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## An intertemporal CGE model for Austria: Model structure and calibration

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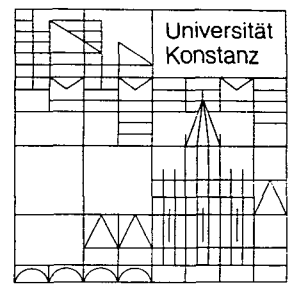
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wissenschaften und Statistik

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Wilhelm Kohler

**An Intertemporal CGE Model for Austria**  
Model Structure and Calibration

**AN INTERTEMPORAL CGE MODEL FOR AUSTRIA**

**Model Structure and Calibration**

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## **Abstract**

The last decade has witnessed the emergence of a neoclassical, microeconomic theory of current account adjustment focusing on intertemporal optimization. More recently, researchers have started to incorporate such an intertemporal framework into large scale simulation models geared towards numerical policy analysis. This paper presents the results of our efforts to construct such a simulation model and calibrate it to Austrian data. The paper is restricted to a presentation of the model structure as well as the method and results of its calibration. It does not contain any simulation results. Notwithstanding future improvements on the model structure as well as the available data, the paper should serve as a convenient source of reference for subsequent work. It is to be hoped that the omission of some of the details presented here will make future reports somewhat easier to digest.

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# 1 Introduction

During the last decade, a growing body of computable general equilibrium (CGE) models has emerged, which have been widely used to simulate the effects of various distortionary policies, in particular protection and other forms of taxation. CGE models have no doubt earned great merits in focusing attention on general equilibrium reallocation and redistribution effects of such policies from an empirical perspective.

But more recently, there has been increasing concern among researchers about the almost complete disregard of intertemporal phenomena which characterizes the first generation of CGE models. Early CGE models have more or less completely ignored the inherently intertemporal nature of savings and investment. They have almost always been closed, in one way or another, by an assumed equality between investment and savings and, hence, by a balanced trade assumption.

This is particularly awkward if trade policy is at the center of ones interest, because there is a widespread notion, at least with policy makers and the general public, that protection will have a favorable current account effect. Indeed, it is a striking fact that current account deficits and poor macroeconomic performance have contributed significantly to protectionist sentiment and legislation (see, for instance, Dornbusch & Frankel, 1987). Yet, at the same time, economists have typically addressed issues of protection within general equilibrium models in which trade was assumed always to be balanced.

From a microeconomic point of view, current account imbalances reflect nothing but intertemporal trading. Hence, an obvious route for improvement of the models used in addressing issues of protection and other distortionary policies is to introduce a rigorous treatment of intertemporal decision making by households (on consumption and savings) and by firms (on investment). While analytical studies of current account adjustment within intertemporal optimization frameworks have been around for about a decade, the incorporation of such a framework into large scale simulation models is comparatively new.

Against the background of the traditional theory of protection, which is largely static theory, it might be questioned that protection of liberalization will have any interesting intertemporal effects at all, since such policies will only change intratemporal but not intertemporal prices. But this argument ignores at least two things:

- Protectionist (or liberalization) policies may themselves have an inherent time dimension

inasmuch as they are anticipated, temporary, or phased in over several periods of time.

- Perhaps more importantly, the reaction of the economy to such policies may have a time dimension because it takes time (and resources) to adjust to a change in relative prices. The principal case that comes to ones mind here is timely and costly reallocation of capital.

We regard it as very important for a simulation exercise to have a model capable of capturing these time dimensions.

Current account adjustments to protectionist policies or terms of trade shocks have been analytically addressed in highly stylized models by, among others, Brock (1988), Sen & Turnovsky (1989) and Gavin (1989, 1991). Inevitably, introducing sectoral disaggregation and other complications such as a government sector with taxation and government purchases into an intertemporal optimization framework will lead to model which is analytically intractable. This is the primary motivation for constructing large scale simulation models incorporating intertemporally optimizing behavior.

This paper is intended to present the results of our first efforts to construct such a simulation model calibrated to Austrian data. Although the model is still preliminary in many respects it does incorporate enough intertemporal structure to be able to address issues such as current account adjustment to commercial policies.

