_i^{D\,\sigma_{dm}^i} P_i^{rr\,1-\sigma_{dm}^i} + \left(1-\beta_i^D\right)^{\sigma_{dm}^i} P_i^{sr\,1-\sigma_{dm}^i} \right\}^{\frac{1}{1-\sigma_{dm}^i}}, \qquad (3.35)$$

where the β_i^D are share parameters, the σ_{dm}^i are the elasticities of substitution between domestic goods and imported goods, the P_i^r are the prices of the consumption goods *i*, the P_i^{rr} are the consumer prices of domestically produced goods *i*, and the P_i^{sr} are the consumer prices of imported (from all foreign regions *s*) goods *i*. Similarly, zero profit for intermediate input demand gives the identities:

$$q_{ji}^r = \left\{ \alpha_{ji}^{ID\,\sigma_{dm}^i} q_{ji}^{rr\,1-\sigma_{dm}^i} + \left(1-\alpha_{ji}^{ID}\right)^{\sigma_{dm}^i} q_{ji}^{sr\,1-\sigma_{dm}^i} \right\}^{\frac{1}{1-\sigma_{dm}^i}}, \qquad (3.36)$$

where the q_{ji}^r are the prices of the intermediate inputs, the q_{ji}^{rr} are the prices of the intermediate inputs which are produced domestically, and the q_{ji}^{sr} are the prices of the intermediate inputs which are imported (from all foreign regions *s*).

3.2.4. Income-Balance Equations

Consumer expenditures are the sum of labor earnings and capital earnings (capital income from domestic capital plus capital income from foreign capital), and transfer payments:[32]

$$CE^r = wE^r + rK^{rr} + r^*K^{rs} + \sum_i t_i^{r^Y}\left(q_i^{r^D} D_i^r + q_i^{r^X} X_i^r\right)$$

$$+\sum_{ij} t_{ij}^{r^{ID}} q_i^{r^{ID}} ID_i^r + \sum_{Fi} t_i^{r^F} q_i^{r^F} FD_i^{r^F} + \sum_i t_i^{r^C} p_i^r C_i^r$$

$$+\sum_{is} t_i^{rs^X} p_i^{rs} M_i^{rs} + \sum_{is} t_i^{rs^M}\left(p_i^{s^X} M_i^{sr}\left(1+t_i^{sr^X}\right) + p^T T_i^{sr}\right), \qquad (3.37)$$

where the CE^r are consumer expenditures, the $ID_i^r \left(= \sum_j Q_j^r a_{ji}^{r^{ID}}\right)$ are intermediate demands for sector *i* in region *r*, the $FD_i^{r^L}$ are labor demands for sector *i* in region *r*, the $FD_i^{r^K}$ are capital demands for sector *i* in region *r*, the $t_i^{r^C}$ are the tax rates on private demand for sector *i* in region *r*, the M_i^{rs} are import demands from region *s*, and the

[32] All tax and tariff revenues are assumed to be rebated to the consumer in lump-sum fashion.

$T_i^{sr}\left(=\tau_i^{rs}M_i^{rs}\right)$ are real transport costs (which are assumed to be proportional to trade) for sector i in region r.

3.2.5. Market-Clearance Conditions

In the domestic market, domestic output equals the sum of domestic demand for consumer goods, and domestic demand for intermediate inputs:

$$D_i^r = C_i^{rr} + ID_i^{rr}. \tag{3.38}$$

Similarly, in the import market, the aggregate supply of imports equals aggregate import demand for private consumption and intermediate inputs:

$$M_i^r = C_i^{sr} + ID_i^{sr}, \tag{3.39}$$

where M_i^r are the aggregate supply of imports. In addition, export supply equals import demand across all trading partners, plus demands for international transport:

$$X_i^r = \sum_s M_i^{rs} + TD_i^r. \tag{3.40}$$

When perfect substitution between domestic outputs and exports is assumed (the elasticity of transformation is infinity), the market-clearance condition for aggregate demand is:

$$Q_i^r = C_i^{rr} + ID_i^{rr} + \sum_s M_i^{rs} + TD_i^r \ . \tag{3.41}$$

As previously stated, private demand and intermediate input demand are defined as Armington aggregations of domestic and imported inputs:

$$C_i^r\left(C_i^{rr}, C_i^{sr}\right) = \left\{ \beta_i^D C_i^{rr\,\frac{\sigma_{dm}-1}{\sigma_{dm}}} + \left(1-\beta_i^D\right) C_i^{sr\,\frac{\sigma_{dm}-1}{\sigma_{dm}}} \right\}^{\frac{\sigma_{dm}}{\sigma_{dm}-1}} \tag{3.42}$$

and

$$ID_{ji}^r\left(ID_{ji}^{rr}, ID_{ji}^{sr}\right) = \xi_{ji} \left\{ \alpha_{ji}^{r\ ID}\, ID_{ji}^{rr\,\frac{\sigma_{ji}-1}{\sigma_{ji}}} + \left(1-\alpha_{ji}^r\right)^{ID} ID_{ji}^{sr\,\frac{\sigma_{ji}-1}{\sigma_{ji}}} \right\}^{\frac{\sigma_{ji}}{\sigma_{ji}-1}} . \tag{3.43}$$

In factor markets, primary factor supply equals primary factor demand. Labor inputs are mobile between sectors, but immobile between regions. Capital inputs are mobile across sectors *and* regions. Therefore, the market-clearance conditions for these factors are:

$$L^r = \sum_i L_i^r \tag{3.44}$$

and

$$K^r = \sum_i \left(K_i^{rr} + K_i^{sr}\right), \tag{3.45}$$

where the L^r are the labor supplies in region *r*, the K^r are the capital supplies in region *r*, the L_i^r are the labor demands for sector *i* in region *r*, the K_i^{rr} are the demands for home-located capital owned by home residents for sector *i*, and the K_i^{sr} are the demands for home-located capital owned by foreigners for sector *i*.

CHAPTER 4

MODEL CALIBRATION

In determining the results of policy simulations, the parameter values for the functional forms are very crucial. The procedure most commonly used to select parameter values is "calibration".[33] The goal of calibration is for the researcher to impose desired elasticities upon the model.

4.1. Exogenous Parameters

The benchmark data set is used for determination of parameter values, which are consistent with that observation. However, for the CES function, the benchmark data set alone is not sufficient to determine all parameter values of the model uniquely. This under-identification problem is solved by exogenously specifying a sufficient number of parameters from the econometric literature. The exogenous parameters are summarized in Table 4-1.

On the production side of the economy, the elasticities of substitution between labor and capital, σ_i, are extraneously specified. I adopt the sector-specific SALTER substitution elasticity values provided by Jomini, Zeitsch, McDougall, Welsh, Brown, Hambley, and Kelly (1991). They are based on a review of the international cross-

[33] Calibration involves a deterministic approach to specifying parameter values to be used in an applied general equilibrium model. The parameter specification methods in CGE models, which use deterministic calibration rather than stochastic estimation, are often troubling to econometricians. However, this calibration approach is widely used, for several reasons: (1) In some applied models, many thousands of parameters are involved, and to estimate simultaneously all of the model parameters using time-series methods would require either unrealistically large numbers of observations or severe identifying restrictions. (2) Benchmark data sets are formulated in value terms, and their decomposition into separate price and quantity observations makes it difficult to sequence equilibrium observations with consistent units through time. See Shoven and Whalley (1992) for details.

section studies which estimated these parameters for various industries: the values are 1.19 for the primary-material sector and non-durable manufactures, 0.56 for the agriculture sector, 1.26 for durable manufactures, and 1.35 for the service sector.[34] The high degree of substitutability in the service sector is caused by the high value of 1.68 in the sector of trade and transportation, which is a sub-sector of the service sector.

On the demand side, home residents are assumed to prefer to invest more money on home-country assets: In the benchmark, the U.S. consumer is assumed to hold 92 percent of total assets in domestic assets and 8 percent of total assets in foreign assets in his portfolio; the consumers in other regions are assumed to hold 92~96 percent of their domestic assets and 4~8 percent of foreign assets in their portfolio. This assumption is based on the empirical examination of international asset-ownership patterns, provided by French and Poterba (1991). They find that that most investors hold nearly all of their wealth in domestic assets: The domestic ownership shares of the U.S., Japanese, and the U.K. investors are estimated as 92.2, 95.7, and 92 percent, respectively.

Based on the econometric literature, the uncompensated labor-supply elasticity, η_L, is assumed to be 0.15 in every region.[35] Simulations will be performed using these central values, and then sensitivity tests with different sets of elasticities of substitution will be run.

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[34] The values are modified to fit in the model, using a weight parameter. Whalley (1985) uses the value of factor substitution elasticities: 0.6 for the primary-material and agricultural sectors, 0.8 for manufactures, 0.9 for non-durable manufactures, and 0.7 for the service sector.

[35] Surveys of the labor-supply literature can be found in Killingsworth (1983), Burtless (1987), and Heckman (1993). See also Fuchs, Krueger, and Poterba (1998).

Table 4-1. Exogenous Parameter Values

	U.S.	*E.U., Japan, ROW*
(Production Side)		
Elasticity of Substitution between Labor and Capital (σ_i)		
Agriculture	0.56	0.56
Primary Materials	1.19	1.19
Durable Manufactures	1.26	1.26
Non-durable Manufactures	1.19	1.19
Services	1.35	1.35
Share of Capital Owned by Home Resident (α_i^K)	0.91	0.95
(Demand Side)		
Share of Domestic Assets in Portfolio (α^A)	0.92	0.92~0.96
Uncompensated Labor-Supply Elasticity (η_L)	0.15	0.15

4.2. Calibration Issues

On the demand side, the elasticity of substitution between consumption and leisure, $\sigma_{c\ell}$, the asset-substitution elasticity, σ_{rs}^A, the elasticity of substitution among different domestic goods, σ_{cc}, and the trade elasticities of substitution, σ_{dm}^i and σ_{mm}^i, are calibrated, using some values specified exogenously. The calibrated parameters are summarized in Table 4-2.

First, I consider the calibration of the elasticity of substitution between consumption and leisure. On the second level, the consumer decides on aggregate consumption and leisure. The demand function for leisure is:

$$\ell^r = \left(\frac{1-\beta^C}{P_\ell} \right)^{\sigma_{c\ell}} \frac{Y_1}{\Omega}, \tag{4.1}$$

where $\Omega = \beta^{C^{\sigma_{c\ell}}} P_c^{\ 1-\sigma_{c\ell}} + \left(1-\beta^C\right)^{\sigma_{c\ell}} P_\ell^{\ 1-\sigma_{c\ell}}$. Then, the uncompensated leisure-demand elasticity, η_ℓ, is:

$$\eta_\ell \equiv \frac{\partial \ell}{\partial P_\ell} \frac{P_\ell}{\ell} = \frac{P_\ell E}{Y_1} - \frac{P_\ell \ell (1-\sigma_{c\ell})}{Y_1} - \sigma_{c\ell}. \tag{4.2}$$

The uncompensated labor-supply elasticity, η_L, can be expressed in terms the amount of labor supplied, L, or in terms of the amount of leisure, ℓ:

$$\eta_L \equiv \frac{\partial L}{\partial P_\ell} \frac{P_\ell}{L} = \frac{\partial (E-\ell)}{\partial P_\ell} \frac{P_\ell}{E-\ell} = \left(\frac{\partial E}{\partial P_\ell} - \frac{\partial \ell}{\partial P_\ell} \right) \frac{P_\ell}{E-\ell}. \tag{4.3}$$

Manipulating equation (4.2) and equation (4.3), and using the fact that $\frac{\partial E}{\partial P_\ell} = 0$, an expression for the leisure-demand elasticity is derived in terms of the labor-supply elasticity, and the time-endowment ratio, Φ:[36]

$$\eta_\ell = -\eta_L \frac{E-\ell}{\ell} = -\eta_L \left(\frac{1}{\Phi - 1} \right). \tag{4.4}$$

Substituting equation (4.8) into equation (4.6), and solving it for $\sigma_{c\ell}$ gives:

$$\sigma_{c\ell} = \frac{\frac{P_\ell E}{Y_1} - \frac{P_\ell \ell}{Y_1} + \eta_L \left(\frac{1}{\Phi - 1} \right)}{1 - \frac{P_\ell \ell}{Y_1}}. \tag{4.5}$$

The elasticity of substitution between consumption and leisure depends on the uncompensated labor-supply elasticity, and on the time-endowment ratio.

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[36] The "time-endowment ratio" is defined as $\Phi = \frac{E}{L}$, where E is the consumer's endowment of time, and L is the amount of labor that is supplied in the base case.

Table 4-2. Calibrated Parameter Values

	U.S.	*E.U., Japan, ROW*
Time-Endowment Ratio (Φ)	1.32	1.35~1.41
Elasticities of Substitution:		
Consumption and Leisure $(\sigma_{c\ell})$	1.13	0.92~1.08
Domestic and Foreign Assets (σ^A_{rs})	1.92~2.01	1.38~1.53
Different Domestic Goods (σ_{cc}) [a]	0.25~1.55	0.25~1.55
Domestic and Imported Goods (σ^i_{dm})	0.50~3.10	0.50~3.10
Different Imported Goods (σ^i_{mm}) [a]	1.00~6.20	1.00~6.20

a. These values are arbitrarily chosen, based on the calibrated σ^i_{dm}.

Researchers have used an extraordinary variety of values for the time-endowment ratio, Φ. One strategy is to select a value for Φ, based on an essentially arbitrary assumption about the number of hours available. The value of Φ is given as 1.75 in Ballard, Fullerton, Shoven, and Whalley (1985), 2.5 in Auerbach and Kotlikoff (1987), 3.846 in Greenwood and Huffman (1991), and 5.0 in Mendoza and Tesar (1998). If the value of the time-endowment ratio is specified exogenously, as in the literature above, equation (4.5) can be used to calibrate the elasticity of substitution, $\sigma_{c\ell}$, very precisely to a desired value of the uncompensated labor-supply elasticity, η_L. However, as Ballard (1999) points out, the values chosen arbitrarily (1.75 ~ 5.0) lead to exceptionally large values of the total-income elasticity of labor supply, η_I, in absolute value. The value of

Φ that is necessary to produce a reasonable value for η_I is far lower than virtually all of the values of Φ that have been chosen arbitrarily in the simulation literature.[37]

A better strategy is to choose the desired value of the total-income elasticity of labor supply, η_I, and to solve for the value of Φ that is consistent with that elasticity.[38] By the Slutsky decomposition, the difference between the compensated and uncompensated elasticities is equal to the absolute value of the total-income elasticity of labor supply:

$$\eta_L^* - \eta_L = -\eta_I . \tag{4.6}$$

Based on the econometric literature, a value of -0.1 for η_I would be reasonable. Since η_L is exogenously given as 0.15, the desired value of η_L^* would be 0.25.

Therefore, I begin with the expenditure function to derive the compensated labor-supply elasticity.

$$E = V\left\{\beta^{\sigma_{c\ell}} P_c^{1-\sigma_{c\ell}} + (1-\beta)^{\sigma_{c\ell}} P_\ell^{1-\sigma_{c\ell}}\right\}^{\frac{1}{1-\sigma_{c\ell}}}, \tag{4.7}$$

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[37] In the model of Ballard (1990b), the value of Φ that is consistent with the reasonable value of η_I, is calibrated as 1.213. He also shows that the values of Φ chosen arbitrarily, 2.5 and 5.0, produce respectively -0.4414 and -0.6787, which is far larger than the most of the econometric estimates of the total-income elasticity, -0.1.

[38] This follows Ballard (2000) closely.

where V is indirect utility function. Shephard's Lemma tells us that the compensated leisure-demand function is the derivative of the expenditure function with respect to the wage rate:

$$\frac{\partial E}{\partial P_\ell} = \ell^* = V(1-\beta)^{\sigma_{c\ell}} P_\ell^{-\sigma_{c\ell}} \left\{\beta^{\sigma_{c\ell}} P_c^{1-\sigma_{c\ell}} + (1-\beta)^{\sigma_{c\ell}} P_\ell^{1-\sigma_{c\ell}}\right\}^{\frac{\sigma_{c\ell}}{1-\sigma_{c\ell}}}. \quad (4.8)$$

Then, the compensated leisure-demand elasticity, η_ℓ^*, is:

$$\eta_\ell^* \equiv \frac{\partial \ell^*}{\partial P_\ell}\frac{P_\ell}{\ell^*} = \frac{\sigma_{c\ell} P_\ell^{\sigma_{c\ell}+1}\left\{(1-\beta)^{\sigma_{c\ell}} P_\ell^{-2\sigma_{c\ell}} \Omega^{\frac{2\sigma_{c\ell}-1}{1-\sigma_{c\ell}}} - P_\ell^{-\sigma_{c\ell}-1}\Omega^{\frac{\sigma_{c\ell}}{1-\sigma_{c\ell}}}\right\}}{\Omega^{\frac{\sigma_{c\ell}}{1-\sigma_{c\ell}}}}$$

(4.9)

where $\Omega = V\left\{\beta^{\sigma_{c\ell}} P_c^{1-\sigma_{c\ell}} + (1-\beta)^{\sigma_{c\ell}} P_\ell^{1-\sigma_{c\ell}}\right\}^{\frac{1}{1-\sigma_{c\ell}}}$. Using equation (4.4), the compensated leisure-demand elasticity converts to the compensated labor-supply elasticity, η_L^*:

$$\eta_L^* = (1-\Phi)\sigma_{c\ell}\left(\frac{P_\ell \ell}{Y_1} - 1\right). \quad (4.10)$$

This equation can be used to calibrate the time-endowment ratio, Φ, that is consistent with the desired value of the compensated labor-supply elasticity, η_L^*.[39] The value of η_L^* will increase monotonically with the value of Φ. Thus, the absolute value of η_I, which has a positive relationship with the value of η_L^*, will increase monotonically with the value of Φ.

Second, I calibrate the asset-substitution elasticity, which may play a relatively large role in an open-economy model. The consumer's share of domestic assets is expected to increase when domestic rental rates are relatively higher. How much are domestic assets in his portfolio increased? The responsiveness of the decision is controlled by the elasticity of substitution between domestic and foreign assets, σ_{rs}^A. This elasticity of substitution is directly related to international capital mobility. A lower value means greater immobility of international capital. The lower value is supported by Feldstein and Horioka (1980), who report empirical evidence suggesting that capital is quite immobile internationally. Previous papers have employed fairly arbitrary assumptions regarding the value of this parameter. Gravelle and Smetters (1998) take the asset-substitution elasticity as 3.0. Thalmann, Goulder, and DeLorme (1996) take it as 4.0. My goal is to calibrate this parameter more precisely, based on the econometric evidence.

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[39] Based on the calibrated time-endowment ratio, the elasticity of substitution between consumption and leisure is re-calibrated.

Table 4-3. Elasticity of Capital Abroad and Calibrated Asset-Substitution Elasticity

Elasticity of Capital Abroad (η_{KA}) [a]		*Elasticity of Domestic Capital* (η_{KD}) [b]	*Calibrated* σ_{rs}^A
(U.S.)			
Altshuler, Grubert, and Newlon (1998)	2.80	0.24	1.92
Grubert and Mutti (2000)	3.23	0.28	2.01
(E.U., Japan, ROW)			
Boskin and Gale (1987)	1.91	0.12	1.53
Slemrod (1990)	0.77	0.05	1.38

a. The η_{KA} in the U.S. represents the elasticity of U.S. direct investment abroad, and the η_{KA} in other regions represents the elasticity of U.S. foreign direct investment.

b. The elasticities are calculated, using $\eta_{KD} = \eta_{KA} \times \left(1 - \alpha^A\right) / \alpha^A$, where α^A is the share of domestic assets in portfolio.

In Chapter 3, the equation for the elasticity of demand for domestic capital with respect to the ratio of domestic and foreign rental rates, η_{KD}, was derived from the consumer's utility maximization. As shown in equation (3.18), the elasticity of demand for domestic capital depends on the amount of domestic capital, K^{rr}, and the asset-substitution elasticity, σ_{rs}^A. Therefore, the asset-substitution elasticity can be calibrated, using the value of η_{KD}, which is calculated based on the value of the elasticity of demand for capital abroad, η_{KA}, which, in turn, is taken from the econometric literature.