The model features

- a semi-small country, facing a given world net interest rate and given prices for imports but downward sloping demand curves for its exports, with
- exogenous trend growth,
- endogenous labor supply,
- intertemporal allocation of consumption,
- forward looking investment behavior subject to installation costs for sector-specific physical capital, and
- current account imbalances as a result of independent savings and investment decisions and, accordingly, accumulation of foreign debt.



A key element in the modelling of intertemporal aspects is the underlying assumption regarding expectations that agents have of future prices. The most ambitious and theoretically consistent approach is to assume perfect foresight, meaning that agents correctly anticipate all future equilibrium prices and never need to revise their decisions because of erroneous judgment. Their expectations are continuously borne out by their own decisions, made subject to these expectations. The implementation of this perfect foresight assumption is essential for a consistent welfare analysis as well as for being able to capture announcement effects of policy changes. On the other hand, it does confront the modeler with computational problems. These problems will, however, not be dealt with in the present paper. Our solution strategy is described in Keuschnigg (1991).

Our model is calibrated to a 1976 benchmark data set. It would, of course, be highly desirable to have a more recent data base, but there is no more recent input-output table available for the Austrian economy. This is unfortunate, but it is beyond our own influence.

The present paper is intended to present the model structure as well as the method and results of its calibration. Future papers will focus on simulation exercises.

The paper is organized as follows. Chapter 2 shows how we have detrended the model such that it features stationary steady state characteristics. Chapter 3 presents the wealth accumulation equations of the model and determines the dating convention that we follow throughout the subsequent model presentation, which will be in discrete time. Chapter 4 is devoted to the intertemporal consumption decision, and chapter 5 shows how investment behavior is determined in our model. This will complete the intertemporal structure of our model. Chapter 6 outlines the temporal structure and the corresponding temporary equilibrium conditions. Finally, chapter 7 describes how we have proceeded in implementing the model empirically by means of calibration. In doing so we will focus on the problems raised by the intertemporal model structure. Standard procedures of calibrating static parameters will be dealt with in due shortness.

## 2 Detrending from Exogenous Population and Productivity Growth

Our general equilibrium model features population growth at a constant exogenous rate  $n$  and labor productivity growth at rate  $x$ . Hence, a class of variables in the model contains exogenous

trend components. For the model to have stationary steady state characteristics, we transform these variables as follows. Let

$$N_t = (1 + n)^t N_0, \quad X_t = (1 + x)^t X_0, \quad (1)$$

where  $N_t$  is the size of the population at the beginning of period  $t$ , and  $X_t$  is the state of technology at the beginning of  $t$ , which determines labor productivity during period  $t$ . The “efficiency unit”  $N_t X_t$  increases at the constant rate  $\bar{g} = (1 + n)(1 + x) - 1$ .

Now consider the relationship between household labor income, consumption, and the accumulation of financial wealth:

$$A_t = (1 + r_t)A_{t-1} + W_t^n L_t^s + Z_t + U_t t y_t - p_t^c C_t, \quad (2)$$

where  $A$  indicates financial wealth,  $r$  is the net (of tax) nominal interest rate,  $W^n$  is the net (of tax) wage rate,  $L^s$  is labor supply,  $Z$  indicates transfers,  $p^c$  indicates a consumption price index (see below), and  $C$  is a consumption quantity aggregate (see below). We have

$$r_t = i_t(1 - t y_t) \quad \text{and} \quad (3)$$

$$W_t^n = W(1 - t s_t)(1 - t y_t), \quad (4)$$

where  $i$  is the market interest rate,  $W$  is the market wage rate,  $t y$  is a general income tax rate, and  $t s$  is a social security tax rate (deductible from income tax). We model a progressive income tax schedule by means of a lump sum tax deduction of  $U$ .

It is crucial to note that all flows are assumed to occur at the beginning of period and stock variables are dated at the beginning of period. Thus, financial wealth at the beginning of period  $t$ ,  $A_t$ , is equal to financial wealth of the previous period,  $A_{t-1}$ , plus net interest income plus savings from labor and transfer income.<sup>1</sup>

Dividing the above equation by  $N_t X_t$  and noting that  $\bar{g} \equiv (N_{t+1} X_{t+1} / N_t X_t) - 1$ , we get

$$(1 + \bar{g})a_t = (1 + r_t)a_{t-1} + (1 + \bar{g})(w_t^n l_t^s + z_t + u_t t y_t - p_t^c c_t), \quad (5)$$

where lower case letters indicate detrended variables. In all cases except the wage rate and labor supply, detrended values are per efficiency unit  $NX$ .  $w$  is detrended from productivity growth and  $l^s$  is labor supply per capita, both remaining constant in the steady state.