As shown in Table 4-3, if I use the value of the elasticity of capital abroad provided by Altshuler, Grubert, and Newlon (1998), I calibrate the asset-substitution elasticity for the U.S. to be 1.92. If I use the elasticity estimated by Grubert and Mutti (2000), the calibrated asset-substitution elasticity is 2.01.[40] Similarly, the asset-substitution elasticities in other regions of the world are calibrated as 1.38 and 1.53, based on the values of the elasticity of capital abroad, provided by Slemrod (1990) and Boskin and Gale (1987). Therefore, in this analysis, I take the central values of the asset-substitution elasticity in the U.S. and other regions as 2.0 and 1.5, respectively, although I will also perform sensitivity analysis.

Finally, I consider the calibration of the elasticities of substitution in the third, fourth, and fifth level of consumer's decision. On the third level, the consumer maximizes aggregate consumption, which is represented by a CES aggregation of consumption demands among different sectors. The demand function for goods is:

$$C_i^r = \left(\frac{\beta_i^C}{P_i^r} \right)^{\sigma_{cc}} \frac{Y_2^r}{\Delta}, \qquad (4.11)$$

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[40] Only available one from the literature is the value of η_{KA} with respect to r^*, not the value of η_{KA} with respect to (r^* / r). For calibrating asset-substitution elasticity, I use this available one as a proxy for the value of η_{KA} with respect to (r^* / r), based on the idea that investment decision depends on the relative size of each region's r, rather than on the absolute size of it. Altshuler, Grubert, and Newlon (1988) estimate the elasticity of real capital abroad with respect to after-tax returns (η_{KA}) as 2.80. Based on this information, and considering the share of domestic assets (α^A) under the assumption of home-country asset preference, I calculate the elasticity of domestic capital (η_{KD}) as 0.24. I also calculate the elasticity of domestic capital as 0.28, using the value of the elasticity of capital abroad, 3.23, which is estimated by Gruber and Mutti (2000).

where $\Delta = \sum_i \beta_i^{C^{\sigma_{cc}}} P_i^{r\,1-\sigma_{cc}}$. Then, the demand elasticities, $\mu^{cc}(i)$, are:

$$\mu^{cc}(i) \equiv \frac{\partial C_i^r}{\partial P_i^r}\frac{P_i^r}{C_i^r} = \frac{(\sigma_{cc}-1)P_i^r C_i^r}{Y_2^r} - \sigma_{cc}. \tag{4.12}$$

Substituting for the expenditure share, $\theta^{cc}(i) = \frac{P_i^r C_i^r}{Y_2^r}$, and arranging for σ_{cc} give:

$$\sigma_{cc} = \frac{\mu^{cc}(i) + \theta^{cc}(i)}{\theta^{cc}(i) - 1}. \tag{4.13}$$

The elasticity of substitution among different domestic goods depends on the price elasticity of demand for a given variety of domestic goods, $\mu^{cc}(i)$, and the expenditure share, $\theta^{cc}(i)$.

The trade elasticities are very crucial, especially in a global model that deals with trade issues. The σ_{dm}^i parameters represent the higher-level Armington elasticities between domestic goods and imported goods, in the fourth level of the consumer's decision, and the σ_{mm}^i parameters represent the lower-level Armington elasticities among imported goods from different regions, in the fifth level of the consumer's decision. These elasticity values are very important, because the magnitude of the terms-of-trade effects varies substantially with these trade elasticities. According to Brown

(1987), lower trade-elasticities tend to produce strong terms-of-trade effects. Shiells and Reinert (1993) suggest that higher values of Armington elasticities must be considered, in order to avoid large terms-of-trade effects. It would be possible to calibrate the trade elasticities on the basis of econometric evidence, as I have just done for the asset-substitution elasticities.

The procedure for calibrating σ_{dm}^{i} and σ_{mm}^{i} is similar to that for calibrating σ_{cc}. An equation for the elasticity of substitution between domestic and imported goods is:

$$\sigma_{dm}^{i} = \frac{\mu_i^{dm}(s) + \theta_i^{dm}(s)}{\theta_i^{dm}(s) - 1}, \tag{4.14}$$

where the $\mu_i^{dm}(s)\left(\equiv \frac{\partial C_i^{sr}}{\partial P_i^{sr}} \frac{P_i^{sr}}{C_i^{sr}}\right)$ are the price elasticities of import demand, and the $\theta_i^{dm}(s)\left(= \frac{P_i^{sr} C_i^{sr}}{Y_3^r}\right)$ are the expenditure shares of imported goods vs. domestically produced goods. In addition, an equation for the elasticity of substitution among different imported goods is:

$$\sigma_{mm}^{i} = \frac{\mu_i^{mm}(s_k) + \theta_i^{mm}(s_k)}{\theta_i^{mm}(s_k) - 1}, \tag{4.15}$$

where $\mu_i^{mm}(s_k)\left(\equiv \frac{\partial C_i^{s_k r}}{\partial P_i^{s_k r}} \frac{P_i^{s_k r}}{C_i^{s_k r}}\right)$ are the price elasticities of import demand for a given variety of imported goods, and the $\theta_i^{mm}(s_k)\left(=\frac{P_i^{s_k r} C_i^{s_k r}}{Y_4^r}\right)$ are the expenditure shares of imported goods from different regions.

I conclude that the elasticities of substitution, σ_{cc}, σ_{dm}^i, and σ_{mm}^i, can be calibrated by selecting the corresponding demand elasticities, $\mu^{cc}(i)$, $\mu_i^{dm}(s)$, and $\mu_i^{mm}(s_k)$, from the econometric literature. Among them, I start with the elasticity of substitution between domestic and imported goods, σ_{dm}^i, that relies on the price elasticities of import demand, $\mu_i^{dm}(s)$, which are relatively more available in the empirical trade literature.[41] Then I arbitrarily choose the values of σ_{cc} and σ_{mm}^i, based on the prior belief that the elasticity of substitution among different imported goods is larger than the elasticity of substitution between domestic and imported goods, which in turn, is larger than the elasticity of substitution among different domestic goods ($\sigma_{cc} < \sigma_{dm}^i < \sigma_{mm}^i$). I choose this procedure, instead of the alternative procedure of calibrating the values of σ_{cc} and σ_{mm}^i, because the information necessary to calibrate σ_{cc} and σ_{mm}^i is relatively less available in the econometric literature.[42]

[41] Sawyer and Sprinkle (1999) review the literature on empirical estimates of the income and price elasticities of demand for imports and exports by country, which have been published since 1976.

[42] In other words, I assume that the price sensitivity when choosing between cars and machines is absolutely lower than the price sensitivity when choosing between domestic and imported cars, and that the sensitivity when choosing between domestic and imported cars is probably less than the price sensitivity

I calibrate the elasticity of substitution between domestic and imported goods. Table 4-4 shows the results. I have a very wide range of calibrated values for σ^i_{dm}, from a low value of 0.8 to a high value of 3.3. The values of σ^i_{dm} depend completely on the values of μ_i^{dm}, of which the econometric literature has an extremely wide range.

Table 4-4. Price Elasticities of Import Demand and Calibrated Trade Elasticity of Substitution

Price Elasticities of Import Demand, μ_i^{dm}		*Calibrated* σ^i_{dm}
Stern, Baum, and Greene (1979)	-2.18	2.7
Haynes and Stone (1984)	-2.83	3.3
Moffett (1989)	-0.68	1.2
Deyak, Sawyer, and Sprinkle (1990)	-0.54	0.9
Carone (1996)	-0.39	0.8
Deyak, Sawyer, and Sprinkle (1997)	-1.32	1.9

Consequently, I defer to the judgment of Jomini, *et al.* (1991), and use the SALTER elasticities of substitution, which represent a compromise between econometric evidence and prior belief, as the central values. In the SALTER setting, the values of

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when choosing among various imported cars. For this reason, the arbitrary value of σ^i_{mm} must be higher than the calibrated value of σ^i_{dm}, and the arbitrary value of σ_{cc} must be smaller than σ^i_{dm}. Fehr, Rosenberg, and Wiegard (1995) follow this procedure: They calibrate the value of $\sigma^i_{dm} = 1.5$, based on the price elasticities of import demand, μ_i^{dm}, which are provided by Stern, Francis, and Schumacher (1976). And they arbitrarily take the values of $\sigma_{cc} = 1.1$ and $\sigma^i_{mm} = 2.0$, based on the calibrated σ^i_{dm}.

σ^i_{dm} are based on preferred estimates from the econometric literature, with some upward adjustment, and the values of σ^i_{mm} are set at twice the values of σ^i_{dm}.[43] According to Dimaranan, McDougall, and Hertel (1998), they are generally higher than those estimated by the econometric literature, to avoid strong terms-of-trade effects, but still low enough to generate terms-of-trade effects. The sector-specified SALTER trade elasticities are shown in Table 4-5.

Table 4-5. The SALTER Trade Elasticities [a]

Sectors	σ^i_{dm}	σ^i_{mm}
Agriculture	2.43	4.86
Primary Materials	2.60	5.20
Durable Manufactures	3.40	6.80
Non-durable Manufactures	2.75	5.50
Services	2.05	4.10

a. The SALTER values, which are provided by Jomini, *et al.* (1991), are modified to fit my model, using a weight parameter.

[43] The estimated trade elasticities in econometric literature are: σ^i_{dm} = 0.14~3.49 in Reinert and Roland-Holst (1992), σ^i_{dm} = 1.0 and σ^i_{mm} = 1.5 in Shiells and Reinert (1993), and Hamilton and Whalley (1985).

CHAPTER 5

DATA AND SIMULATION METHOD

5.1. Data Interpretation

5.1.1. Data Aggregation

I begin by aggregating the 45 regions in the GTAP database into four regions; the United States, the European Union, Japan, and the Rest of the World (hereafter ROW). This four-region version of the model is well suited for analysis of the tax policies affecting the major developed trading areas. Table 5-1 shows the levels of economic activity for the four regions. The transactions are measured in billions of 1995 dollars. The United States, the European Union, and Japan have more than 70 percent of the world income, and jointly participate in a large fraction (about 60 percent) of world trade. The mappings of regions are shown in Table 5-2.

Table 5-1. Levels of Economic Activity by Region

(Unit: Billions of 1995 dollars)

	Income	*Income %*	*Trade* [a]	*Trade %*
U.S.	7,126.4	25.17	1,640.1	13.58
E.U.	7,852.5	27.73	4,424.6	36.64
Japan	5,091.7	17.98	976.9	8.89
ROW	8,243.7	29.12	5,035.2	41.69

a. The figures are calculated as the sum of the values of imports and exports.

Table 5-2. Dataset Mapping of Regions from GTAP version 4

Regions in GTAP	*Mapping in the Model*	*Regions in GTAP*	*Mapping in the Model*
Australia	ROW	Argentina	ROW
New Zealand	ROW	Brazil	ROW
		Chile	ROW
Japan	JPN	Uruguay	ROW
		Rest of South America	ROW
Republic of Korea	ROW		
Indonesia	ROW	United Kingdom	TEU
Malaysia	ROW	Germany	TEU
Philippines	ROW	Denmark	TEU
Singapore	ROW		
Thailand	ROW	Sweden	ROW
Vietnam	ROW	Finland	ROW
China	ROW		
Hong Kong	ROW	Rest of EU [a]	TEU
Taiwan	ROW		
India	ROW	European Free Trade Area [b]	ROW
Sri Lanka	ROW	Central European Associates	ROW
Rest of South Asia	ROW	Former Soviet Union	ROW
Canada	ROW	Turkey	ROW
		Rest of Middle East	ROW
United States of America	USA	Morocco	ROW
		Rest of North Africa	ROW
Mexico	ROW	South Africa	ROW
Central America and Caribbean	ROW	Rest of South Africa	ROW
		Rest of Sub-Saharan Africa	ROW
Venezuela	ROW	Rest of the World	ROW
Colombia	ROW		
Rest of Andean Pact	ROW		

a. Rest of EU includes France, Greece, Italy, Portugal, Netherlands, Belgium, Spain, Ireland, Luxembourg, and Austria.
b. EFT includes Norway and Switzerland.

The GTAP database originally has 50 sectors. These are aggregated to five sectors for the analysis: agriculture, primary materials, durable manufactures, non-durable manufactures, and services. The mappings of sectors are shown in Table 5-3.

Table 5-3. Dataset Mapping of Sectors from GTAP version 4 [a]

Sectors in GTAP	*Mapping in the Model*	*Sectors in GTAP*	*Mapping in the Model*
Paddy rice	AGR	Wearing apparel	NMF
Wheat	AGR	Leather goods	NMF
Grains (other than rice and wheat)	AGR	Lumber and wood	NMF
		Pulp and paper	NMF
Vegetable fruit nuts	AGR		
Oil seeds	AGR	Petroleum and coal products	PRY
Sugar cane and beet	AGR		
Plant-based fibers	AGR	Chemicals rubber and plastics	PRY
Crops n.e.c.	AGR		
Bovine cattle - sheep and goats -horse	AGR	Non-metallic mineral products	PRY
Animal products n.e.c.	AGR	Primary ferrous metals	PRY
Raw milk	AGR	Non-ferrous metals	PRY
Wool	AGR		
Forestry	AGR	Fabricated metal products	DMF
Fishing	AGR	Motor vehicles	DMF
		Other transport equipment	DMF
Coal	PRY	Electronic equipment	DMF
Oil	PRY	Machinery and equipment	DMF
Natural gas	PRY	Other manufacturing products	DMF
Other minerals	PRY		
Bovine cattle meat products	NMF	Electricity	SVS
Meat products n.e.c.	NMF	Gas manufacturing and distribution	SVS
Vegetable oils	NMF		
Dairy products	NMF	Water	SVS
Processed rice	NMF	Construction	SVS
Sugar	NMF	Trade and transport	SVS
Other food products	NMF	Other services (private)	SVS
Beverages and tobacco	NMF	Other services (public)	SVS
Textiles	NMF	Dwellings	SVS

a. AGR=agriculture, PRY=primary materials, NMF=non-durable manufactures, DMF=durable manufactures, SVS=services

5.1.2. Tax Rates and Trade Data

In this section, the structures of factor taxes and consumption taxes are reviewed. Table 5-4 shows the different factor-tax rates in each of three major trading areas.[44]

Table 5-4 indicates that the overall tax rates on capital income are not very different across regions. In each region, capital income is taxed at about 35 percent. However, capital-tax rates in each sector are much differentiated across regions. The tax rate on durable manufacturers in the U.S. is 2~3 times as large as those in the E.U. and Japan. The tax rates on labor income are considerably more differentiated across regions. The tax rates on labor income are significantly higher in the European Union. The tax rates on capital income are much higher than those on labor income in the U.S. and Japan, while the tax rates on capital income are much lower than those on labor income in the European Union.

The effective tax rates on capital income in the United States are calculated by the formula;[45]

$$\tau_K = \frac{Capital\ \ Tax\ \ Liabilities}{Net\ \ Payments\ \ to\ \ Capital}. \tag{5.1}$$

[44] The tax rates in the ROW are taken as arithmetic averages of the corresponding taxes in the United States, the European Union, and Japan.

[45] Thus, we calculate the average tax rate, and then assume that marginal tax rates are equal to the average rates. This is the procedure used by Harberger (1962), Fullerton, Shoven, and Whalley (1983), and others. An alternative would be to calculate marginal effective tax rates, based on data and assumptions regarding variables such as depreciation schedules, nominal tax rates, and discount rates, and then to assume that average tax rates are equal to the marginal rates. This method, in the tradition of Hall and Jorgenson (1967), is used by Jorgenson and Wilcoxen (1997). One of our reasons for choosing the former approach is that the data requirements for the latter approach are very formidable in a global model such as ours.

Table 5-4. Factor Taxes in the Model [a]

(Unit: %)

	U.S. [b]		*E.U.*		*Japan* [e]	
	Capital Taxes (1)	Labor Taxes (2)	Capital Taxes [c] (3)	Labor Taxes [d] (4)	Capital Taxes (5)	Labor Taxes (6)
AGR	8.53	12.57	18.05	48.50	34.69	18.20
PRY	22.26	13.38	27.74	48.50	21.18	22.61
DMF	93.11	13.15	43.45	59.45	31.95	23.42
NMF	53.01	13.24	41.19	50.50	34.73	24.09
SVS	30.00	17.32	33.69	51.28	34.85	24.18
Overall	35.74	16.27	33.57	51.66	34.25	22.59

Source: Author's calculations.

a. These rates are all calculated as rates of tax on net-of-tax factor incomes.
b. 1995 data.
c. The rates are weighted averages of 1993 data for Germany, France, Italy, and the U.K.
d. 1994 data for Italy.
e. 1998 data on capital taxes, and 1999 data on labor taxes.

The return to capital, net-of-factor taxes, includes corporate profits after tax with inventory valuation adjustment, the return to unincorporated capital, capital consumption adjustment, net rent paid, and net interest paid. The tax on capital income at the industry level has three components: the corporation income tax levied by the federal government, corporation franchise taxes levied by the state governments, and property taxes levied by the state and local governments.[46] The August 1998 *Survey of Current Business* (SCB) gives us data on the capital income net-of-tax and capital tax liabilities, directly or

[46] For simplicity, corporation franchise taxes, which are relatively small, are assumed to be zero.

indirectly.[47] The column (1) of Table 5-4 shows the U.S. tax rates on capital income. The U.S. capital taxes have much variance across sectors: the tax rates are highest in durable manufactures, and lowest in agriculture.

The effective tax rates on labor income in the United States are calculated by the formula;[48]

$$\tau_L = \frac{Labor\ \ Tax\ \ Liabilities}{Net\ \ Payments\ \ to\ \ Labor}. \tag{5.2}$$

The net-of-factor-tax return to labor is the sum of wages, salaries, and the estimated return to the labor of self-employed individuals. The tax on labor income includes employer contributions to social insurance, employer contributions to OASDHI (Old Age, Survivors, Disability, and Hospital Insurance), and self-employed contributions to OASDHI. The data on labor-tax liabilities, as well as the net-of-factor-tax return to labor, are provided directly or indirectly by the August 1998 *SCB*, and unpublished worksheets from NID.[49] As shown in the column (2) of Table 5-4, the U.S. labor taxes are close to the overall average of 16 percent.

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[47] Since the August 1998 *SCB* provides us only the data on the aggregate of capital consumption adjustment, the aggregate of net rent paid, and the aggregate of industrial property taxes, I distribute those aggregate values to each sector, on the basis of the corporate capital consumption allowance by sectors, net interest paid by sectors, and corporation income taxes by sectors, which are available in the August 1998 *SCB* and unpublished worksheet from National Income Division (NID), respectively.

[48] This method is also followed in GEMTAP.

[49] Unpublished worksheets from NID are available in http://www.bea.doc.gov.

Among the E.U. members, only four countries (Germany, France, Italy, and the United Kingdom) are considered, in computing tax rates of the European Union. The sum of GDP of those four countries consists of more than 70 percent of total GDP in the European Union.

Each country's rates of tax on net-of-tax capital income are calculated by dividing the corresponding country's capital-tax liabilities by the corresponding country's after-tax capital income. The taxes on capital income include household's payments of capital income taxes, the payments of capital income taxes made by corporations, all recurrent taxes on immovable property, and taxes on financial and capital transactions, which are available in *National Accounts Statistics: Main Aggregates and Detailed Tables, 1995*, and *Revenue Statistics of OECD Member Countries, 1965-1994*. The after-tax capital income can be replaced by the net-of-tax operating surplus of the economy as a whole, which is defined as gross output less the sum of intermediate consumption, compensation of employees, consumption of fixed capital, and indirect taxes.[50] *National Accounts Statistics: Main Aggregates and Detailed Tables, 1995,* gives us the data on operating surplus.

To get sector-specific tax rates on capital income, I distribute the aggregate value of the taxes on capital income to each sector, on the basis of the each sector's share of total investment, which is available in *OECD Economic Surveys*, and divide those distributed values over sector-specific operating surplus, which are provided by *National Accounts Statistics: Main Aggregates and Detailed Tables, 1995.*

[50] See Mendoza, Razin, and Tesar (1994) for details.

The overall and sector-specific tax rates in the four countries are shown in Table 5-5. The capital-income tax is significantly higher in the United Kingdom than in the other countries of the European Union. Generally, the sector of manufactures has the highest tax rates in most countries.

Finally, I attach a weight on each country, on the basis of the level of each country's GDP, which are available in *National Accounts, Main Aggregates, 1960-1997*, to get the weighted average of tax rates of the European Union. The last column of Table 5-5 has the weighted average of tax rates on capital income in the European Union.

Table 5-5. Capital Taxes in E.U.

(Unit: %)

	Germany	*France*	*Italy*	*U.K.*	*E.U. (weighted average)*
AGR	26.29	5.25	12.28	25.91	18.05
PRY	26.29	32.80	12.28	42.96	27.74
DMF	54.20	17.67	27.15	75.35	43.45
NMF	54.20	7.96	27.15	75.35	41.19
SVS	25.38	20.96	34.26	63.27	33.69
Overall	29.60	18.12	31.60	61.79	33.57

Source: Author's calculations.

Data on the sector-specific labor tax rates are sparse. Based on information in Messere (ed., 1998), I calculate sector-specific tax rates for Italy. I use these rates for the European Union as a whole. The column (4) of Table 5-4 shows the assumed E.U. rates on labor income.

For Japan, the effective tax rates on capital income are computed by dividing corporation tax by corporate income assessed, which are provided by *Japan Statistical Yearbook 2001*. The effective tax rates on labor income are calculated by dividing labor cost, which includes the cost of retirement allowances, cost of obligatory welfare services, and cost of non-obligatory welfare services, over the total value of cash earnings. *Japan Statistical Yearbook 2001* gives us data on labor cost and value of cash earnings. The tax rates on net-of-tax factor income in Japan are shown in the columns (5) and (6) of Table 5-4.

Table 5-6. Consumption Tax Rates in the Model [a]

(Unit: %)

	U.S.	*E.U.*	*Japan*	*ROW*
Consumption Taxes				
Agriculture	1.66	2.72	-	1.40
Primary Materials	3.36	3.58	5.83	6.26
Durable Manufactures	0.72	2.53	3.19	6.35
Non-durable Manufactures	2.65	2.61	6.48	6.03
Services	7.86	2.45	3.16	3.05

a. Tax rates are calculated, based on dataset.

The consumer taxes on goods purchased are computed, based on the dataset for the gross-of-tax values of goods purchased, and the net-of-tax values of goods purchased. Indirect taxes, such as the commodity taxes and the selective excise taxes, are treated as the consumer taxes on goods purchased. Table 5-6 reports the consumption tax rates in the dataset.[51] Generally, higher tax rates are levied on primary-material goods purchased. In the U.S., the rates are very differentiated across sectors: the highest rates are on services, and the lowest rates are on durable manufactures.

Table 5-7. Import Tariffs by Sector

(Unit: %)

Source \ *Destination*	*U.S.*	*E.U.*	*Japan*	*ROW*
(Agriculture)				
U.S.		11.64	164.56	24.56
E.U.	4.69		33.80	19.13
Japan	0.90	8.50		6.59
ROW	4.30	9.26	34.40	0.13
(Primary Materials)				
U.S.		3.19	1.52	5.34
E.U.	3.49		2.12	8.22
Japan	3.38	4.85		10.79
ROW	1.24	1.21	0.78	0.09
(Durable Manufactures)				
U.S.		3.43	0.94	5.66
E.U.	2.69		0.42	10.65
Japan	2.76	5.29		13.03
ROW	1.09	3.01	0.51	0.11
(Non-durable Manufactures)				
U.S.		7.97	17.70	10.64
E.U.	10.01		22.58	16.50
Japan	6.17	8.32		27.83
ROW	6.68	9.25	13.34	0.20
(Services)				
U.S.		-	3.00	0.19
E.U.	-		2.99	0.32
Japan	-	-		0.15
ROW	-	-	2.99	

[51] Most European countries adopt the value-added tax (VAT). However, the VAT is not included in the dataset. If the VAT is considered, the effective consumption tax rates for the E.U. would be higher. In order to maintain the overall balance of the data base, I do not simply change one region's tax rates, leaving the rest of the data base unchanged.

Next, I analyze the import tariffs and the patterns of trade. Table 5-7 reports the import tariffs in the dataset. In most regions, there is considerable variation in tariff rates across sectors. In Japan, import barriers for agriculture range from 33.8 to 164.6 percent.

The data on imports and exports are reported in Table 5-8, and the data on bilateral trade flows by sectors are summarized in Table 5-9. The United States has a trade deficit, whereas Japan has a trade surplus, and the European Union is almost in the state of trade balance. The United States is a "net importer" in the sectors of primary materials, durable manufactures, and non-durable manufactures, and is a "net exporter" in the sectors of agriculture and services. Especially, in durable manufactures, the data on bilateral trade flows say that the United States is an overall "net importer", but is a "net exporter" in a trade with the European Union.

Table 5-8. Total Value of Imports and Exports by Sector and Region [a]

(Unit: Billions of 1995 dollars)

	U.S.	*E.U.*	*Japan*	*ROW*
Value by Sector				
AGR	18.8/37.7	91.1/56.7	45.0/0.70	103.8/106.4
PRY	177.6/103.9	538.0/478.9	115.7/67.3	616.4/645.8
DMF	435.7/317.0	777.3/825.3	98.9/344.8	1,079.1/698.7
NMF	142.5/73.6	419.9/368.8	100.9/15.1	421.6/491.3
SVS	129.7/203.8	392.7/475.8	113.8/74.8	391.5/480.6
Total Value	904.2/735.9	2,219.1/2,205.5	474.3/502.6	2,612.4/2,422.8

a. The figures are imports/exports.

Table 5-9. Bilateral Trade Flows by Sector

(Unit: Billions of 1995 dollars)

Source \ Destination	*U.S.*	*E.U.*	*Japan*	*ROW*	*All Exports*
(Agriculture)					
U.S.		5.73	8.49	23.45	37.67
E.U.	1.07	41.38 [a]	0.89	13.35	56.99
Japan	0.06	0.05		0.57	0.68
ROW	15.36	32.60	12.23	46.23 [a]	106.42
All Imports [b]	16.45	79.76	21.61	83.60	
(Primary Materials)					
U.S.		23.12	10.00	70.76	103.88
E.U.	30.95	296.70 [a]	10.37	140.84	478.86
Japan	10.26	6.83		50.16	67.25
ROW	120.42	172.10	85.23	268.04 [a]	645.79
All Imports [b]	161.63	498.75	105.60	529.80	
(Durable Manufactures)					
U.S.		69.08	30.54	217.33	316.95
E.U.	66.94	461.75 [a]	18.82	277.82	825.33
Japan	107.02	55.25		182.53	344.80
ROW	235.69	152.04	44.14	266.83 [a]	698.69
All Imports [b]	409.65	738.12	93.50	944.51	
(Non-durable Manufactures)					
U.S.		11.21	13.92	48.49	73.62
E.U.	16.74	234.03 [a]	10.09	107.95	368.81
Japan	1.69	1.39		11.96	15.05
ROW	106.44	139.84	60.43	184.60 [a]	491.31
All Imports [b]	124.87	386.47	84.44	353.00	
(Services)					
U.S.		75.48	19.85	73.77	169.10 [c]
E.U.	60.73	184.19 [a]	13.42	140.87	399.21 [c]
Japan	12.34	12.24		32.08	56.66 [c]
ROW	55.80	114.05	74.39	137.51 [a]	381.75 [c]
All Imports [b]	128.87	385.96	107.66	384.23	

a. These figures are the values of the intra-region trades.
b. These figures are different from the gross-tariff values of total imports, in Table 5-8.
c. These figures are different from the values of total exports that include international transport sales, in Table 5-8.

5.2. Simulation Method

Quasi-Newton Iterations are applied in this analysis. The Newton methods are used in several recent applied general equilibrium models to compute counterfactual equilibria associated with changes in polices. These methods solve the systems of nonlinear equations characterizing equilibrium by using successive linear approximations to the nonlinear system.[52] The equation system that characterizes equilibrium cannot typically be written in closed form, since market demands are the sum of individual agent demands. As a result, point estimates of derivatives of market excess demand functions are repeatedly calculated and used to estimate successive adjustments to the initial guess of the equilibrium prices. These Newton steps allow large initial adjustments to the starting vector of prices. When successive adjustments produce divergence rather than convergence in solution, the Jacobian matrix must be recalculated during the computation process.

[52] See Shoven and Whalley (1992).

CHAPTER 6

SIMULATION RESULTS IN THE STATIC CASE

I analyze the international spillover effects of U.S. tax reform. Since many of the proposals for tax reform point toward reduced taxation of capital income, and toward increased consumption taxation, I consider here the extreme case of complete elimination of capital taxes.[53] The lost revenues are replaced with higher rates of consumption tax, so that tax revenue remains unchanged.[54] After eliminating capital taxes, a new competitive equilibrium is calculated and compared with the benchmark equilibrium. The results, such as changes in output, imports, terms of trade, consumption, and utility levels, are measured in percentage changes from the benchmark equilibrium. The changes in utility between the new and old equilibria are also measured by using the equivalent variation.[55]

6.1. Central-Case Simulation

A simulation, using the central values of parameters, begins with the analysis of unilateral replacement of U.S. capital taxes. The fiscal policy initiated by one country

[53] I take "the complete elimination of capital taxes with a replacement of consumption taxes" as the main scenario in the analysis. Later in this chapter, I will deal with some alternative scenarios.

[54] I model the personal income tax on capital income as if it were paid at the industry level, for simplicity. So, the sector-specific capital taxes, which include corporate-income taxes and property taxes, are incorporated in the model.

[55] The equivalent variation, in the case where preferences are linearly homogenous, is written as:

$$EV = \frac{H^N - H^O}{H^O} \cdot I^O ,$$

where H^N is the new utility level, H^O is the old utility level, and I^O is the old income level.

has important impacts on prices and resources allocation in other countries, as well as in that country. The spillovers occur through both terms-of-trade changes and through effects on international capital flows.

Unlike a conventional closed-economy analysis, the terms-of-trade effects must be considered in the analysis of tax-policy changes in a global trade model, which takes international trade flows into account.[56] In the international trade setting in this model, which allows for changes in imports and exports, the terms-of-trade effects associated with tax changes have effects on worldwide welfare: One region may improve its terms of trade with another, giving an increase in welfare for one region and a decrease in welfare for the other. In the analysis of elimination of the sector-specific capital taxes in the U.S., negative terms-of-trade effects are expected for the United States. If the U.S. eliminates capital taxes, there will be decreases in the gross-of-capital-tax prices of U.S. output. Thus, there will be a decline in the prices of U.S. exports and in the prices of U.S. output produced for the domestic market (the first-order effect). Since the prices of domestic goods decrease, domestic consumers will consume more domestic goods and fewer imports. The reduction in its demand for imports leads to a decrease in its import prices (the second-order effect). The first-order effect typically dominates the second-order effect, so that negative terms-of-trade effects are expected. These negative effects reduce the U.S. welfare gains from the elimination of domestic distortions.[57]

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[56] A country's terms of trade is measured by an index of the prices of its exports relative to the prices of its imports. An improvement in the U.S. terms of trade means that each unit of U.S. exports yields more units of imports available to the U.S. economy than previously.

[57] Whalley (1980) also explains the terms-of-trade effects of factor taxes. Since taxes on factors in the U.S. operate in the form of origin-based taxes, which are not rebated on exports, factor taxes produce terms-of-trade gains. He analyzes the effect of removing domestic factor taxes, and shows that the abolition of factor taxes causes a deterioration in the terms of trade.

International capital flows must be also considered in the open-economy model, in which investors hold internationally diversified portfolios, and exhibit sensitivity to differentials in returns on assets from different national financial markets. A fiscal-policy change initiated by a given country may alter investors' share of domestic assets. As a result of tax-policy changes, there is a reallocation of the existing world capital stock among all of the sectors in the world. The reduction in U.S. capital taxes raises the after-tax returns on U.S.-located capital, and thus leads investors to reallocate more capital stocks in the U.S., out of other countries. The U.S. changes the tax rate on capital in its five sectors, and this leads to a change in the amount of capital located in each of those five sectors, as well as in each of the other 15 sectors (five sectors each in E.U., Japan, and ROW). This leads to a new equilibrium in which the rates of return on both domestic and foreign assets have changed. This change can have significant welfare consequences.

In addition to both terms-of-trade and capital-flow effects, Harberger effects are expected only for the United States that initiates the tax-policy changes, since the equalization of capital tax rates leads to a more efficient allocation of the U.S. capital stock.

Table 6-1 summarizes the possible effects of reducing U.S. capital taxes on the entire world. Whether each country will have positive (or negative) welfare gains totally depends on the relative sizes of those three effects. For the U.S., if the two positive effects dominate the negative terms-of-trade effects, then positive welfare gains will occur. For the other countries, the terms of trade will be improved, but the capital stocks will flow out of those countries to the United States. If the positive terms-of-trade effects dominate the negative capital-flow effects, then welfare gains will occur.

Table 6-1. Possible Effects of Reducing U.S. Capital Taxes

	U.S.	*E.U., Japan, ROW*
A. Terms-of-Trade Effects	–	+
B. Capital-Flow Effects	+	–
C. Harberger Effects	+	
Overall Effects	?	?

6.1.1. Effects on Capital Flows and Terms of Trade

Table 6-2 and Table 6-3 show the results of two of the mechanisms that determine the overall welfare effects. First, I consider the spillovers that occur as a result of international capital flows. The reduction in U.S. capital taxes raises the after-tax returns on U.S.-located capital, relative to the rate of return on foreign capital. Consequently, the reduction of capital taxes in the U.S. will tend to be accompanied by a reallocation of global capital, with a greater share of the world's capital stock being located in the United States.

Under our central-case parameters, the overall U.S. capital stock is increased by 8.5 percent.[58] The largest increase in capital in the U.S. is in the durable-manufacturing sector, because this is the sector that faced the highest capital-tax burden before the policy change. However, capital in U.S. agriculture actually decreases, because

[58] The model used here is essentially static, but has a "medium-run" time frame, in which there is enough time for capital to be reallocated among sectors or countries. This model, as the Harberger model, involves a time frame of at least three years, but probably not as much as ten years. As a result, the amount of capital that is reallocated is fairly large.

agriculture loses its tax-preferred position as a result of the tax reform. The overall capital stock in other regions is decreased by 1.8~2.5 percent.

Table 6-2. Effects on Capital Flows

(Unit: % Changes [a])

	U.S.	*E.U.*	*Japan*	*ROW*
Rental Price of Capital	8.86	-5.13	-5.64	-4.92
Capital Flows by Sector				
Agriculture	-0.26	0.24	-1.85	-0.74
Primary Materials	4.32	-2.03	-2.42	-2.37
Durable Manufactures	54.47	-3.66	-2.94	-5.83
Non-durable Manufactures	18.76	-2.46	-2.64	-3.58
Services	3.82	-1.58	-2.80	-1.59
Overall	8.49	-1.84	-2.54	-2.13

a. The figures are deviations from the benchmark values, in percent.

International spillovers also occur through changes in terms-of-trade effects. If the U.S. eliminates capital income taxes, the gross-of-capital-tax prices of the U.S. output will decrease, and thus its prices of exports will decline: U.S. export prices decline by 8.8 percent in primary materials, 11.6~14.2 percent in non-durable and durable manufactures, and 8.9 percent in services. The relatively higher change in the durable-manufacture sector can be explained by the characteristics of the U.S. tax system, in which capital use in the manufacturing sector (especially in durable manufacturing) is relatively heavily taxed. (See Table 5-4.)

Table 6-3. Effects on the Terms of Trade

(Unit: % Changes [a])

	U.S.	*E.U.*	*Japan*	*ROW*
Export Prices by Sector				
Agriculture	-6.22	-7.32	-8.10	-7.89
Primary Materials	-8.81	-7.36	-8.29	-7.91
Durable Manufactures	-14.19	-7.62	-8.79	-8.48
Non-durable Manufactures	-11.56	-7.44	-8.56	-8.05
Services	-8.94	-7.43	-8.43	-8.24
Import Prices by Sector				
Agriculture	-7.97	-7.05	-7.18	-7.55
Primary Materials	-8.07	-7.25	-8.14	-8.23
Durable Manufactures	-8.61	-7.36	-10.71	-10.07
Non-durable Manufactures	-8.15	-7.39	-8.83	-8.73
Services	-8.41	-7.77	-8.47	-8.52
Terms of Trade	-1.51	0.12	0.23	0.44

a. The figures are deviations from the benchmark values, in percent.

On the other hand, as a result of the reduction in the price of domestic goods, domestic consumers will consume fewer imports. This leads to a decrease in import prices: U.S. import prices decrease by 8.0~8.6 percent in each sector. However, the reduction in U.S. export prices is larger than the reduction in U.S. import prices, and this causes a 1.5-percent deterioration in the terms of trade for the United States. After the changes in U.S. tax policy, the other regions of the world have small changes in the terms of trade, due to a larger reduction in their import prices: there is not much change in the European Union, and improvements of 0.1~0.4 percent in Japan and ROW.

6.1.2. Aggregate Effects on the U.S. Economy

Table 6-4 reports the results for the United States, which is the policy-initiating economy. Under the complete elimination of capital taxes, higher rates of consumption tax are used to achieve equal tax-revenue yield for the government. I consider a multiplicative increase in tax rates, as well as an additive increase.

The first column of Table 6-4 shows the results of the case where consumption-tax rates are increased multiplicatively (*i.e.*, all rates are increased by the same percentage). The results show that the tax-policy changes lead to a 2.0-percent increase in the overall U.S. output level: 5.9 percent in primary materials, 19.2 percent in durable manufactures, and 7.3 percent in non-durable manufactures. Because of the larger decreases in the gross-of-tax prices of the outputs in durable manufactures, the increases in outputs are larger in that sector. The overall U.S. imports are increased by 1.7 percent: U.S. imports are decreased by 4.0 percent in durable manufactures, 1.7 percent in non-durable manufactures, and 2.6 percent in services, whereas they are increased by 5.3 percent in primary materials and 11.8 percent in agriculture.

The tax-policy changes cause U.S. consumption to rise by 1.1 percent. The increase in U.S. output is much larger than the increase in U.S. consumption. This is because U.S. exports are greatly stimulated by the change in the terms of trade. Consequently, the tax-policy changes lead to U.S. welfare gains of around $98 billion per year in 1995 dollars, which amounts to about 1.4 percent of GDP. The percentage increase in welfare is larger than the percentage increase in consumption. This is because, when I use the central-case labor-supply elasticities, the decrease in the net wage rate leads to an increase in leisure.

Table 6-4. Domestic Effects of the Tax-Policy Change on the U.S. Economy

	Changes in Consumption Tax	
	Multiplicative	*Additive*
Output by Sector (% changes) [a]		
Agriculture	3.14	3.15
Primary Materials	5.93	6.17
Durable Manufactures	19.17	20.51
Non-durable Manufactures	7.34	7.47
Services	0.34	-0.17
Overall	2.02	2.13
Imports by Sector (% changes)		
Agriculture	11.76	10.78
Primary Materials	5.31	5.37
Durable Manufactures	-3.99	-3.91
Non-durable Manufactures	-1.72	-1.69
Services	-2.56	-2.56
Overall	1.67	1.65
Consumption (% changes)	1.13	1.32
Equivalent Variation ($ billions)	98.3	117.6
EV (as % of GDP)	1.38	1.65

a. Units are in parentheses.

Under the multiplicative change in consumption-tax rates, the *relative* sizes of the consumption-tax rates in different sectors are maintained. Since multiplicative replacement does nothing to alleviate consumption distortion, it may lead to smaller welfare gains than those that would occur under a different set of replacement taxes. Therefore, I also consider an additive tax-rate change. The second column of Table 6-4 has the results of the case where consumption-tax rates are increased additively (*i.e.*, all rates are increased by the same absolute amount). With the "additive" tax-rate changes, consumption in the U.S. increases by 1.3 percent (vs. 1.1 percent with multiplicative scaling), and U.S. welfare gains are around $118 billion per year, which amounts to 1.7 percent of GDP (vs. 1.4 percent with multiplicative scaling).

6.1.3. Aggregate Effects on the Foreign Economies

The policy initiated by one country affects the allocation of resources across regions. The spillovers occur through changes in both commodity flows and capital flows. The results of the policy change in the U.S. on the foreign economies are reported in Table 6-5.

The results show that the U.S. tax-policy change, which replaces capital taxes with consumption taxes, leads to lower outputs in the foreign regions. The overall outputs in the foreign economy are decreased by 0.5~1.0 percent. The reduction of output is primarily attributable to international capital outflows. As pointed out by Thalmann, Goulder, and DeLorme (1996), the mechanisms that determine the overall welfare impacts can be complex.