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<sup>1</sup>Notice that interest income of period  $t - 1$  plus new assets bought at time  $t - 1$  are already included in  $A_{t-1}$ . The above equation essentially states that total assets are equal to the stock of previously accumulated assets plus new assets acquired from savings.

The above dating convention and detrending practice is followed throughout the paper. The structure of the model is presented in terms of transformed variables (indicated by lower case letters) only, the original variables can easily be obtained by appropriately multiplying with the exogenous growth factor.

In our model, financial wealth  $a$  can be held in any one of the following assets: government debt  $d^g$ , net foreign assets  $d^f$ , and equity  $v$ . We assume perfect substitutability between these assets. Hence, for households to simultaneously accept all assets in their portfolios, the following equations of motion must hold:

$$(1 + \bar{g})d_t^g = (1 + r_t)d_{t-1}^g - (1 + \bar{g})b_t^g. \quad (6)$$

$$(1 + \bar{g})d_t^f = (1 + r_t)d_{t-1}^f + (1 + \bar{g})b_t^f. \quad (7)$$

$$(1 + \bar{g})v_t = (1 + r_t)v_{t-1} - (1 + \bar{g})\chi_t. \quad (8)$$

In the above equations  $b^g$  is the primary government surplus,  $b^f$  is the trade surplus, and  $\chi$  stands for net of tax dividends paid by firms, whose total value (ex dividend) is  $v$ . While (6) and (7) indicate how the stocks of government and foreign debt accumulate over time, (8) is an arbitrage condition which restricts the rate of return on firm equity to the prevailing net market interest rate.<sup>2</sup> Defining  $a = d^g + d^f + v$ , and ensuring that the above equations of motion (6 - 8) are fulfilled implies a flow equilibrium on the market for financial capital: Household savings as defined in (5) plus dividends are equal to the government deficit plus the trade surplus.

### 3 Intertemporal Structure of the Model: Household Decision

It is assumed that the economy is populated by agents with an operative altruistic bequest motive towards their heirs. They fully internalize the interests of future generations and may, hence, be thought of as infinitely lived consumers [see Barro (1974) and Weil (1987)]. Their intertemporal preferences are represented by a utility functional of the following form [see Sinn (1987), pp. 26-28 for a detailed discussion]:

$$U_t = \sum_{s=t}^{\infty} (1 + \rho)^{t-s} N_s u(c_s, X_s, h_s). \quad (9)$$

We assume intertemporal preferences to be additively separable, with exponential discounting at a subjective discount rate  $\rho$ . We thus employ a ‘‘Benthamite’’ utility function, since per capita

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<sup>2</sup>We enforce this arbitrage condition by assuming that firm behavior is determined by maximizing cum dividend firm values, whereby firm values are defined as the solution to the above difference equation for  $v$ .

momentary utility  $u$  (felicity) is weighted by family size  $N_s$ . Felicity, in turn, depends on per capita consumption  $c_s X_s$ , and per capita leisure  $h_s \equiv 1 - l_s^s$  according to a time invariant function  $u(\cdot)$ . In a steady state, per capita leisure must remain constant, but per capita consumption must steadily increase with the productivity growth rate  $x$ . As King, Plosser and Rebelo (1988) show, the most general functional form compatible with such steady state characteristics is

$$u(c_s X_s, h_s) = \frac{(c_s X_s)^{1-1/\gamma}}{1-1/\gamma} v(h_s). \quad (10)$$

Thus, momentary utility features multiplicative separability in consumption and leisure, where the parameter  $\gamma$  represents the intertemporal elasticity of substitution in consumption.<sup>3</sup> Concavity of  $u(\cdot)$  requires that  $\gamma > 0$  and  $v(\cdot) > 0$ . Furthermore,  $v(\cdot)$  must be increasing and concave if  $\gamma > 1$ , and decreasing and convex if  $\gamma < 1$ .  $u(\cdot)$  is the top level of a multi-level utility nesting which will be described in appropriate detail below.<sup>4</sup>