Table 6-5. Spillover Effects of the U.S. Tax-Policy Change on Foreign Economies

	Foreign Economy					
	E.U.		*Japan*		*ROW*	
	(1) [b]	*(2)* [c]	*(1)*	*(2)*	*(1)*	*(2)*
Output by Sector (% changes) [a]						
Agriculture	-0.39	-0.42	-0.69	-0.61	-0.16	-0.14
Primary Materials	-0.52	-0.63	-0.81	-0.85	-0.78	-0.79
Durable Manufactures	-1.09	-1.11	-1.28	-1.32	-1.63	-1.69
Non-durable Manufactures	-0.53	-0.62	-0.80	-0.82	-1.11	-1.14
Services	-0.41	-0.38	-0.75	-0.76	-0.34	-0.31
Overall	-0.54	-0.56	-0.84	-0.87	-0.93	-0.95
Imports by Sector (% changes)						
Agriculture	-0.80	-0.82	-0.93	-0.99	-0.83	-0.99
Primary Materials	-0.75	-0.79	-0.81	-1.08	-0.87	-1.01
Durable Manufactures	0.09	0.14	0.79	0.69	-0.47	-0.53
Non-durable Manufactures	0.53	0.52	0.24	0.34	-0.51	-0.54
Services	-0.41	-0.42	-0.42	-0.46	0.31	0.21
Overall	-0.47	-0.51	-0.53	-0.66	-0.60	-0.67
Consumption (% changes)	-0.52	-0.53	-0.76	-0.79	-0.66	-0.71
Equivalent Variation ($ billions)	-32.9	-35.3	-31.1	-32.0	-42.0	-48.6
EV (as % of GDP)	-0.42	-0.45	-0.61	-0.63	-0.51	-0.59

a. Units are in parentheses.
b. Each column (1) shows the results from a simulation with multiplicative changes in consumption-tax rates in the United States.
c. Each column (2) shows the results from a simulation with additive changes in consumption-tax rates in the United States.

On the one hand, the U.S. tax policy raises after-tax returns on U.S.-located capital, which benefits foreigners who own such capital. By raising these foreigners' capital income, the tax policy generates revenues to the foreign government. On the other hand, the higher returns in the United States tend to increase the attractiveness of investment in U.S.-located capital, so there will be reallocation of capital from the foreign economies to the United States. The reduction in foreign-located capital leads to a negative impact on the welfare of the foreign economies. The latter negative effects are partly offset by the former positive effects. Therefore, if I focus only on the capital market, the foreign economies suffer welfare losses.

Due to the elimination of the U.S. capital taxes, the terms of trade for foreign economies are improved, by small amounts of 0.1~0.4 percent. However, the positive terms-of-trade effects for the foreign economies are dominated by the negative capital-flow effects. As a result, there is lower consumption and lower welfare in the foreign economies. The levels of consumption in the European Union, Japan, and the ROW are decreased by 0.5 percent, 0.8 percent, and 0.7 percent, respectively. The welfare losses are 0.4~0.6 percent of their GDP.

6.1.4. Decomposing the Welfare Effects

In this section, the overall welfare effects are decomposed. Table 6-6 shows the process of the decomposition for the U.S. welfare. The overall effects can be isolated, with comparing of four different cases: the case with central values of the trade elasticity of substitution and the asset-substitution elasticities, the case with zero value of the asset-substitution elasticity (which has zero capital-flow effects), the case with big value of the trade elasticity of substitution (which is big enough to have zero terms-of-trade effects), and the case with zero asset-substitution elasticity and big trade elasticity of substitution.

Table 6-6. U.S. Static Welfare Changes of Unilateral Case, As a Function of the Trade and the Asset Parameters

(Unit: % of GDP)

		Trade Elasticity of Substitution			
		Central	*Big*		*Terms-of-Trade Effects*
Asset-Substitution	*Central*	1.38	2.05	⇒	-0.67 [c]
Elasticity	*Zero*	0.15	0.74	⇒	-0.59 [d]
		⇓	⇓		
Capital-Flow Effects		1.23 [a]	1.31 [b]		

a. the case with holding constant trade parameters
b. the case with holding constant trade parameters, and terms-of-trade effects at zero
c. the case with holding constant asset parameters
d. the case with holding constant asset parameters, and capital-flow effects at zero

The capital-flow effects can be isolated from comparing the case with central and zero asset-substitution elasticities, holding constant trade parameters and also terms-of-trade effects at zero. In this simulation, the positive capital-flow effects are estimated as 1.3 percent of GDP. Similarly, the negative terms-of-trade effects, which lead to welfare losses of 0.6 percent of GDP, are estimated from comparing the case with central and big trade elasticities substitution, holding constant asset parameters and also capital-flow effects at zero. Lastly, Harberger effects, which amount to 0.7 percent of GDP, are estimated directly from the simulation with zero asset-substitution elasticity and big trade elasticity of substitution.

Table 6-7 summarizes the results for other regions, as well as the United States. As shown in Table 6-7, the numbers representing the overall effects are not necessarily equalized to the numbers, which are the sums of three effects. This is because some intersections among three effects are expected.[59] The results show that the capital-flow effects are relatively dominant everywhere. For the U.S., the positive effects (the capital-flow effects and Harberger effects) dominate negative terms-of-trade effects. For other regions, the bigger negative capital-flow effects, which are associated with welfare changes of -0.9 percent of GDP, dominate the smaller positive terms-of-trade effects, which are associated with welfare gains of 0.3~0.4 percent of GDP.

Table 6-7. Decomposing the Static EVs

(Unit: % of GDP)

	U.S.	*E.U.*	*Japan*	*ROW*
A. Terms-of-Trade Effects	-0.59	0.39	0.29	0.36
B. Capital-Flow Effects	1.31	-0.87	-0.94	-0.91
C. Harberger Effects	0.74			
Overall Effects	1.38	-0.42	-0.61	-0.51

[59] I find some intersections between the terms-of-trade effects and the capital-flow effects, in which the terms-of-trade effects are partly controlled by the asset-substitution elasticity. As domestic assets and foreign assets become closer substitutes, the terms-of-trade loss in the U.S. also becomes larger: The more sensitive investors are, the greater will be the increase in the quantity of capital supplied to the United States. As a result, a higher asset-substitution elasticity is associated with a larger decrease in the gross-of-tax price of U.S. capital. Consequently, a higher asset-substitution elasticity will be associated with a larger decrease in the price of U.S. exports, so that the deterioration of the terms of trade will be more severe.

6.2. Sensitivity Analyses

In this section, I conduct sensitivity analyses for the key parameters: (1) trade elasticities of substitution, (2) asset-substitution elasticities, and (3) labor-supply elasticities.

6.2.1. Sensitivity Analysis with Respect to the Armington Elasticities

I start with a sensitivity analysis for the Armington trade elasticities of substitution, in which four possible cases are considered. These are: (a) changes in $\sigma_{dm}(usa)$, (b) changes in $\sigma_{dm}(others)$, (c) changes in $\sigma_{mm}(usa)$, and (d) changes in $\sigma_{mm}(others)$. The results are shown in Table 6-8 through 6-11, and briefly summarized in Table 6-12.

(a) *As the* $\sigma_{dm}(usa)$ *become larger, the terms-of-trade effects become smaller.*[60] In other words, as imports become closer substitutes with domestically produced goods in the U.S., the terms-of-trade loss in the U.S. becomes smaller. The more sensitive domestic consumers are, the greater is the shift into domestically produced goods, and hence the greater will be the decreases in import prices. As the $\sigma_{dm}(usa)$ increases by 50 percent and 100 percent, the U.S. terms-of-trade loss becomes smaller by 33.2 and 52.3 percent (relative to the revised case with central-case parameters), and this leads to

[60] This differs from the result in Brown (1987). She evaluates how national product differentiation relates to the terms-of-trade effects of a tariff, and shows that the terms-of-trade effects would *increase* in magnitude, as the elasticity of substitution between domestic and imported goods becomes larger. However, we find that the terms-of-trade effects are *smaller* when the elasticity of substitution is larger. This difference comes from the fact that imposing a tariff drives the export price *up*, whereas eliminating capital-income taxation drives it *down*. Imposing a tariff leads to an increase in export prices and a decrease in import prices, and thus generates terms-of-trade gains. When the elasticity of substitution is larger, the import prices fall farther, so that the terms-of-trade gains are increased.

an increase in the U.S. welfare gain by 8.0 and 14.5 percent (relative to the revised case with central-case parameters), respectively.

Table 6-8. Sensitivity Analysis with Respect to the Elasticities of Substitution between Domestic and Imported Goods I [a]

	$\sigma^i_{dm}(usa)$				
	-50% *(1.33)*	*central* [b] *(2.65)* [c]	*25%* *(3.31)*	*50%* *(3.98)*	*100%* *(5.30)*
U.S.	(1) -2.33 (2) 0.94 (3) 1.17	(1) -1.51 (2) 1.13 (3) 1.38	(1) -1.21 (2) 1.20 (3) 1.45	(1) -1.01 (2) 1.25 (3) 1.49	(1) -0.72 (2) 1.36 (3) 1.58
E.U.	(1) 0.14 (2) -0.51 (3) -0.41	(1) 0.12 (2) -0.52 (3) -0.42	(1) 0.10 (2) -0.52 (3) -0.42	(1) 0.09 (2) -0.53 (3) -0.43	(1) 0.06 (2) -0.53 (3) -0.43
Japan	(1) 0.33 (2) -0.74 (3) -0.55	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.19 (2) -0.78 (3) -0.63	(1) 0.16 (2) -0.80 (3) -0.64	(1) 0.14 (2) -0.81 (3) -0.66
ROW	(1) 0.50 (2) -0.47 (3) -0.54	(1) 0.44 (2) -0.66 (3) -0.51	(1) 0.40 (2) -0.53 (3) -0.47	(1) 0.36 (2) -0.52 (3) -0.45	(1) 0.28 (2) -0.50 (3) -0.40

a. (1) = % changes in terms of trade
(2) = % changes in consumption level
(3) = equivalent variation (as % of GDP)

b. The central values of σ^i_{dm} are 2.43 for agriculture, 2.60 for primary materials, 3.40 for durable manufactures, 2.75 for non-durable manufactures, and 2.05 for services.

c. The figures in the parentheses (of the column heading) are represented as the weighted average of σ^i_{dm}.

Table 6-9. Sensitivity Analysis with Respect to the Elasticities of Substitution between Domestic and Imported Good II [a]

	$\sigma^i_{dm}(teu) = \sigma^i_{dm}(jpn) = \sigma^i_{dm}(row)$				
	-50% (*1.33*)	*central* [b] (*2.65*) [c]	*25%* (*3.31*)	*50%* (*3.98*)	*100%* (*5.30*)
U.S.	(1) -1.64 (2) 1.11 (3) 1.33	(1) -1.51 (2) 1.13 (3) 1.38	(1) -1.44 (2) 1.15 (3) 1.40	(1) -1.41 (2) 1.16 (3) 1.41	(1) -1.35 (2) 1.17 (3) 1.43
E.U.	(1) 0.10 (2) -0.53 (3) -0.44	(1) 0.12 (2) -0.52 (3) -0.42	(1) 0.13 (2) -0.52 (3) -0.42	(1) 0.13 (2) -0.51 (3) -0.41	(1) 0.14 (2) -0.51 (3) -0.41
Japan	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.23 (2) -0.76 (3) -0.61
ROW	(1) 0.47 (2) -0.65 (3) -0.51	(1) 0.44 (2) -0.66 (3) -0.51	(1) 0.40 (2) -0.67 (3) -0.51	(1) 0.38 (2) -0.67 (3) -0.52	(1) 0.36 (2) -0.68 (3) -0.52

a. (1) = % changes in terms of trade
(2) = % changes in consumption level
(3) = equivalent variation (as % of GDP)

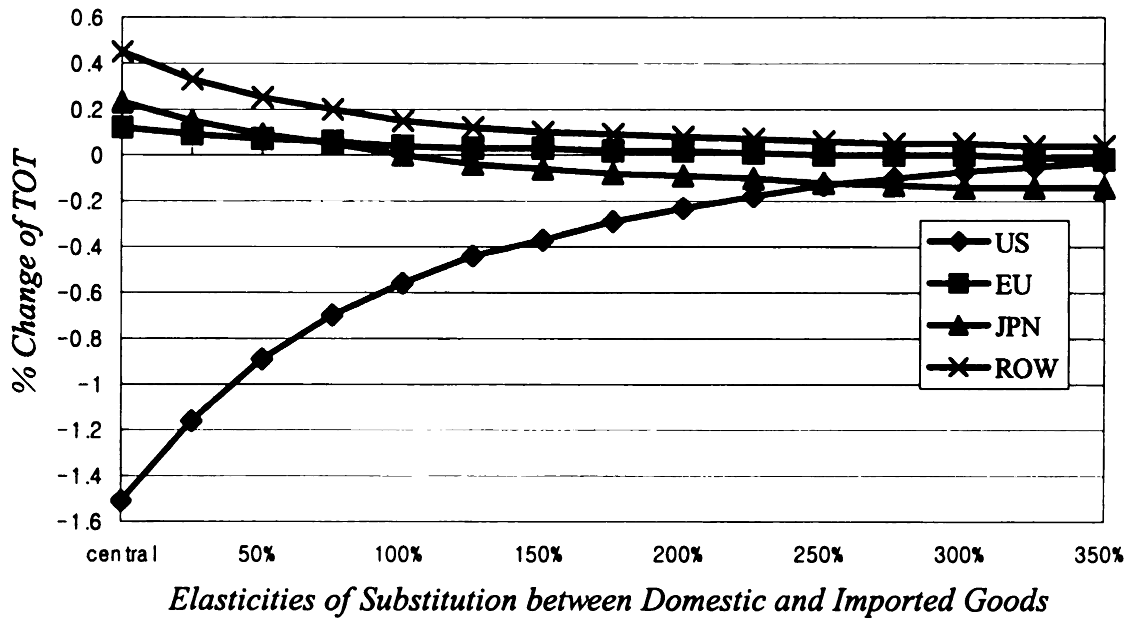
b. The central values of σ^i_{dm} are 2.43 for agriculture, 2.60 for primary materials, 3.40 for durable manufactures, 2.75 for non-durable manufactures, and 2.05 for services.

c. The figures in the parentheses (of the column heading) are represented as the weighted average of σ^i_{dm}.

(b) *As the $\sigma_{dm}(other)$ become larger, the terms-of-trade effects become smaller.*

In other words, as the domestically produced goods in the foreign regions become closer substitutes with imports (*i.e.*, with exports from the U.S.), the U.S. terms-of-trade loss becomes smaller. After the change of the U.S tax policy, foreign consumers will consume more imports and fewer of their domestically produced goods, due to relative decline in the price of imports. The more sensitive foreign consumers are, the greater is the shift out of their domestically produced goods and into imported goods. This leads to decreases in U.S. import prices, and increases in U.S export prices, when compared with a situation in which the elasticities are smaller. Both the reduction of U.S. import prices and the rise in U.S. export prices will reduce the U.S. terms-of-trade loss. As the $\sigma_{dm}(others)$ increases by 50 percent and 100 percent, the U.S. terms-of-trade loss becomes smaller by 6.9 and 10.4 percent, and this leads to a small increase in the U.S. welfare gains.

Figure 6-1. Terms-of-Trade Effects from Elimination of U.S. Capital Taxes, As a Function of the Elasticity of Substitution Between Domestic and Imported Goods



Based on (a) and (b), we can say that the terms-of-trade effects become smaller when the $\sigma_{dm}(all)$ become larger. Figure 6-1 shows that higher elasticities tend to produce weaker terms-of-trade effects. As the $\sigma_{dm}(all)$ are increased by near 350 percent, the terms-of-trade effects for the United States disappear.

(c) *As the* $\sigma_{mm}(usa)$ *become larger, there are no substantial changes in the terms-of-trade effects.* The magnitudes of the elasticity of substitution among different imports in the U.S. don't have a significant effect on U.S. import and export prices. This is to be expected. The terms-of-trade effects for the U.S. depend on the ease with which consumers can substitute between U.S. goods and goods from other regions, not on the ease with which U.S. consumers can substitute between goods from Germany and goods from Japan. Therefore, the U.S. welfare gains don't change from 1.4 percent, even if σ^{i}_{mm} is increased.

(d) *As the* $\sigma_{mm}(others)$ *become larger, the terms-of-trade effects become smaller.* In the model, the elasticity of substitution among different imported goods in other regions, $\sigma_{mm}(others)$, has the same role as the elasticity of substitution between domestic and imported goods in the U.S., $\sigma_{dm}(usa)$. As the $\sigma_{mm}(others)$ increases by 50 percent and 100 percent, the U.S. terms-of-trade loss become smaller by 26.6 and 45.1 percent, and this leads to an increase in the U.S. welfare gain by 6.4 and 11.8 percent, respectively.

Table 6-10. Sensitivity Analysis with Respect to the Elasticities of Substitution among Different Imported Goods I [a]

	$\sigma^i_{mm}(usa)$				
	-50% (2.66)	*central* [b] (5.30) [c]	*25%* (6.62)	*50%* (7.96)	*100%* (10.60)
U.S.	(1) -1.52 (2) 1.13 (3) 1.38	(1) -1.51 (2) 1.13 (3) 1.38	(1) -1.51 (2) 1.13 (3) 1.38	(1) -1.51 (2) 1.13 (3) 1.38	(1) -1.50 (2) 1.13 (3) 1.38
E.U.	(1) 0.11 (2) -0.52 (3) -0.42	(1) 0.12 (2) -0.52 (3) -0.42	(1) 0.12 (2) -0.52 (3) -0.42	(1) 0.12 (2) -0.51 (3) -0.42	(1) 0.13 (2) -0.51 (3) -0.42
Japan	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.24 (2) -0.76 (3) -0.61
ROW	(1) 0.45 (2) -0.66 (3) -0.51	(1) 0.44 (2) -0.66 (3) -0.51	(1) 0.43 (2) -0.67 (3) -0.51	(1) 0.42 (2) -0.67 (3) -0.52	(1) 0.42 (2) -0.67 (3) -0.52

a. (1) = % changes in terms of trade
(2) = % changes in consumption level
(3) = equivalent variation (as % of GDP)

b. The central values of σ^i_{mm} are 4.86 for agriculture, 5.20 for primary materials, 6.80 for durable manufactures, 5.50 for non-durable manufactures, and 4.10 for services.

c. The figures in the parentheses (of the column heading) are represented as the weighted average of σ^i_{mm}.

Table 6-11. Sensitivity Analysis with Respect to the Elasticities of Substitution among Different Imported Goods II [a]

	$\sigma^i_{mm}(teu)=\sigma^i_{mm}(jpn)=\sigma^i_{mm}(row)$				
	-50% (2.66)	*central* [b] (5.30) [c]	*25%* (6.62)	*50%* (7.96)	*100%* (10.60)
U.S.	(1) -2.44 (2) 0.95 (3) 1.21	(1) -1.51 (2) 1.13 (3) 1.38	(1) -1.27 (2) 1.18 (3) 1.43	(1) -1.11 (2) 1.23 (3) 1.47	(1) -0.83 (2) 1.34 (3) 1.54
E.U.	(1) 0.14 (2) -0.50 (3) -0.45	(1) 0.12 (2) -0.52 (3) -0.42	(1) 0.10 (2) -0.53 (3) -0.42	(1) 0.09 (2) -0.53 (3) -0.43	(1) 0.09 (2) -0.54 (3) -0.43
Japan	(1) 0.28 (2) -0.74 (3) -0.60	(1) 0.23 (2) -0.76 (3) -0.61	(1) 0.20 (2) -0.77 (3) -0.61	(1) 0.17 (2) -0.77 (3) -0.62	(1) 0.15 (2) -0.78 (3) -0.62
ROW	(1) 0.49 (2) -0.63 (3) -0.48	(1) 0.44 (2) -0.66 (3) -0.51	(1) 0.40 (2) -0.70 (3) -0.54	(1) 0.38 (2) -0.72 (3) -0.55	(1) 0.36 (2) -0.74 (3) -0.58

a. (1) = % changes in terms of trade
(2) = % changes in consumption level
(3) = equivalent variation (as % of GDP)

b. The central values of σ^i_{mm} are 4.86 for agriculture, 5.20 for primary materials, 6.80 for durable manufactures, 5.50 for non-durable manufactures, and 4.10 for services.

c. The figures in the parentheses (of the column heading) are represented as the weighted average of σ^i_{mm}.