Given constant growth rates  $n$  and  $x$ , (9) can be written as

$$U_t = N_t X_t^{(1-1/\gamma)} \sum_{s=t}^{\infty} \beta^{s-t} u(c_s, h_s), \quad \beta \equiv \left[ \left( \frac{1+n}{1+\rho} \right) (1+x)^{(1-1/\gamma)} \right]. \quad (11)$$

This is quite convenient because the constant  $N_t X_t^{(1-1/\gamma)}$  can be ignored in the following optimization exercise.  $\beta$  is a modified discount factor. For computational purposes, felicity has to be parameterized, and we use a Cobb–Douglas nested within a constant intertemporal elasticity function:

$$u_s = u[v(c_s, h_s)] = \frac{\left[ c_s^\alpha h_s^{(1-\alpha)} \right]^{(1-1/\gamma)}}{1-1/\gamma}. \quad (12)$$

While Cobb–Douglas may seem restrictive, it is in fact the most general form compatible with wage trend growth. Furthermore, homogeneity of degree one allows to separate optimization into separate stages. This is most easily done by rewriting the dynamic budget constraint as

$$(1 + \bar{g})a_s = (1 + r_s)a_{s-1} + (1 + \bar{g})(w_s^n + z_s + u_s t y_s - m_s), \quad (13)$$

$$\text{where } m_s = p_s c_s + w_s^n h_s. \quad (14)$$

$m$  is the overall budget spent on consumption and leisure. Writing  $v_s = v(c_s, h_s)$  for the Cobb–Douglas aggregate of consumption and leisure, and assuming that  $v$  will always be obtained at

<sup>3</sup>It is assumed that  $\gamma \neq 1$ . Alternatively,  $u(\cdot)$  could be specified as  $\ln(c_s)v(h_s)$  for the special case of  $\gamma = 1$ .

<sup>4</sup>We want to mention at this stage that “subutility”  $c$  must be homogeneous of degree one for a growth model like the present one to possess the usual steady state characteristics. In particular, if  $c$  were not linearly homogeneous, the consumption pattern would not remain stationary in the “steady state”. Instead, all commodities with income elasticities of demand less than 1 would asymptotically vanish in the “steady state” consumption bundle.

minimum unit cost, we can use the unit cost function as the price index  $p^v$  associated with the aggregate  $v$ :  $m_s = p_s^v \cdot v_s$ . We will henceforth call  $v$  full consumption, whereas  $c$  will be called the commodity consumption bundle.

The representative household is assumed to choose a time path for full consumption that maximizes  $\sum_{s=t}^{\infty} \beta^{(s-t)} u(v_s)$  subject to the above dynamic budget constraint. While we do not want to rule out temporary indebtedness, there must be a restriction on borrowing (no-Ponzi game condition) for otherwise the problem would be misspecified. Hence, in addition to the initial condition  $a_{t-1} = a^0$  there must be a terminal condition ensuring asymptotic solvency:  $\lim_{T \rightarrow \infty} a_T \geq 0$ .

This intertemporal consumption problem can be solved by Lagrangean methods. In perfect analogy to Keuschnigg (1991), we obtain the following profile for the aggregate consumption bundle:

$$v_s = \left[ \frac{1 + \bar{g}}{1 + r_{s+1}} \frac{p_{s+1}^v}{p_s^v} \right]^\gamma \beta^{-\gamma} v_{s+1}. \quad (15)$$

The term in square brackets is the consumption based real interest rate (intertemporal rate of transformation). Hence, (15) equates the rate of transformation to the intertemporal rate of substitution [see also Dornbusch (1983)]. We assume the net (of tax) interest rate  $r$  to be given exogenously (small country). Notice that the existence of a steady state equilibrium requires that the interest rate satisfies

$$r = (1 + \bar{g})/\beta - 1. \quad (16)$$

For our computational model, we of course need to know more than the consumption profile. We need to know the level of consumption in addition to the rate of its change in every period, i.e., we need a “consumption function”. By forward solution of the dynamic budget equation (13) and using the transversality condition for the optimum gives an intertemporal budget constraint according to which

$$\sum_{s=t}^{\infty} p_s^v v_s R_{t+1,s} = TW_t; \quad TW_t \equiv \frac{1 + r_t}{1 + \bar{g}} a_{t-1} + H_t; \quad H_t \equiv \sum_{s=t}^{\infty} (w_s^n + z_s + u_s t y_s) R_{t+1,s}. \quad (17)$$