Table 6-12. Sensitivity Analysis with Respect to the Different Combinations of Trade Elasticities of Substitution [a]

Elasticities of Substitution	*Changes*			
$\sigma^i_{dm}(usa)$	*-50%*	*central*	*+50%*	*+100%*
U.S. T.O.T. (% changes)	-2.33	-1.51	-1.01	-0.72
	(-54.17)	(0.00)	(33.19)	(52.32)
U.S. EV (as % of GDP)	1.17	1.38	1.49	1.58
	(-15.37)	(0.00)	(8.01)	(14.49)
$\sigma^i_{dm}(teu) = \sigma^i_{dm}(jpn) = \sigma^i_{dm}(row)$	*-50%*	*central*	*+50%*	*+100%*
U.S. T.O.T. (% changes)	-1.64	-1.51	-1.41	-1.35
	(-9.21)	(0.00)	(6.87)	(10.37)
U.S. EV (as % of GDP)	1.33	1.38	1.41	1.43
	(-3.91)	(0.00)	(2.34)	(3.67)
$\sigma^i_{mm}(usa)$	*-50%*	*central*	*+50%*	*+100%*
U.S. T.O.T. (% changes)	-1.52	-1.51	-1.51	-1.50
	(-0.42)	(0.00)	(0.32)	(0.59)
U.S. EV (as % of GDP)	1.38	1.38	1.38	1.38
	(0.00)	(0.00)	(0.00)	(0.00)
$\sigma^i_{mm}(teu) = \sigma^i_{mm}(jpn) = \sigma^i_{mm}(row)$	*-50%*	*central*	*+50%*	*+100%*
U.S. T.O.T. (% changes)	-2.44	-1.51	-1.11	-0.83
	(-61.43)	(0.00)	(26.56)	(45.12)
U.S. EV (as % of GDP)	1.21	1.38	1.47	1.54
	(-12.03)	(0.00)	(6.39)	(11.83)

a. Numbers in parentheses represent percentage changes with respect to the values in the central case.

6.2.2. Sensitivity Analysis with Respect to the Asset-Substitution Elasticities

Secondly, I conduct a sensitivity analysis with respect to the asset-substitution elasticities. The elasticity of substitution between domestic and foreign assets in portfolios, σ_{rs}^{A}, determines the ease of substitution between the two assets, and thus the degree of international capital mobility. When these elasticities of substitution are altered, there will be changes in the results of replacing the U.S. capital taxes.

Table 6-13 reports the results. I take the central values of the asset-substitution elasticity as 2.0 for the U.S. and 1.5 for other regions. For the sensitivity analysis, the values of these elasticities of substitution are increased by up to 100 percent, to 4.0 and 3.0, to represent a greater degree of international capital mobility, and they are decreased by 100 percent, to zero, which represents no mobility of international capital. Under the U.S. tax-policy changes, as the asset-substitution elasticities become larger, there are more capital inflows into the United States. The more sensitive investors are, the more domestic capital is demanded, due to the higher after-tax returns in the United States. If σ_{rs}^{A} is increased by 100 percent, the capital stock located in the U.S. will increase by 11.9 percent, relative to the base case. This compares with an increase of 8.5 percent when the central-case parameters are used. Consequently, the amount of capital outflow from the other regions will be substantially greater when the asset-substitution elasticity is larger than in the central case. (See Figure 6-2.)

Figure 6-2. Capital-Flow Effects from Elimination of U.S. Capital Taxes, As a Function of the Elasticity of Substitution Between Domestic and Foreign Assets

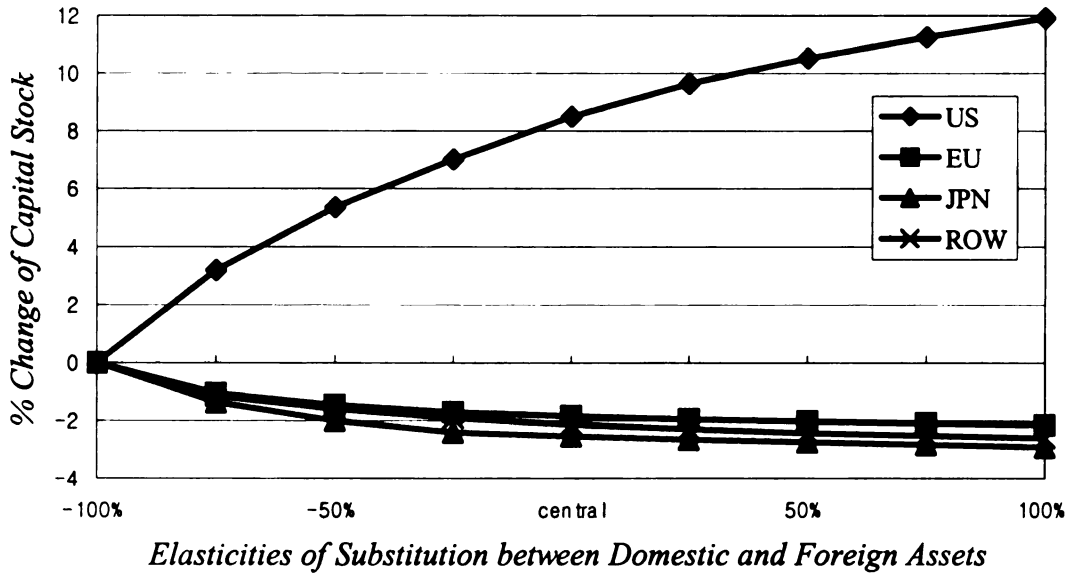


Table 6-13 also shows that higher asset-substitution elasticities are associated with larger increases in welfare gains in the United States. As σ_{rs}^{A} is increased by 100%, the U.S. welfare gains increase by 43.5 percent, relative to the revised case with central-case parameters. However, the other regions experience more capital outflows, with higher asset-substitution elasticities. As σ_{rs}^{A} is increased by 100%, the welfare losses for the other regions are increased by 33.3~40.5 percent.

Table 6-13. Sensitivity Analysis with Respect to the Asset-Substitution Elasticities [a]

Variables	σ_{rs}^{A}				
	-100%	*-50%*	*central* [b]	*+50%*	*+100%*
Capital Flows (% changes)					
U.S.	0.00	5.35	8.49	10.51	11.92
	(-100.00)	(-36.98)	(0.00)	(23.79)	(40.40)
E.U.	0.00	-1.46	-1.84	-2.03	-2.15
	(100.00)	(20.65)	(0.00)	(-10.33)	(-16.85)
Japan	0.00	-2.00	-2.54	-2.75	-2.93
	(100.00)	(21.26)	(0.00)	(-8.27)	(-15.35)
ROW	0.00	-1.61	-2.13	-2.42	-2.60
	(100.00)	(24.41)	(0.00)	(-13.62)	(-22.07)
EV (as % of GDP)					
U.S.	0.15	1.03	1.38	1.70	1.98
	(-89.13)	(-25.36)	(0.00)	(23.19)	(43.48)
E.U.	0.15	-0.14	-0.42	-0.51	-0.59
	(135.71)	(66.67)	(0.00)	(-21.43)	(-40.48)
Japan	0.12	-0.29	-0.61	-0.73	-0.83
	(119.67)	(52.46)	(0.00)	(-19.67)	(-36.07)
ROW	0.17	-0.24	-0.51	-0.61	-0.68
	(133.33)	(52.94)	(0.00)	(-19.61)	(-33.33)

a. Numbers in parentheses represent percentage changes with respect to the values in the central case.

b. The central values of σ_{rs}^{A} are 2.0 for U.S., and 1.5 for other regions.

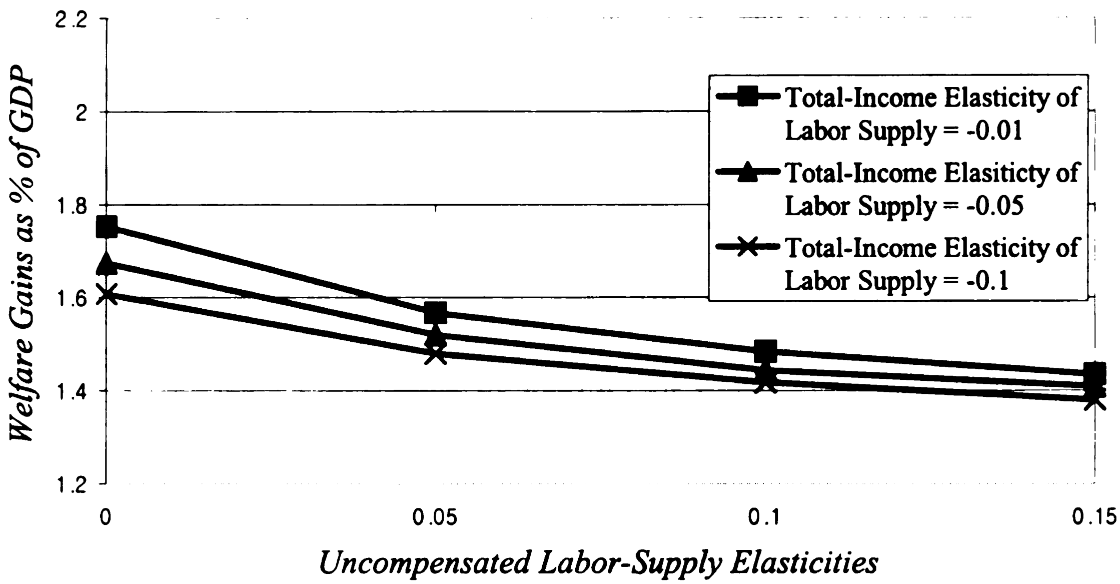
6.2.3. Sensitivity Analysis with Respect to the Labor-Supply Elasticities

Next, I examine the implications of changing the uncompensated labor-supply elasticities, η_L, and the total-income elasticity of labor supply, η_I. After the unilateral U.S. tax-policy changes, the demand for U.S. capital is expected to increase, due to the relatively higher after-tax returns in the United States. The higher demand for capital causes the wage rate to decrease. Also, the gross-of-tax prices of consumer goods in the U.S. are increased, because consumption taxes are used to replace the revenue lost as a result of the elimination of capital taxes. These price increases lead to decreases in the real wage rate. The decrease in labor supply will be greater when η_L is greater.

Labor supply can also be affected through the income effect, which is controlled by η_I. After the tax-policy changes, the consumer's net capital income will be larger. Because of the increase in non-labor income, the consumer will enjoy more leisure, and thus will supply less labor. This effect will be greater when η_I is greater in absolute value. Thus, higher values of η_L and η_I (in absolute value) are associated with larger decreases in labor supply, through both the wage effect and the income effect. Consequently, a smaller welfare gain is expected when either of these labor elasticities is larger in absolute value.

Figure 6-3 shows the effects of changes in the labor-supply elasticities on the welfare gains from the tax-policy change for the United States. The central values of η_L and η_I are 0.15 and -0.1, respectively. As expected, the welfare gains for the U.S. are smaller when the labor-supply elasticities are larger in absolute value. However, the magnitude of this effect is relatively small. This indicates that other influences (such as capital inflows, and the improvement in the efficiency of use of the capital stock) are more important than labor-supply effects, in determining the welfare gains.[61]

Figure 6-3. Welfare Gains for the U.S. from Unilateral Elimination of Capital Taxes, As a Function of Labor-Supply Elasticity



6.3. Alternative Scenarios

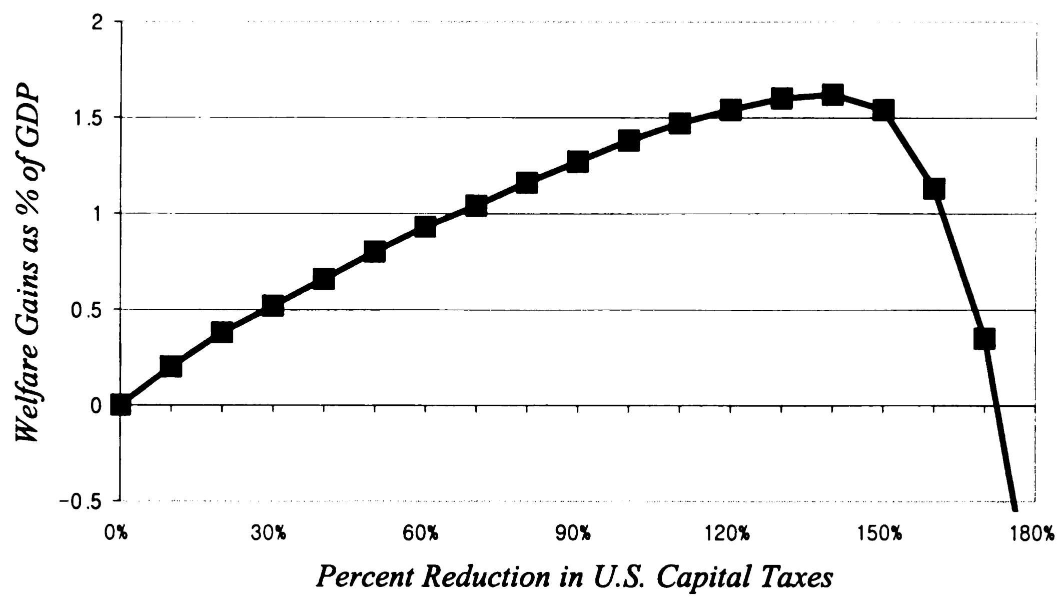
6.3.1. U.S. Policy Changes of Different Sizes

I investigate the optimal strategy for the United States, by simulating the analysis with alternative scenarios, in which U.S. government controls the size of the unilateral tax policy change. Figure 6-4 plots the U.S. equivalent variations, which correspond to policy changes of different sizes (from a 0% reduction to a 180% reduction in U.S.

[61] Also, I note that I vary the labor-supply elasticities over a relatively small range, but this is because the econometric literature has made substantial progress toward identifying the labor-supply parameters. Most estimates of the elasticity of male labor supply fall within a fairly narrow range, and the range of estimates of female labor supply has been reduced in the last two decades.

capital taxes). As the size of the policy change increases, the EV increases at a diminishing rate. The EV reaches a maximum point at a 140% reduction in U.S capital taxes, but it falls sharply with greater reductions of U.S. capital taxes. If the U.S. were to reduce its capital taxes by 180%, it would actually suffer welfare losses. This is because the continued reduction in capital tax rates leads to a need for ever-greater increases in the consumption taxes that are used to replace the lost revenues. As the consumption-tax rates increase, their distortionary effects become dramatically larger. I conclude that an optimal strategy for the United States is to subsidize capital, *if* other countries don't respond.

Figure 6-4. Optimal Strategy for the United States



6.3.2. Non-Zero Equalization of U.S. Capital Taxes

Consider the policy in which U.S. capital-tax rates are equalized at a non-zero value. In this simulation, the rates are equalized at 32.2 percent, so that the revenues are constant. Thus, U.S. consumption-tax rates are not increased in this case. Table 6-14 shows the U.S. domestic effects of non-zero equalization, and compares with the effects of zero equalization (which means complete elimination of capital taxes).

Table 6-14. Domestic Effects of Non-Zero Equalization of U.S. Capital Taxes

	Non-Zero Equalization	*Zero Equalization*
Capital Flows by Sector (% changes)		
Agriculture	-3.17	-1.26
Primary Materials	-1.34	4.32
Durable Manufactures	36.57	54.47
Non-durable Manufactures	11.28	18.76
Services	1.13	3.82
Overall	4.17	8.49
EV (as % of GDP)	1.07	1.38

With the policy of non-zero equalization of U.S. capital taxes, positive U.S. welfare gains are also expected. The equalized rates lead to a more efficient allocation of the U.S. capital stock. This policy change also has a positive effect on capital flows, but the size of the effect is smaller than in the case of complete elimination. The equalized U.S. capital-tax rate is still lower than the overall capital-tax rates in other regions. However, the equalized tax rates in some sectors, such as agriculture and primary materials, are even higher than the capital-tax rates in those sectors in other regions. The higher tax rates in those sectors lead the after-tax return on U.S.-located capital to move downward in those sectors. This leads to capital outflows in those sectors (3.2 percent in agriculture, and 1.3 percent in primary materials), and thus drives in the direction of lessening the total amount of capital inflows in the United States. Consequently, comparing to the policy of complete elimination, the U.S. welfare gains are reduced (from 1.4 to 1.1 percent of GDP), since the capital inflows into the U.S. become smaller (from 8.5 to 4.2 percent).

6.3.3. Labor-Tax Replacement

Consider the alternative scenario in which U.S. capital taxes are replaced by labor taxes, rather than by consumption taxes. As shown in Table 6-15, in the case of using labor taxes for equal revenue yield, the increase in the level of consumption and the welfare gains for the U.S. become larger. This can be mainly explained by the fact that the labor taxes are closer to uniform, while the consumption taxes are differentiated across sectors.[62]

Table 6-15. Domestic Effects of U.S. Labor-Tax Replacement

	Labor-Tax Replacement	*Consumption-Tax Replacement*
Consumption (% changes)	1.27	1.13
TOT (% changes)	-0.96	-1.51
EV (as % of GDP)	1.62	1.38

[62] The sector-specific labor taxes are not differentiated across regions: The rates are around 13 percent in all sectors, except in services. See Chapter 5 for details.

In addition, the negative terms-of-trade effect becomes smaller, since the negative terms-of-trade effect is partly canceled by the increase in the labor taxes: If the sector-specific labor taxes are increased, there are increases in the gross-of-labor-tax prices of U.S. output. Thus, there is an increase in the prices of U.S. exports (the first-order effect). And there is also an increase in the prices of U.S. imports, due to higher demand for imports (the second-order effect). The dominant first-order effect leads to improve the terms of trade in the United States.

Table 6-16. Sensitivity Analyses with Different Combinations of Labor-Supply Elasticities and Goods Elasticity of Substitution

	EV with Labor-Tax Replacement	*EV with Consumption-Tax Replacement*
η_L *(with a central value of* σ_{cc}*)*		
0.0	2.35	1.87
0.15 [a]	1.62	1.38
0.30	1.30	1.22
σ_{cc} *(with a central value of* η_L*)*		
0.8	1.68	1.56
1.3 [a]	1.62	1.38
1.8	1.58	1.23
Combinations (σ_{cc}, η_L)		
(1.3, 0.15)	1.62	1.38
(0.8, 0.30)	1.34	1.23
(0.3, 0.60)	1.16	1.11
(0.1, 0.90)	1.02	1.01

a. central values

Table 6-16 shows how the U.S. welfare gains for both replacements are affected by the labor-supply elasticity and elasticity of substitution among goods. It is expected that the welfare gains with labor-tax replacement are directly controlled more by the labor-supply elasticity. If the uncompensated labor-supply elasticity becomes larger, we expect that the welfare gains for both replacements would be decreased. However, since the labor-supply elasticity has a more direct effect on the welfare gains with labor-tax replacement, changing the value of the labor-supply elasticity would have a greater effect on the welfare gains with labor-tax replacement, rather than on those with consumption-tax replacement.

In the simulation, if the central value of the uncompensated labor-supply elasticity is doubled, the welfare gains with labor-tax replacement drop by 19.8 percent (from 1.6 percent of GDP to 1.3 percent of GDP), while those with consumption-tax replacement drop by 11.6 percent (from 1.4 percent of GDP to 1.2 percent of GDP). However, even though the absolute value of the change in EV is larger with labor-tax replacement, the ratio of EV with consumption-tax replacement to EV with labor-tax replacement doesn't change much. Similarly, if the goods elasticity of substitution is larger, the decreases of the welfare gains with consumption-tax replacement are bigger than the decreases of those with labor-tax replacement. The last part of Table 6-16 shows that, if both a smaller goods elasticity of substitution and a larger labor-supply elasticity are assumed, the gaps between the welfare gains for both of these replacements become smaller.

6.3.4. Responses of Foreign Governments

Finally, I consider the case of multilateral policy changes, in which other regions also eliminate their capital taxes. Figure 6-5 shows the comparison of the effects of unilateral and multilateral policy changes. The multilateral policy changes produce welfare gains for the entire world, whereas the unilateral policy changes produce a welfare gain only for the United States, which is the country undertaking the policy changes. This is because the multilateral policy changes encourage more efficient use of capital everywhere.

Figure 6-5. Welfare Effects - Unilateral vs. Multilateral

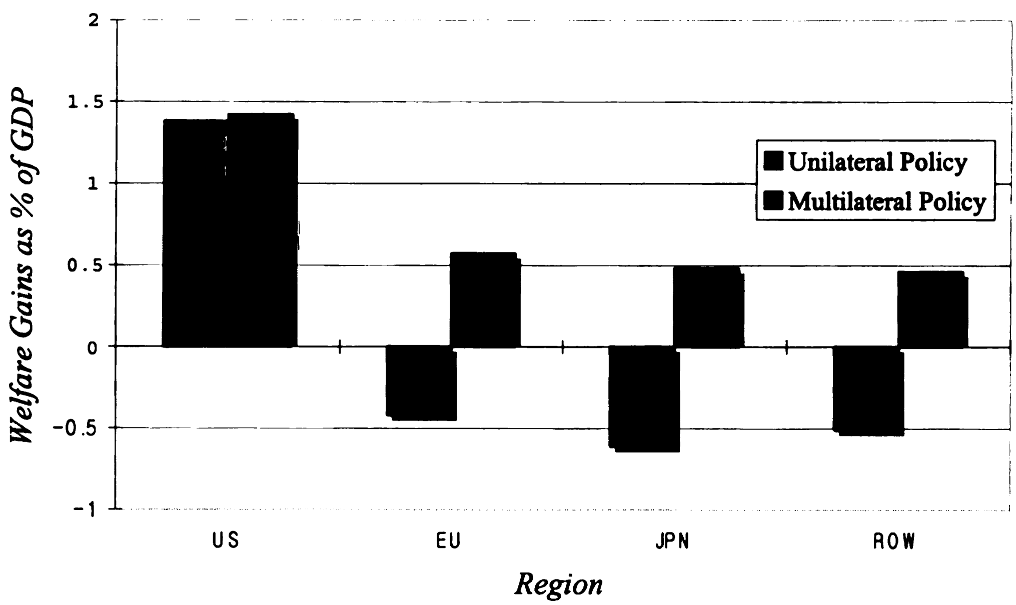


Table 6-17 shows the decomposition of the U.S. overall effects. The multilateral case produces less capital-flow effects, and less terms-of-trade effects, comparing to unilateral case. Even though other regions also pursue same policy, the after-tax returns on U.S.-located capital are still relatively higher than the after-tax returns on foreign-located capital. This comes from the difference of characteristics of capital-tax structures for each region. The simultaneous eliminating of capital taxes also leads to smaller U.S. terms-of-trade losses. This is due to the fact that the terms-of-trade losses associated with a unilateral policy change are partially offset by terms-of-trade gains to trading partners, when the policy change occur on a multilateral basis. For the United States, welfare losses associated with reduced capital inflows are almost offset by the extra welfare gains from the improvement of terms of trade. Thus, the multilateral case doesn't lead to much change in U.S. welfare gains.

Table 6-17. U.S. Static Welfare Changes of Multilateral Case,
As a Function of the Trade and the Asset Parameters

(Unit: % of GDP)

		Trade Elasticity of Substitution			
		Central	*Big*		*Terms-of-Trade Effects*
Asset-Substitution	*Central*	1.42	1.49	⇒	-0.07 [c]
Elasticity	*Zero*	1.05	0.96	⇒	-0.09 [d]
		⇓	⇓		
Capital-Flow Effects		0.37 [a]	0.53 [b]		

a. the case with holding constant trade parameters
b. the case with holding constant trade parameters, and terms-of-trade effects at zero
c. the case with holding constant asset parameters
d. the case with holding constant asset parameters, and capital-flow effects at zero

CHAPTER 7

DYNAMIC MODEL

Thus far, I have analyzed the effect of U.S. tax reform with a static model, in which tax-policy evaluations are based on single-period equilibria. In this static framework, the distorting effects of capital taxes may be understated, since the effects on saving decisions are not captured. The dynamic version of the model, in which consumers make a saving decision in each period, is required to capture intertemporal distortions.

7.1. Model and Calibration Issues

The dynamic structure here involves multiple repetition of an essentially two-period maximization problem, which was used in the GEMTAP model. An alternative approach is the lifetime-utility-function approach, which involves maximization of a lifetime utility function, subject to a multiperiod budget constraint. This approach, which was used in Summers (1981) and Auerbach and Kotlikoff (1983), has become quite popular in recent years. Despite the popularity and some advantages of lifetime-utility-function approach, it has at least one serious problem.[63] Under seemingly reasonable assumptions about the important parameters, such as the rate of time preference and the intertemporal substitution elasticity, the lifetime-utility-function approach can yield very high responses of savings to changes in tax rates. This problem does not arise in the GEMTAP model, which can be calibrated precisely to any desired savings elasticity.

[63] The problems of excessive intertemporal responsiveness were previously discussed in detail, in Chapter 2. Also, see Ballard (1987, 1990a) for further discussion.

The first equilibrium in every sequence is for the 1995 benchmark year. The equilibria in any sequence are connected to each other through capital accumulation. In other words, saving in the current period will augment the capital-service endowment available in the next period. The endowment of labor grows at a constant rate.

In every sequence, the utility levels in region *r*, U^r, are represented by a CES function:

$$U^r\left(H^r, C_f{}^r\right) = \left\{ \beta^{r^F} H^{r\frac{\sigma_{hs}-1}{\sigma_{hs}}} + \left(1-\beta^{r^F}\right) C_f{}^{r\frac{\sigma_{hs}-1}{\sigma_{hs}}} \right\}^{\frac{\sigma_{hs}}{\sigma_{hs}-1}}, \qquad (7.1)$$

where the H^r are current expenditure in region *r*, the $C_f{}^r$ are future consumption in region *r*, and the σ_{hs} are the elasticities of substitution between H^r and $C_f{}^r$. That is, saving decisions are based on the maximization of a nested utility function, where the outer nest is defined over current expenditure (a composite of leisure and present-consumption goods) and the expected future-consumption stream made possible from savings.

The consumer's budget constraints are given by:

$$P_H{}^r H^r + P_S{}^r S^r = wE^r + \bar{r}\bar{K}^{rr} + \bar{r}^*\bar{K}^{rs} + TR^r \equiv Y_1^r, \qquad (7.3)$$

where the ${P_H}^r$ are the composite prices of leisure and present-consumption goods, the ${P_S}^r S^r$ are the values of savings in region *r*, and the Y_1^r are region *r*'s expanded income, which includes the value of the consumer's labor endowments, the value of the consumer's capital income from domestic capital, the value of the consumer's capital income from foreign capital, and transfer payments.

As in the static framework, the allocation of capital between home and abroad is viewed as prior to the decision about current consumption and future consumption. In this sense, the consumer's capital income in (7.3) is treated as given, since it was derived from the maximization of A^r:

$$A^r\left(rK^{rr}, r^*K^{rs}\right) = \left\{ {\alpha^r}^A \left(rK^{rr}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}} + \left(1 - {\alpha^r}^A\right)\left(r^*K^{rs}\right)^{\frac{\sigma_{rs}^A - 1}{\sigma_{rs}^A}} \right\}^{\frac{\sigma_{rs}^A}{\sigma_{rs}^A - 1}}. \tag{7.4}$$

where the ${\alpha^r}^A$ are share parameters, the σ_{rs}^A are the elasticities of substitution between domestic and foreign capital assets, the rK^{rr} are income from domestic assets (home-located capital invested by home resident) in region *r*, and the r^*K^{rs} are income from foreign assets (foreign-located capital invested by home resident) in region *r*.

In this model, there is no financial intermediation between saving and investment. That is, a consumer buys investment goods directly with his savings. The model assumes that the consumer who buys S units of capital will realize a capital service flow of γS

per period,[64] and each unit of capital services is expected to earn P_K per period. This yield of saving is, in turn, sold for future consumption. Let $P_c{}^r$ be the price of consumption today. Under the assumption of static expectation, the consumer expects that future consumption, $C_f{}^r$, will cost $P_c{}^r$ in each future year. Therefore,

$$P_c{}^r C_f{}^r = P_K{}^r \gamma S^r . \tag{7.5}$$

Rearranging this, then I have:

$$P_S{}^r S^r = \left(\frac{P_S{}^r P_c{}^r}{P_K{}^r \gamma} \right) C_f{}^r . \tag{7.6}$$

This states that the value of saving equals the discounted present value of the expected future consumption that can be brought with that saving. Using (7.6), I can rewrite the budget constraints:

$$P_H{}^r H^r + \left(\frac{P_S{}^r P_c{}^r}{P_K{}^r \gamma} \right) C_f{}^r = Y_1^r . \tag{7.7}$$

[64] I assign to γ the same value that I assign to r in the benchmark, 0.04. However, in GEMTAP, the value of γ is not same as r, because of the effect of personal taxes.

Constrained maximization of the utility functions F^r yields the demand functions:

$$H^r = \left(\frac{\beta^F}{P_H{}^r}\right)^{\sigma_{hs}} \frac{Y_1^r}{\beta^{F^{\sigma_{hs}}} P_H{}^{r^{1-\sigma_{hs}}} + \left(1-\beta^F\right)^{\sigma_{hs}} \left(\frac{P_S{}^r P_c{}^r}{P_K{}^r \gamma}\right)^{1-\sigma_{hs}}} \qquad (7.8)$$

and

$$C_f{}^r = \left(\frac{1-\beta^F}{\left(\frac{P_S{}^r P_c{}^r}{P_K{}^r \gamma}\right)}\right)^{\sigma_{hs}} \frac{Y_1^r}{\beta^{F^{\sigma_{hs}}} P_H{}^{r^{1-\sigma_{hs}}} + \left(1-\beta^F\right)^{\sigma_{hs}} \left(\frac{P_S{}^r P_c{}^r}{P_K{}^r \gamma}\right)^{1-\sigma_{hs}}}. \qquad (7.9)$$

Now, I consider the calibration of the elasticity of substitution between current expenditure and future consumption. Differentiating the demand function for future consumption in (7.9) with respect to P_K yields:

$$\frac{\partial S}{\partial P_K} = \frac{\left(1-\beta^F\right)^{\sigma_{hs}} K}{\frac{P_K \gamma}{P_c}\left(\frac{P_S P_c}{P_K \gamma}\right)^{\sigma_{hs}} \Psi} - \frac{S\left(1-\beta^F\right)^{\sigma_{hs}}(\sigma_{hs}-1)}{P_K\left(\frac{P_S P_c}{P_K \gamma}\right)^{\sigma_{hs}-1} \Psi} + \frac{S(\sigma_{hs}-1)}{P_K}, \qquad (7.10)$$

where $\Psi = \beta^{F^{\sigma_{hs}}} P_H{}^{1-\sigma_{hs}} + \left(1-\beta^F\right)^{\sigma_{hs}} \left(\frac{P_S P_c}{P_K \gamma}\right)^{1-\sigma_{hs}}$. Manipulating the demand function for future consumption and substituting into (7.10) gives us a simple expression for the saving elasticity:

$$\rho \equiv \frac{\partial S}{\partial P_K}\frac{P_K}{S} = \frac{P_K K}{Y_1} - \frac{P_S S(\sigma_{hs}-1)}{Y_1} + (\sigma_{hs}-1). \tag{7.11}$$

Solving for σ_{hs} gives:

$$\sigma_{hs} = \frac{\rho + 1 - \dfrac{K+S}{Y_1}}{1 - \dfrac{S}{Y_1}}. \tag{7.12}$$

The σ_{hs} parameters are calibrated to match with desired levels of the savings elasticity. Regarding the savings elasticity, the empirical literature is kind of a mix. Some articles give support for positive elasticities, but some also give support for negative elasticities, or for responses that are not distinguished from zero. In this study, I take the central value of the savings elasticity with respect to the return to capital (ρ) to be 0.4, which was found by Boskin (1978), and then a sensitivity test with different values will be run. Boskin's work has shifted the consensus toward the belief that the savings elasticity is positive. And, his estimates are generally statistically significant, and he suggests that they are economically significant, as well.

If constrained maximization of the utility function, U^r, occurs repeatedly, then utility depends on a stream of consumption that extends infinitely into the future. When I move through the sequences, the capital stock grows because of saving. The growth rates of capital and labor are chosen so that the base case is indeed on a balanced growth path.

7.2. Simulation Results

I analyze the dynamic effects of changes in U.S. tax policy on the global economy. Here again, I consider the complete elimination of U.S. capital taxes. The lost revenues are replaced with higher rates of consumption taxes. Under the dynamic framework, the future path of the economy can be analyzed explicitly. Table 7-1 through 7-3 plot the transitional dynamic paths of consumption, leisure, and utility in all regions. The vertical axis represents the deviations from the pre-tax-reform equilibrium, in percentage terms. The first 40 years of the sequence of equilibria are shown on the horizontal axis.

Figure 7-1. Consumption Path - All Regions

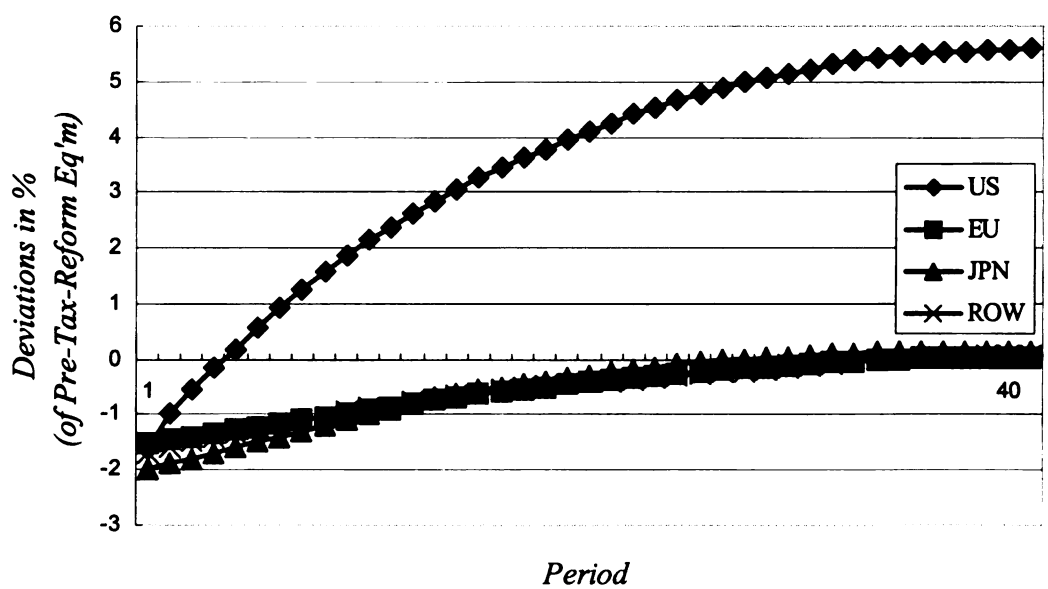


Figure 7-2. Leisure Path - All Regions

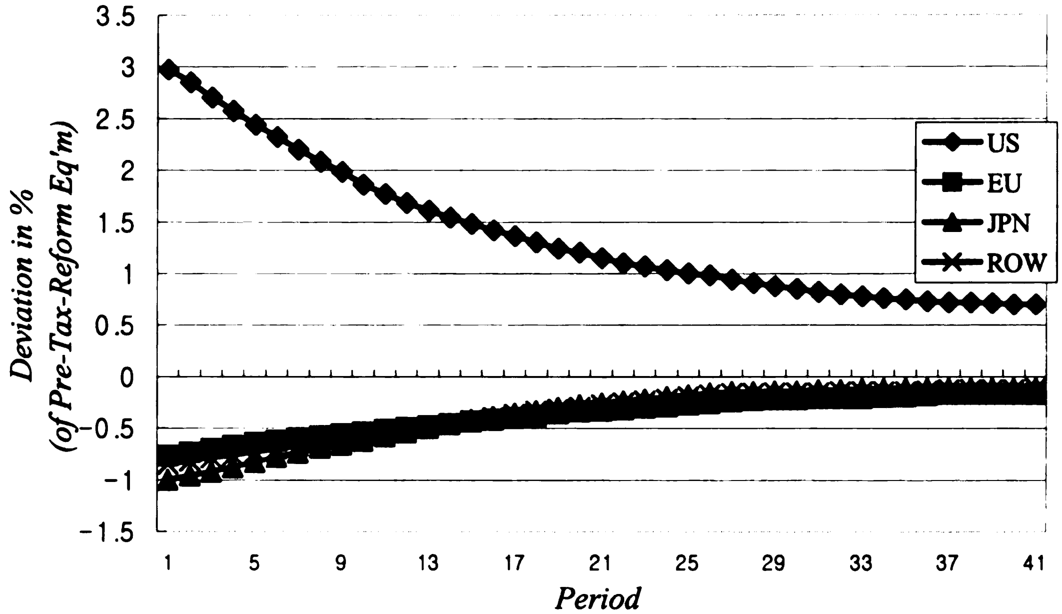
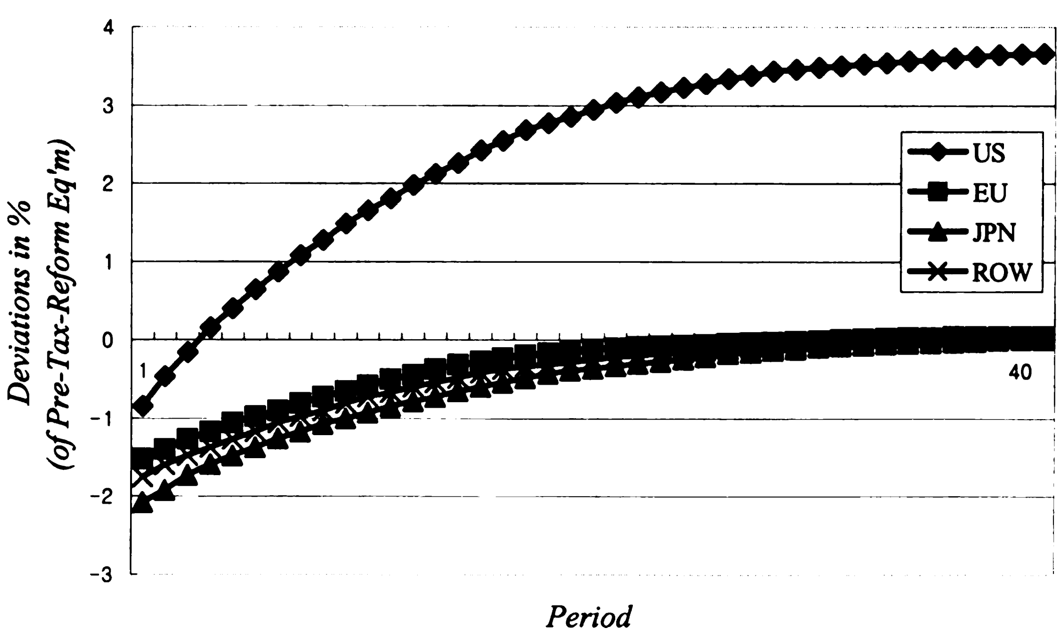


Figure 7-3. Utility Path - All Regions



The U.S. consumption and utility paths are shown to be growing at a stronger pace, while the other regions have flatter paths of consumption and utility. This is because of higher capital accumulation, along with capital inflows to the United States.

Now, I investigate the dynamic effects on the U.S. domestic economy in detail. To investigate the transitional effects, I also consider the case in which lost revenues are replaced with higher rates of labor taxes, and compare the results to the case with higher rates of consumption taxes. Table 7-1 shows the dynamic results of impact and long-run effects. Consider first the case in which capital taxes are replaced by higher consumption taxes. The impact effects show that the consumption level drops by 1.6 percent, and the utility level decreases by 0.6 percent, relative to the pre-tax-reform equilibrium. The level of consumption falls sharply, since the increase in output level is surpassed by the increase in the savings level. The decrease in the utility level is rather smaller, due to the increase of leisure. The decrease in the net wage rate leads to a substantial increase in leisure. In the long run, utility level increases by 4.0 percent, mostly due to higher increases in consumption level.

In the second case, in which capital taxes are replaced by labor taxes, the impact effects show that the utility level decreases by 0.1 percent, relative to the pre-tax-reform equilibrium. This is due to small decreases in the consumption level, at the time of the changes in tax policy. The level of consumption does not move so much in the case of labor-tax replacement, while it falls sharply in the case of the replacement with consumption taxes, since an increase in the output level is almost canceled by an increase in the savings level. The increase in leisure is larger than that in the case of consumption-tax replacement, since the increase in labor taxes directly leads to a increase in leisure. In the long run, consumption and utility level increase by 4.5 and 3.9 percent, respectively.

Table 7-1. The Impact and Long-Run Effects of Replacing of U.S. Capital Taxes

(Unit: % Changes [a])

	Replacing by Consumption Tax		*Replacing by Labor Tax*	
	Impact Effect	*Long-Run Effect*	*Impact Effect*	*Long-Run Effect*
Consumption	-1.62	5.60	-0.63	4.45
Leisure	2.97	0.70	3.12	1.20
Utility	-0.55	4.00	-0.06	3.86

a. Figures are percentage changes relative to pre-tax-reform equilibrium.