The right hand side is total wealth  $TW$ , which consists of financial wealth (previously accumulated) and human wealth  $H_t$ . The discount factor in these calculations is defined as

$$R_{t,s} \equiv \prod_{u=t}^s \left( \frac{1 + \bar{g}}{1 + r_u} \right), \quad R_{t+1,t} \equiv 1. \quad (18)$$

This version of the budget constraint states that discounted lifetime consumption must be equal in value to present financial wealth plus human wealth. The consumption profile given in (15)

allows to substitute out all future consumption terms in this budget constraint, and we obtain the following consumption function:

$$p_t^v v_t = \Omega_t^{-1} T W_t, \quad \text{where} \quad (19)$$

$$\Omega_t \equiv \sum_{s=0}^{\infty} \beta^{s\gamma} \left( R_{t+1,t+s} \frac{p_{t+s}^v}{p_t^v} \right)^{(1-\gamma)}. \quad (20)$$

The factor  $(\Omega_t)^{-1}$  is the marginal propensity to consume out of total wealth, and it depends on the price of present relative to future consumption. We can see that present consumption depends on future prices, both of consumption and of labor (via  $H$ ). We have to specify how expectations of these future prices are formed and, as mentioned in the introduction, we implement the assumption of perfect foresight in our computational model (see below).

Once we know  $p_t^v v_t$ , optimal aggregate consumption  $c_t$  and leisure  $h_t$  can easily be determined by solving the static problem of minimizing the cost of obtaining  $v_t$  subject to  $v_t = c_t^\alpha h_t^{(1-\alpha)}$ .

## 4 Intertemporal Structure of the Model: Investment Decision

For ease of notation we abstain from using a sector index in the following presentation of firm behavior. Later on, subscripts  $i$  and  $j$  are used to denote sectors. Dividends per efficiency unit received by equity holders at the beginning of period  $s$  are:

$$\chi_s = (1 - ty_s) \left[ \tilde{p}_s (f_s - \Phi_s) - w_s^g l_s^d \right] - (1 - e_s ty_s) p_s^{in} in_s, \quad (21)$$

where  $f$  is the value added product,  $\Phi$  is the output loss due to the cost that has to be incurred in the process of installing new physical capital,  $w^g$  is the gross (of factor tax) wage rate, and  $in$  is the amount of new capital installed.  $\tilde{p}$  is a sector-specific price for the value added product.  $in$  should be thought of as demand for a composite capital good with a price  $p^{in}$ . Details on  $\tilde{p}$ ,  $in$ , and  $p^{in}$  will follow in the subsequent chapter presenting the temporal structure of the model. We assume that there is a tax incentive for investment which is parameterized by  $e$ .

It is worthwhile to pause for a moment and compare this approach with that of Goulder & Eichengreen (1989a and 1989b). There are several differences worth mentioning. First, we assume for simplicity that all investment is financed internally by retained earnings, i.e., firms do not have debt. Moreover, firms never issue new equity. Hence, dividends are equal to after tax profits less investment expenditure. Finally, profits are subject to the income tax rate  $ty$ , rather than a separate corporate tax rate. Notice also that, partly as a result of the above

mentioned simplifications, our arbitrage condition for equity [see (8) above] is different from the one used by Goulder & Eichengreen. In our case there is no additional taxation of dividends in the arbitrage condition (because they are derived from after tax profits),<sup>5</sup> there is no capital gains tax and, finally, there is no risk premium for equity. These simplifications, especially the ones relating to the tax structure, are primarily dictated by data restrictions.

The value added product per efficiency unit is a linearly homogeneous function of the capital stock per efficiency unit and per capita labor input:<sup>6</sup>

$$f_s = \phi \left[ \eta l_s^{\alpha(\mu-1)/\mu} + (1 - \eta) k_s^{(\mu-1)/\mu} \right]^{\mu/(\mu-1)}. \quad (22)$$

The capital stock accumulates according to

$$(1 + \bar{g})k_{s+1} = in_s + (1 - \delta)k_s, \quad (23)$$

where  $\delta$  is the rate of decay.