Figure 7-4. Consumption Path - U.S.

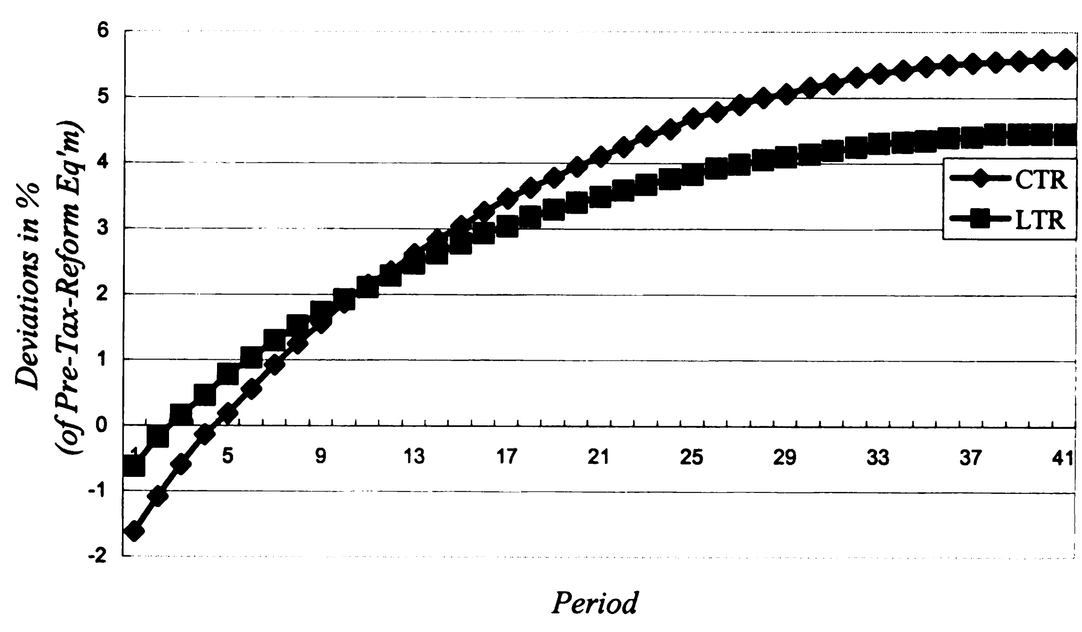


Figure 7-4 through 7-6 show the transitions of consumption, leisure, and utility level in the United States, after the policy shock occurs in the first year. In the case of the replacement with consumption taxes, the level of consumption is lower in the first year, by around -1.6 percent. However, consumption then rises at a faster rate, as a result of the greater amount of capital accumulation. The level of consumption approaches a new balanced-growth path asymptotically, and reaches a gain of 5.6 percent from the base case beyond year 40. In the case of replacement with labor taxes, consumption rises at a slower rate, and reaches a gain of 4.5 percent from the base case beyond year 40. The paths of leisure in both cases have similar shapes: the level of leisure is higher at first year, and then decreases as time goes on. With the labor tax replacement, labor decreases more, and thus leisure increases more.

Figure 7-5. Leisure Path - U.S.

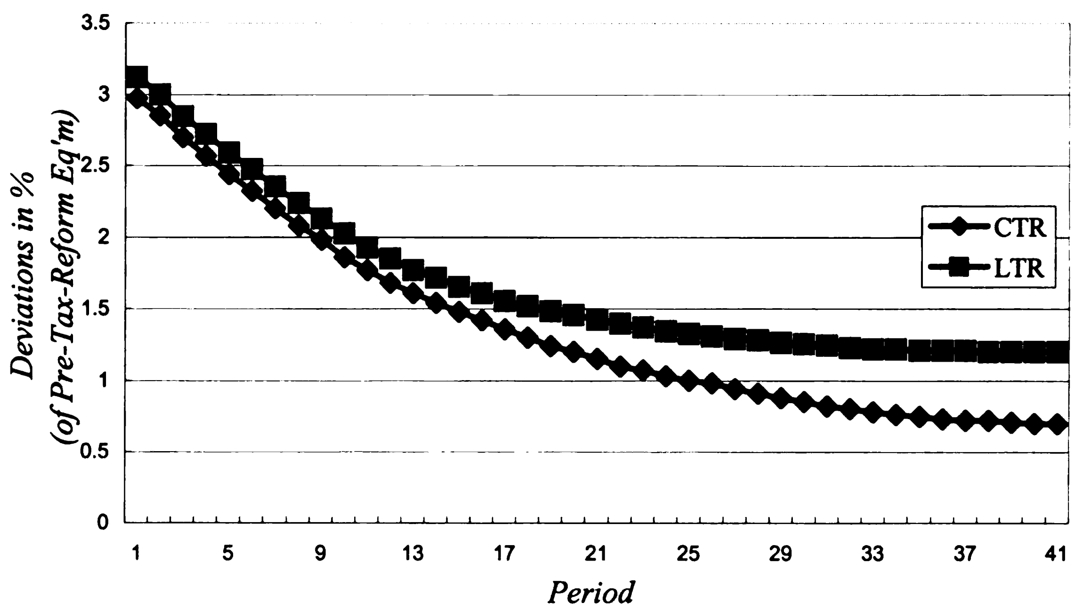


Figure 7-6. Utility Path - U.S.

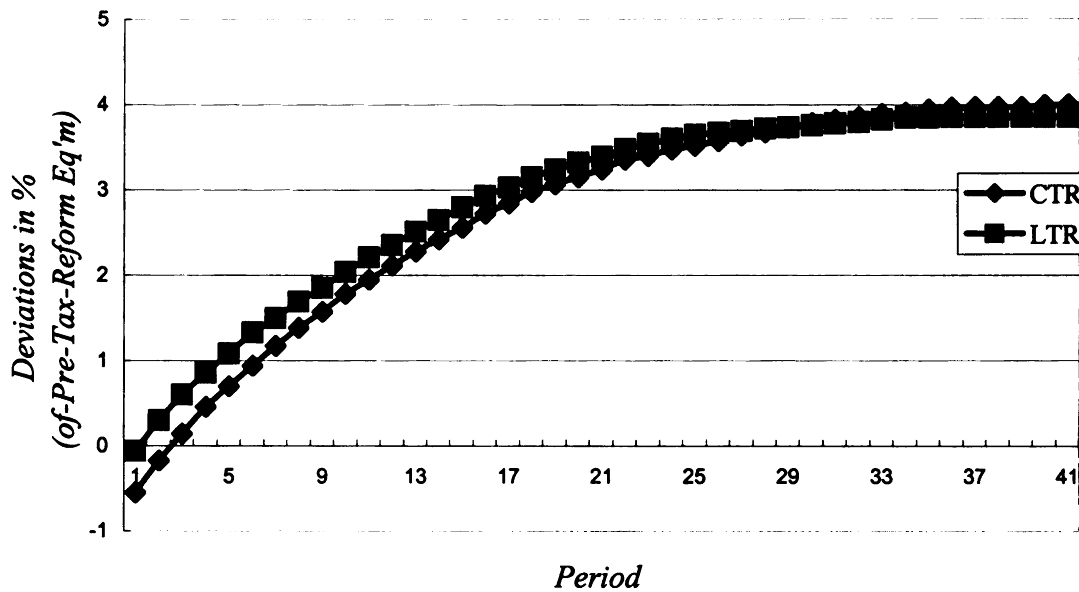
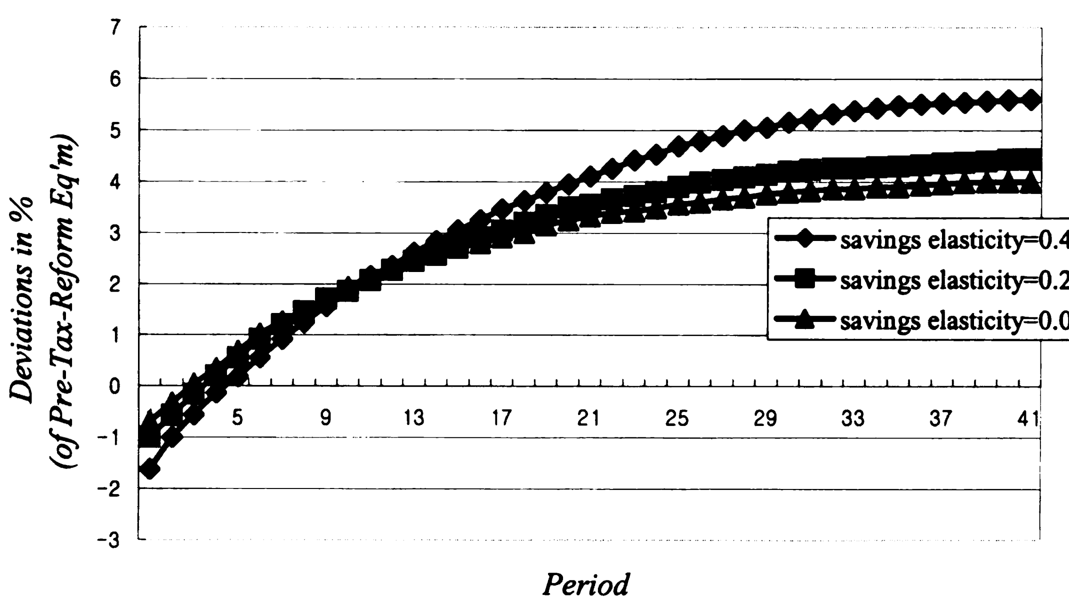


Figure 7-7. U.S. Consumption Path, As a Function of Savings Elasticity



I also report the sensitivity analysis of the U.S. consumption path with respect to savings elasticity. As shown in Figure 7-7, for a larger savings elasticity, consumption drops farther at first, and then it recovers more quickly, and the level of consumption finally reaches at higher point at year 40, compared to the lower-elasticity case.

Last, I calculate the dynamic welfare gains, using the present value of the stream of the equivalent variation over 40 years and more.[65] Although the economy approaches the new steady state closely by the end of 40 years, I use longer periods to ensure that the approach to the new steady state is very close.[66] The approximation is involved in calculations of the termination term.[67] Table 7-2 and 7-3 show the results of a unilateral policy change. The results show that a 100-year simulation provides a U.S. welfare gain of around $4.0 trillion, while a 200-year simulation provides around $4.1 trillion. These amount to about 2.2 percent of GDP stream, which are discounted over the simulation period (vs. 1.4 percent of GDP in static simulation). The welfare losses for the European Union, Japan, and the Rest of World are 0.4~0.7 percent of their GDP streams (vs. 0.4~0.6 percent of their GDP in static simulation).

The welfare gains of a multilateral policy change are shown in Table 7-4 and 7-5. The results show that a 100-year simulation yields a U.S. welfare gain of around $3.3

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[65] For dynamic welfare evaluation, I use the H^r function, not the U^r function. If savings are included in the evaluation of utility in the current period, the "double counting" problem would happen, since savings are used to buy future consumption.

[66] The dynamic procedure here does not guarantee that the change in welfare will be invariant with respect to the numbers of years between first and last equilibrium. In general, the longer is the numbers of years, the closer is the equivalent variation to the actual steady-state value. See Ballard, *et al.* (1985) for details.

[67] Over 40 years in a revised-case calculation, the economy asymptotically approaches a new steady state. However, it will not actually reach the new steady state. As far as a policy is designed to increase saving, the economy will still be experiencing a small amount of capital deepening, even after many years. For calculating the termination term, I assume a slight decrease in saving from the amount that I actually calculated for the termination year.

trillion, while a 200-year simulation yields around $3.4 trillion. These amount to about 1.8 percent of GDP stream, which are discounted over the simulation period (vs. 1.4 percent of GDP in static simulation). Under a multilateral policy change, other regions also have welfare gains, which amount to about 1.1~1.2 percent of their GDP streams (vs. 0.5~0.6 percent of their GDP in static simulation).

Table 7-2. The Equivalent Variation I - Dynamic Simulation of Unilateral Case

(Unit: Billions of 1995 Dollars)

Simulation Period	*U.S.*	*E.U.*	*Japan*	*ROW*
40	2,735.38	-881.81	-888.58	-1,165.95
60	3,475.34	-872.91	-887.14	-1,159.94
80	3,813.35	-868.85	-886.48	-1,156.75
100	3,967.75	-866.99	-886.18	-1,155.29
120	4,038.28	-866.15	-886.05	-1,154.62
140	4,070.50	-865.76	-885.98	-1,154.32
160	4,085.22	-865.58	-885.96	-1,154.18
180	4,091.94	-865.50	-885.94	-1,154.12
200	4,095.01	-865.46	-885.94	-1,154.09

Table 7-3. The Equivalent Variation II - Dynamic Simulation of Unilateral Case

(Unit: % of GDP Stream)

Simulation Period	*U.S.*	*E.U.*	*Japan*	*ROW*
40	1.84	-0.54	-0.84	-0.68
60	2.06	-0.47	-0.74	-0.60
80	2.15	-0.44	-0.70	-0.56
100	2.18	-0.43	-0.68	-0.55
120	2.19	-0.43	-0.68	-0.54
140	2.20	-0.43	-0.67	-0.54
160	2.21	-0.43	-0.67	-0.54
180	2.21	-0.42	-0.67	-0.54
200	2.21	-0.42	-0.67	-0.54

Table 7-4. The Equivalent Variation III - Dynamic Simulation of Multilateral Case

(Unit: Billions of 1995 Dollars)

Simulation Period	*U.S.*	*E.U.*	*Japan*	*ROW*
40	2,329.59	1,524.93	826.99	1,418.34
60	2,905.79	1,978.86	1,147.78	1,892.14
80	3,169.00	2,186.13	1,294.07	2,108.40
100	3,289.24	2,280.76	1,360.79	2,207.11
120	3,344.16	2,323.97	1,391.21	2,252.16
140	3,369.25	2,343.69	1,405.83	2,272.72
160	3,380.71	2,352.70	1,411.41	2,282.11
180	3,385.94	2,356.81	1,414.30	2,286.39
200	3,388.33	2,358.69	1,415.61	2,288.35

Table 7-5. The Equivalent Variation IV - Dynamic Simulation of Multilateral Case

(Unit: % of GDP Stream)

Simulation Period	*U.S.*	*E.U.*	*Japan*	*ROW*
40	1.57	0.93	0.78	0.83
60	1.72	1.11	0.95	0.97
80	1.78	1.11	1.03	1.03
100	1.81	1.14	1.05	1.05
120	1.82	1.15	1.06	1.06
140	1.82	1.15	1.07	1.06
160	1.83	1.15	1.07	1.07
180	1.83	1.15	1.07	1.07
200	1.83	1.16	1.07	1.07

Table 7-6. U.S. Dynamic Welfare Changes of Unilateral Case,
As a Function of the Trade and the Asset Parameters

(Unit: % of GDP)

		Trade Elasticity of Substitution			
		Central	*Big*		*Terms-of-Trade Effects*
Asset-Substitution	*Central*	2.22	2.54	⇒	-0.32 [c]
Elasticity	*Zero*	1.01	1.24	⇒	-0.23 [d]
		⇓	⇓		
Capital-Flow Effects		1.21 [a]	1.30 [b]		

a. the case with holding constant trade parameters
b. the case with holding constant trade parameters, and terms-of-trade effects at zero
c. the case with holding constant asset parameters
d. the case with holding constant asset parameters, and capital-flow effects at zero

Next, the overall U.S. welfare effects of a 200-year simulation are decomposed. I consider both a unilateral case and a multilateral case. The results are shown in Table 7-6 and 7-7. The capital-flow effects and the terms-of-trade effects can be isolated, through the same process used in the static case. The method of isolating Harberger effects is different. In the static case, the numbers being estimated directly from the simulation with zero asset-substitution elasticity and big trade elasticity of substitution simply represent Harberger effects (0.74 in Table 6-6, and 0.96 in Table 6-17). However, in the dynamic case, they can't be interpreted as only Harberger effects (1.24 in Table 7-6, and 1.58 in Table 7-7). Since they include the positive effects on saving decision, which are not captured in the static framework, they must be interpreted as the sum of Harberger effects and the intertemporal effects. As shown in Table 7-8, the intertemporal effects are estimated as 0.5~0.6 percent of GDP.

Table 7-7. U.S. Dynamic Welfare Changes of Multilateral Case,
As a Function of the Trade and the Asset Parameters

(Unit: % of GDP)

		Trade Elasticity of Substitution			
		Central	*Big*		*Terms-of-Trade Effects*
Asset-Substitution	*Central*	1.83	1.84	⇒	-0.01 [c]
Elasticity	*Zero*	1.49	1.58	⇒	-0.09 [d]
		⇓	⇓		
Capital-Flow Effects		0.34 [a]	0.26 [b]		

a. the case with holding constant trade parameters
b. the case with holding constant trade parameters, and terms-of-trade effects at zero
c. the case with holding constant asset parameters
d. the case with holding constant asset parameters, and capital-flow effects at zero

Table 7-8. Intertemporal Effects for the U.S.

(Unit: % of GDP)

	Static	*Dynamic*		*Intertemporal Effects*
Unilateral Case [a]				
EV	0.74	1.24	⇒	0.50
Multilateral Case [a]				
EV	0.96	1.58	⇒	0.62

a. the case with zero asset-substitution elasticity and big trade elasticity of substitution

Table 7-9. Welfare Effects for Whole World

	U.S	*E.U.*	*Japan*	*ROW*	*World*
Unilateral Case					
EV ($ billions) [a]	4,095.01	-865.46	-885.94	-1,154.09	1,189.52
EV (% of World GDP Stream)					0.16
Multilateral Case					
EV ($ billions)	3,388.33	2,358.69	1,415.61	2,288.35	9,450.98
EV (% of World GDP Stream)					1.28

a. Units are in parentheses.

So far, I focused on each region's welfare gains or losses, rather than welfare effects for whole world. Now, I calculate the overall welfare gains in both unilateral and multilateral case, using a 200-year simulation. Table 7-9 shows that a unilateral policy change yields world welfare gains of around $1.2 trillion. These amount to about only

0.2 percent of world GDP stream, which are discounted over the simulation period. However, under a multilateral policy change, the world enjoys tremendous welfare gains of $9.5 trillion, which amount to about 1.3 percent of world GDP stream. The results show that a worldwide tax reform is superior over a unilateral tax reform, in a sense that a worldwide reform leads to larger *world* welfare gains.

CHAPTER 8

CONCLUSION

This paper has described a global trade model in which international spillover effects can occur through changes in commodity flows and changes in capital flows. I use both static and dynamic computational general-equilibrium models that divide the world into four regions. The data are from Global Trade Analysis Project for 1995. My model incorporates a labor/leisure choice and international cross-ownership of assets. I report and interpret the results of simulations of changes in U.S. tax policy.

In the static simulation, I find that unilateral elimination of U.S. capital taxes generates welfare gains for the United States. The tax-policy changes improve the allocation of the domestic capital stock, and they generate capital inflows, but they also generate negative effects on the terms of trade. The positive effects dominate the negative effects, so that U.S. welfare is improved. Conversely, foreign economies experience capital outflows, along with positive terms-of-trade effects. Since the positive terms-of-trade effects are dominated by the negative capital-flow effects, the foreign economies have welfare losses. However, when all regions remove their capital taxes, the entire world experiences welfare gains.

As the trade elasticities of substitution become larger, the terms-of-trade effects become smaller. A larger asset-substitution elasticity causes larger capital-flow effects, and it also causes larger terms-of-trade effects. When labor supply is more elastic, the welfare gains are reduced.

Under the dynamic framework, the future path of the economy is analyzed explicitly. The consumption path for the United States is shown to be growing at relatively stronger pace, while the other regions have a flatter path of consumption, because of higher capital accumulation, along with capital inflows to the United States: The U.S. consumption is decreased in the first year when the policy shock occurs. However, the level of consumption then rises at a faster rate, and finally approaches a new balanced-growth path asymptotically. With a larger savings elasticity, consumption drops farther at first, and it recovers more quickly.

The analysis of welfare gains for the United States indicates that unilateral elimination of U.S. capital taxes yields dynamic gains, whose present values are around \$4.0~\$4.1 trillion, while it yields an annual static welfare gain of around \$98 billion in 1995 dollars. The dynamic gains are estimated as 2.2 percent of GDP stream, while the static gain is estimated as 1.4 percent of GDP. If all regions adopt the policy changes, the dynamic gains for the United States are 1.8 percent of GDP stream, compared with 1.4 percent of GDP in the static case.

APPENDIX

1. Factor Demand Functions with CES

A firm with CES technology demands quantities $\bar{x}_i$ of factor i when market prices are $\bar{p}_i$ and taxes are $\bar{t}_i$. Assuming an elasticity of substitution equal to σ, find the compensated demand for the ith factor when market prices and taxes are given by p_j and t_j

The production function is CES, so it can be written:

$$y = \psi\left\{\alpha x_1^{\rho} + (1-\alpha)x_2^{\rho}\right\}^{\frac{1}{\rho}} \text{, where } \rho = \frac{\sigma - 1}{\sigma}$$

The compensated demand functions for this production function can be then derived using standard *Lagrangean* techniques:

$$L = p_1(1+t_1)x_1 + p_2(1+t_2)x_2 + \lambda\left[y - \psi\left(\alpha x_1^{\frac{\sigma-1}{\sigma}} + (1-\alpha)x_2^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}\right]$$

If this is differentiated with respect to x_1 and x_2,

$$p_1(1+t_1)=\lambda\psi\left(\frac{\sigma}{\sigma-1}\right)\left(\alpha x_1^{\frac{\sigma-1}{\sigma}}+(1-\alpha)x_2^{\frac{\sigma-1}{\sigma}}\right)^{\frac{1}{\sigma-1}}\alpha\left(\frac{\sigma-1}{\sigma}\right)x_1^{\frac{-1}{\sigma}} \qquad (1)$$

$$p_2(1+t_2)=\lambda\psi\left(\frac{\sigma}{\sigma-1}\right)\left(\alpha x_1^{\frac{\sigma-1}{\sigma}}+(1-\alpha)x_2^{\frac{\sigma-1}{\sigma}}\right)^{\frac{1}{\sigma-1}}(1-\alpha)\left(\frac{\sigma-1}{\sigma}\right)x_2^{\frac{-1}{\sigma}} \qquad (2)$$

Dividing (1) by (2), and arranging for x_2,

$$x_2=\left(\frac{p_1(1+t_1)}{p_2(1+t_2)}\right)^{\sigma}\left(\frac{1-\alpha}{\alpha}\right)^{\sigma}x_1 \qquad (3)$$

Putting (3) into the cost function,

$$C=p_1(1+t_1)x_1+p_2(1+t_2)x_2$$

$$=(p_1(1+t_1))^{\sigma}\left\{\frac{\alpha^{\sigma}(p_1(1+t_1))^{1-\sigma}+(1-\alpha)^{\sigma}(p_2(1+t_2))^{1-\sigma}}{\alpha^{\sigma}}\right\}x_1$$

Therefore, compensated demand functions can be written:

$$x_1 = \left\{\frac{\alpha}{p_1(1+t_1)}\right\}^{\sigma} \frac{C}{\alpha^{\sigma}(p_1(1+t_1))^{1-\sigma} + (1-\alpha)^{\sigma}(p_2(1+t_2))^{1-\sigma}} \tag{4}$$

and

$$x_2 = \left\{\frac{1-\alpha}{p_2(1+t_2)}\right\}^{\sigma} \frac{C}{\alpha^{\sigma}(p_1(1+t_1))^{1-\sigma} + (1-\alpha)^{\sigma}(p_2(1+t_2))^{1-\sigma}} \tag{5}$$

For simplicity, let $\alpha^{\sigma}(p_1(1+t_1))^{1-\sigma} + (1-\alpha)^{\sigma}(p_2(1+t_2))^{1-\sigma} \equiv \Delta$, and putting (4) and (5) into the production function,

$$y = \psi\left\{\alpha\left(\left(\frac{\alpha}{p_1(1+t_1)}\right)^{\sigma}\frac{C}{\Delta}\right)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)\left(\left(\frac{1-\alpha}{p_2(1+t_2)}\right)^{\sigma}\frac{C}{\Delta}\right)^{\frac{\sigma-1}{\sigma}}\right\}^{\frac{\sigma}{\sigma-1}}$$

$$= \psi C \Delta^{\frac{1}{\sigma-1}}$$

Now, we can get the unit cost function:

$$c \equiv \frac{C}{y} = \frac{C}{\psi C \Delta^{\frac{1}{\sigma-1}}} = \psi^{-1}\Delta^{\frac{1}{1-\sigma}} \tag{6}$$

$$= \frac{1}{\psi}\left\{\alpha^{\sigma}\left(p_1(1+t_1)\right)^{1-\sigma} + (1-\alpha)^{\sigma}\left(p_2(1+t_2)\right)^{1-\sigma}\right\}^{\frac{1}{1-\sigma}}$$

Putting (6) into equations (4) and (5), we get associated demand functions:

$$x_1 = \left(\frac{y}{\psi}\right)\left\{\frac{\alpha\psi c}{p_1(1+t_1)}\right\}^{\sigma} \tag{7}$$

and

$$x_2 = \left(\frac{y}{\psi}\right)\left\{\frac{(1-\alpha)\psi c}{p_2(1+t_2)}\right\}^{\sigma} \tag{8}$$

Next step is to calibrate functional parameters to a single benchmark equilibrium.[68] From (3), we get the value of α:

$$\alpha = \frac{\bar{p}_1(1+\bar{t}_1)\bar{x}_1^{\frac{1}{\sigma}}}{\bar{p}_1(1+\bar{t}_1)\bar{x}_1^{\frac{1}{\sigma}} + \bar{p}_2(1+\bar{t}_2)\bar{x}_2^{\frac{1}{\sigma}}} = \frac{\bar{p}_1(1+\bar{t}_1)\bar{x}_1^{1-\rho}}{\bar{p}_1(1+\bar{t}_1)\bar{x}_1^{1-\rho} + \bar{p}_2(1+\bar{t}_2)\bar{x}_2^{1-\rho}}$$

If we define θ as the value share of x_1 at the benchmark point:

[68] In most large-scale applied general-equilibrium models, we have many function parameters to specify with relatively few observations. The conventional approach is to calibrate functional parameters to a single benchmark equilibrium. See GAMS Development Corporation (1998).

$$\theta = \frac{\bar{p}_1(1+\bar{t}_1)\bar{x}_1}{\bar{p}_1(1+\bar{t}_1)\bar{x}_1 + \bar{p}_2(1+\bar{t}_2)\bar{x}_2}$$

then the relationship between θ and α is presented:

$$\theta = \frac{\alpha\bar{x}_1^{\rho}}{\alpha\bar{x}_1^{\rho} + (1-\alpha)\bar{x}_2^{\rho}}$$

And, we get the value of ψ from the production function:

$$\psi = \bar{y}\left\{\alpha\bar{x}_1^{\rho} + (1-\alpha)\bar{x}_2^{\rho}\right\}^{-\frac{1}{\rho}}$$

Using these calibrated parameters, the cost and demand functions can be expressed as the calibrated share from. In the calibrated form, the cost and demand functions explicitly incorporate benchmark demands, benchmark factor price, benchmark tax rate, the elasticity of substitution, benchmark cost, benchmark output, and benchmark value share. First, the production function in the calibrated share form is presented, using the value of $\bar{y}$ and θ:

$$y = \bar{y}\left\{\theta\left(\frac{x_1}{\bar{x}_1}\right)^{\rho} + (1-\theta)\left(\frac{x_2}{\bar{x}_2}\right)^{\rho}\right\}^{\frac{1}{\rho}} \qquad (9)$$

Next, using the value of $\bar{c}$ and θ, the unit cost function in the calibrated share form is presented:

$$c = \bar{c}\left\{\theta\left(\frac{p_1(1+t_1)}{\bar{p}_1(1+\bar{t}_1)}\right)^{1-\sigma} + (1-\theta)\left(\frac{p_2(1+t_2)}{\bar{p}_2(1+\bar{t}_2)}\right)^{1-\sigma}\right\}^{\frac{1}{1-\sigma}} \qquad (10)$$

Lastly, the compensated demand function in the calibrated share form is presented:

$$x_1 = \left(\frac{y}{\bar{y}}\right)\bar{x}_1\left(\frac{\bar{p}_1(1+\bar{t}_1)c}{p_1(1+t_1)\bar{c}}\right)^{\sigma}$$

and

$$x_2 = \left(\frac{y}{\bar{y}}\right)\bar{x}_2\left(\frac{\bar{p}_2(1+\bar{t}_2)c}{p_2(1+t_2)\bar{c}}\right)^{\sigma}$$

Therefore, in general, the unit compensated demand function in the calibrated share form $(\bar{y} = \bar{c} = 1)$ can be expressed:

$$x_i = \bar{x}_i\left(\frac{\bar{p}_i(1+\bar{t}_i)c}{p_i(1+t_i)}\right)^{\sigma}, \text{ where } c = \left\{\sum_i \theta_i\left(\frac{p_i(1+t_i)}{\bar{p}_i(1+\bar{t}_i)}\right)^{1-\sigma}\right\}^{\frac{1}{1-\sigma}} \qquad (11)$$

2. Compensated Demand Functions with CES

A consumer with CES utility consumes quantities $\bar{x}_i$ *when market prices are* $\bar{p}_i$. *Assuming an elasticity of substitution equal to* σ, *find the compensated demand for the ith good when market prices are given by* p_j.

The utility function is CES, so it can be written:

$$U = \left\{\alpha x_1^{\rho} + (1-\alpha)x_2^{\rho}\right\}^{\frac{1}{\rho}} \text{, where } \rho = \frac{\sigma - 1}{\sigma}$$

Constrained maximization of the utility function U yields the compensated demand functions:

$$x_1 = \left\{\frac{\alpha}{p_1}\right\}^{\sigma} \frac{Y}{\alpha^{\sigma} p_1{}^{1-\sigma} + (1-\alpha)^{\sigma} p_2{}^{1-\sigma}} \tag{1}$$

and

$$x_2 = \left\{\frac{1-\alpha}{p_2}\right\}^{\sigma} \frac{Y}{\alpha^{\sigma} p_1{}^{1-\sigma} + (1-\alpha)^{\sigma} p_2{}^{1-\sigma}} \tag{2}$$

For simplicity, let $\alpha^{\sigma} p_1{}^{1-\sigma} + (1-\alpha)^{\sigma} p_2{}^{1-\sigma} \equiv \Delta$, and putting (1) and (2) into the utility function, we have the indirect utility function:

$$V = \left\{ \alpha \left(\left(\frac{\alpha}{p_1} \right)^{\sigma} \frac{Y}{\Delta} \right)^{\frac{\sigma-1}{\sigma}} + (1-\alpha) \left(\left(\frac{1-\alpha}{p_2} \right)^{\sigma} \frac{Y}{\Delta} \right)^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}}$$

$$= Y \Delta^{\frac{1}{\sigma-1}}$$

So, the expenditure function is expressed:

$$E = V \Delta^{\frac{1}{1-\sigma}}$$

$$= V \left(\alpha^{\sigma} p_1^{1-\sigma} + (1-\alpha)^{\sigma} p_2^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \qquad (3)$$

Next step is to calibrate functional parameters to a single benchmark equilibrium.

We get the value of α:

$$\alpha = \frac{\bar{p}_1 \bar{x}_1^{\frac{1}{\sigma}}}{\bar{p}_1 \bar{x}_1^{\frac{1}{\sigma}} + \bar{p}_2 \bar{x}_2^{\frac{1}{\sigma}}} = \frac{\bar{p}_1 \bar{x}_1^{1-\rho}}{\bar{p}_1 \bar{x}_1^{1-\rho} + \bar{p}_2 \bar{x}_2^{1-\rho}}$$

If we define θ as the value share of x_1 at the benchmark point:

$$\theta = \frac{\bar{p}_1\bar{x}_1}{\bar{p}_1\bar{x}_1 + \bar{p}_2\bar{x}_2}$$

then the relationship between θ and α is presented:

$$\theta = \frac{\alpha\bar{x}_1^{\rho}}{\alpha\bar{x}_1^{\rho} + (1-\alpha)\bar{x}_2^{\rho}}$$

And, we get the value of $\bar{U}$ from the utility function:

$$\bar{U} = \left\{\alpha\bar{x}_1^{\rho} + (1-\alpha)\bar{x}_2^{\rho}\right\}^{\frac{1}{\rho}}$$

Using these calibrated parameters, the demand functions can be expressed as the calibrated share from. First, the utility function in the calibrated share form is presented, using the value of $\bar{U}(=1)$ and θ:

$$U = \left\{\theta\left(\frac{x_1}{\bar{x}_1}\right)^{\rho} + (1-\theta)\left(\frac{x_2}{\bar{x}_2}\right)^{\rho}\right\}^{\frac{1}{\rho}} \quad (4)$$

Next, using the value of $\bar{E}(=1)$ and θ, the unit expenditure function in the calibrated share form is presented:

$$e = \left\{ \theta \left(\frac{p_1}{\bar{p}_1} \right)^{1-\sigma} + (1-\theta) \left(\frac{p_2}{\bar{p}_2} \right)^{1-\sigma} \right\}^{\frac{1}{1-\sigma}} \tag{5}$$

And, lastly, using the relationship between the expenditure and the indirect utility functions:

$$V = \frac{Y}{\bar{Y}e},$$

the compensated demand function in the calibrated share form is presented:

$$x_1 = \bar{x}_1 V \left(\frac{e\bar{p}_1}{p_1} \right)^{\sigma}$$

and

$$x_2 = \bar{x}_2 V \left(\frac{e\bar{p}_2}{p_2} \right)^{\sigma}$$

Therefore, in general, the unit compensated demand function in the calibrated share form $(\bar{U} = \bar{E} = 1)$ can be expressed:

$$x_i = \bar{x}_i V \left(\frac{e\bar{p}_i}{p_i} \right)^{\sigma}, \text{ where } e = \left\{ \sum_i \left(\theta \left(\frac{p_i}{\bar{p}_i} \right)^{1-\sigma} \right) \right\}^{\frac{1}{1-\sigma}} \text{ and } V = \frac{Y}{\bar{Y}e} \tag{6}$$

3. Supply Functions with CET

A firm with a CET technology produces joint products (outputs) $\bar{x}_i$ when market prices are $\bar{p}_i$ and output tax is $\bar{t}_y$. Assuming a constant elasticity of transformation equal to η, let's find the supply functions of the ith output when market prices and taxes are given by p_j and t_y.

The production function is CET, so it can be written:

$$y = \psi \left\{ \alpha x_1^{\frac{\eta+1}{\eta}} + (1-\alpha) x_2^{\frac{\eta+1}{\eta}} \right\}^{\frac{\eta}{\eta+1}}$$

Constrained maximization yields the supply functions (assuming same output taxes on two products):

$$x_1 = \left(\frac{\alpha^{-\eta}}{p_1^{-\eta}(1-t_y)} \right) \frac{C}{\alpha^{-\eta} p_1^{1+\eta} + (1-\alpha)^{-\eta} p_2^{1+\eta}} \tag{1}$$

and

$$x_2 = \left(\frac{(1-\alpha)^{-\eta}}{p_2^{-\eta}(1-t_y)} \right) \frac{C}{\alpha^{-\eta} p_1^{1+\eta} + (1-\alpha)^{-\eta} p_2^{1+\eta}} \tag{2}$$

For simplicity, let $\alpha^{-\eta} p_1^{1+\eta} + (1-\alpha)^{-\eta} p_2^{1+\eta} \equiv \Delta$, and putting (1) and (2) into the production function,

$$y = \psi \left\{ \alpha \left(\left(\frac{\alpha^{-\eta}}{p_1^{-\eta}(1-t_y)} \right) \frac{C}{\Delta} \right)^{\frac{\eta+1}{\eta}} + (1-\alpha) \left(\left(\frac{(1-\alpha)^{-\eta}}{p_2^{-\eta}(1-t_y)} \right) \frac{C}{\Delta} \right)^{\frac{\eta+1}{\eta}} \right\}^{\frac{\eta}{\eta+1}}$$

$$= \psi C \left(\frac{1}{1-t_y} \right) \Delta^{-\frac{1}{\eta+1}}$$

Now, we can get the unit cost function:

$$c \equiv \frac{C}{y} = \frac{C}{\psi C \Delta^{-\frac{1}{\eta+1}} \left(\frac{1}{1-t_y} \right)} = \psi^{-1} \Delta^{\frac{1}{\eta+1}} (1-t_y) \tag{3}$$

$$= \frac{1}{\psi} \left\{ \alpha^{-\eta} p_1^{1+\eta} + (1-\alpha)^{-\eta} p_2^{1+\eta} \right\}^{\frac{1}{\eta+1}} (1-t_y)$$

Putting (3) into equations (1) and (2), we get associated supply functions:

$$x_1 = \left(\frac{y}{\psi}\right)\left\{\frac{\alpha\psi c}{p_1(1-t_y)}\right\}^{-\eta} \tag{4}$$

and

$$x_2 = \left(\frac{y}{\psi}\right)\left\{\frac{(1-\alpha)\psi c}{p_2(1-t_y)}\right\}^{-\eta} \tag{5}$$

Next step is to calibrate functional parameters to a single benchmark equilibrium. We get the value of α:

$$\alpha = \frac{\bar{p}_1 \bar{x}_1^{-\frac{1}{\eta}}}{\bar{p}_1 \bar{x}_1^{-\frac{1}{\eta}} + \bar{p}_2 \bar{x}_2^{-\frac{1}{\eta}}}$$

If we define θ as the value share of x_1 at the benchmark point:

$$\theta = \frac{\bar{p}_1 \bar{x}_1}{\bar{p}_1 \bar{x}_1 + \bar{p}_2 \bar{x}_2}$$

then the relationship between θ and α is presented:

$$\theta = \frac{\alpha \bar{x}_1^{\frac{\eta+1}{\eta}}}{\alpha \bar{x}_1^{\frac{\eta+1}{\eta}} + (1-\alpha)\bar{x}_2^{\frac{\eta+1}{\eta}}}$$

And, we get the value of ψ from the production function:

$$\psi = \bar{y}\left\{\alpha \bar{x}_1^{\frac{\eta+1}{\eta}} + (1-\alpha)\bar{x}_2^{\frac{\eta+1}{\eta}}\right\}^{-\frac{\eta}{\eta+1}}$$

Using these calibrated parameters, the cost and demand functions can be expressed as the calibrated share form. First, the production function in the calibrated share form is presented, using the value of $\bar{y}$ and θ:

$$y = \bar{y}\left\{\theta\left(\frac{x_1}{\bar{x}_1}\right)^{\frac{\eta+1}{\eta}} + (1-\theta)\left(\frac{x_2}{\bar{x}_2}\right)^{\frac{\eta+1}{\eta}}\right\}^{\frac{\eta}{\eta+1}} \tag{6}$$

Next, using the value of $\bar{c}$ and θ, the unit cost function in the calibrated share form is presented:

$$c = \bar{c}\left\{\theta\left(\frac{p_1}{\bar{p}_1}\right)^{1+\eta} + (1-\theta)\left(\frac{p_2}{\bar{p}_2}\right)^{1+\eta}\right\}^{\frac{1}{1+\eta}} \frac{(1-t_y)}{(1-\bar{t}_y)} \tag{7}$$

Lastly, the supply function in the calibrated share form is presented:

$$x_1 = \left(\frac{y}{\bar{y}}\right)\bar{x}_1\left(\frac{\bar{p}_1\left(1-\bar{t}_y\right)c}{p_1\left(1-t_y\right)\bar{c}}\right)^{-\eta}$$

and

$$x_2 = \left(\frac{y}{\bar{y}}\right)\bar{x}_2\left(\frac{\bar{p}_2\left(1-\bar{t}_y\right)c}{p_2\left(1-t_y\right)\bar{c}}\right)^{-\eta}$$

Therefore, in general, the unit supply function in the calibrated share form $\left(\bar{y} = \bar{c} = 1\right)$ can be expressed:

$$x_i = \bar{x}_i\left(\frac{\bar{p}_i\left(1-\bar{t}_y\right)c}{p_i\left(1-t_y\right)}\right)^{-\eta} \quad \text{where} \quad c = \left\{\sum_i \theta_i\left(\frac{p_i}{\bar{p}_i}\right)^{1+\eta}\right\}^{\frac{1}{1+\eta}}\frac{\left(1-t_y\right)}{\left(1-\bar{t}_y\right)}$$

or

$$x_i = \bar{x}_i\left(\frac{\dfrac{p_i}{\bar{p}_i}}{\left\{\sum_i \theta_i\left(\dfrac{p_i}{\bar{p}_i}\right)^{1+\eta}\right\}^{\frac{1}{1+\eta}}}\right)^{\eta} \qquad (8)$$

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