The installation cost function is

$$\Phi_s = \Phi(in_s, k_s) = \psi \left( \frac{in_s}{k_s} - (\bar{g} + \delta) \right) in_s. \quad (24)$$

We assume that maintaining a given capital stock per efficiency unit does not cause any cost of capital installation. It may seem strange to model adjustment cost in this way because they become negative if investment falls below its steady state value. However, we argue that it is more appropriate to focus on the “net” value added production function

$$y_s = f(k_s, l_s) - \Phi(k_s, in_s) = y(k_s, l_s, in_s), \quad (25)$$

where  $y(\cdot)$  is linearly homogeneous if  $f(\cdot)$  and  $\Phi(\cdot)$  are. The most important aspect of our adjustment cost function is that  $y_{in}$  is still negative at the steady state value of investment.<sup>7</sup> Reducing investment below its steady state value does increase net output, which is a perfectly reasonable assumption to make. What the choice of our adjustment function amounts to is an arbitrary scaling decision. Our motivation for this choice is that we want to have  $\Phi$  equal to zero in the benchmark equilibrium to which we calibrate the model. At the same time we

<sup>5</sup>In other words, our model does not capture the double taxation feature of a separate corporate tax in addition to a personal income tax.

<sup>6</sup>Total value added produced is  $F_s = f(K_s, L_s^d, X_s)$ , where capital letters indicate absolute levels.

<sup>7</sup>We generally denote partial derivatives by subscript variable names.

wanted to have  $\Phi_{in} \neq 0$  as well as  $\Phi_k \neq 0$  in the steady state for the calibration of intertemporal parameters of the model (see below).

Solving the above arbitrage condition (8) for firm value and dividends by forward integration and introducing a transversality condition ruling out eternal bubbles gives the cum dividend value of the firm as

$$v_t + \chi_t = \sum_{s=t}^{\infty} \chi_s R_{t+1,s}. \quad (26)$$

We now assume that firms choose investment and labor input during all future periods  $s \geq t$  such that cum dividend firm value is maximized subject to a given initial capital stock  $k_t = k^0$ , a non-negativity constraint for the capital stock throughout the transition path,  $k_s > 0$  for all  $s = t, \dots, \infty$ , and subject to the above equation for capital accumulation.

Optimal labor input must satisfy the usual static first order condition of equality between the marginal value product of labor and the nominal gross wage rate:

$$\tilde{p}_t f_{l_t} = w_t^g, \quad (27)$$

where  $w_t^g = w_t(1 + tl_t)$ , and  $tl_t$  is a sector specific indirect tax rate on labor use. This defines a short run labor demand function  $l^d = l^d(\tilde{p}, w^g, k)$ . Capital is assumed to be sector-specific so that capital reallocation can only take place through investment.

Optimal investment can be determined by Lagrangean methods. The Lagrangean of the problem is

$$\mathcal{L}_t = \sum_{s=t}^{\infty} \{ \chi_s + q_s [in_s + (1 - \delta)k_s - (1 + \bar{g})k_{s+1}] \} R_{t+1,s}. \quad (28)$$

The first order conditions are:

$$q_s = (1 - ty_s)\tilde{p}_s \Phi_{in_s} + (1 - e_s ty_s)p_s^{in}. \quad (29)$$

$$(1 + \bar{g})q_{s-1}R_{t+1,s-1} = [(1 - ty_s)\tilde{p}_s(f_{k_s} - \Phi_{k_s}) + (1 - \delta)q_s]R_{t+1,s}. \quad (30)$$

$$\lim_{s \rightarrow \infty} k_{s+1}q_s R_{t+1,s} = 0. \quad (31)$$

plus the equation of motion for the capital stock. In the above equations, a subscript variable name again indicates the corresponding partial derivative.

Using the transversality condition and solving the difference equation for the multiplier  $q$  gives the usual economic interpretation that the marginal shadow value of the capital stock is



equal to the present value of incremental future net income streams that would be created by an additional unit of capital stock:

$$q_t = \frac{1}{1 - \delta} \sum_{s=t+1}^{\infty} (1 - ty_s) \bar{p}_s (fk_s - \Phi_{k_s}) \prod_{u=t+1}^s \left( \frac{1 - \delta}{1 + r_u} \right). \quad (32)$$

Inserting this equation into the first order condition for investment gives an implicit investment function. As with the aggregate consumption bundle above, we realize that investment depends on future prices. Again, we will implement the perfect foresight assumption in our computational model. But for reasons explained in detail in Keuschnigg (1991), we do not use the shadow value of capital  $q$  as the forward looking variable in the computation of the perfect foresight equilibrium. Instead, we invoke the Hayashi theorem which equates the value of the firm to the shadow value of new capital:  $v_t = (1 + \bar{g})k_{t+1}q_t$ . We exploit this relationship to eliminate  $q_t$  in (29). Using (23) and the functional form given in (24), the condition for optimal investment in (29) is

$$\frac{v_t}{in_t + (1 - \delta)k_t} = (1 - ty_t) \bar{p}_t \left[ 2\psi \frac{in_t}{k_t} - \psi(\bar{g} + \delta) \right] + (1 - e_t ty_t) p_t^{in}. \quad (33)$$

Investment demand is now determined by the positive root of this quadratic equation.

## 5 Intratemporal Structure of the Model

In the preceding discussion of the intertemporal features of our model, two commodity aggregates have emerged:  $c_t$  and  $in_t$ . Since these are aggregate demands we now start presenting the features of the temporary equilibrium by considering these and other categories of demand in some detail. Subsequent chapters will focus on supply and the intratemporal equilibrium conditions, including some general remarks on the solution strategy. Since time is no longer important in this chapter, we abstain from time-indexing our variables. Moreover, we try to keep the presentation as general as possible, relegating specific functional forms to a summary table in the appendix. We use  $\vec{x}_i$  to indicate a vector representation of the elements  $x_i$ , where  $i$  is a sector index. Where necessary, we use an additional subscript  $j$  to indicate sectors.

### 5.1 Final Demand

Our model has four types of domestic agents generating demand for commodities: consumers, the government, investors, and producers. The first three generate what is usually called domestic final demand, whereas producers demand intermediate inputs.

In addition, there will be export demand by foreign agents, and part of demand by domestic agents will be for imported goods. For reasons outlined in detail in Kohler (1990), we always assume domestic and imported commodities to be imperfect substitutes, and we employ the so-called Armington procedure to model this.<sup>8</sup> Thus, any demand for sector  $i$  commodities, wherever it may originate, must be thought of as demand for a sector specific aggregate composed of a home produced and an imported commodity, denoted by a superscript  $h$  and  $m$ , respectively. As regards exports, we assume that goods sold domestically are identical to goods sold on the world market, with downward sloping export demand curves.<sup>9</sup> These sector-specific aggregates enter a second level of aggregation leading to the commodity consumption aggregate  $c$  and the capital good  $in$  mentioned above. The functional forms of these top-level aggregates are Cobb-Douglas. The resulting relationship between the intertemporal and the temporary model structure is overviewed in figure 1.

Our model allows for three types of indirect taxes: a value added tax, a general excise tax, and import tariffs. Tax rates for these indirect taxes are allowed to vary as between different categories of demand, reflecting both different treatment by the tax law as well as different compositions of aggregates by individual commodities. But all demanders face an identical market price of  $p_i^h$  for the home produced and  $p_i^m$  for the imported good. Thus, the price gross of indirect taxes that final demand of category  $n$  has to pay for an imported and home produced commodity  $i$ , respectively, is

$$p_i^{n,h} = p_i^h(1 + tv_i^{n,h} + tx_i^{n,h}), \quad \text{and} \quad (34)$$

$$p_i^{n,m} = \mathcal{E}p_i^m(1 + tv_i^{n,m} + tx_i^{n,m} + tm_i^n), \quad (35)$$

where  $n = c$  (for private consumption),  $in$  (for investment),  $gv$  (for government consumption), and  $tv$  is a value added tax rate,  $tx$  is an excise tax rate, and  $tm$  is the tariff rate.  $\mathcal{E}$  is an exchange rate variable which we introduce to convert world market prices such that they become comparable to home goods prices. In the computational exercises we will, however, normalize the price system by setting this exchange rate variable equal to unity.

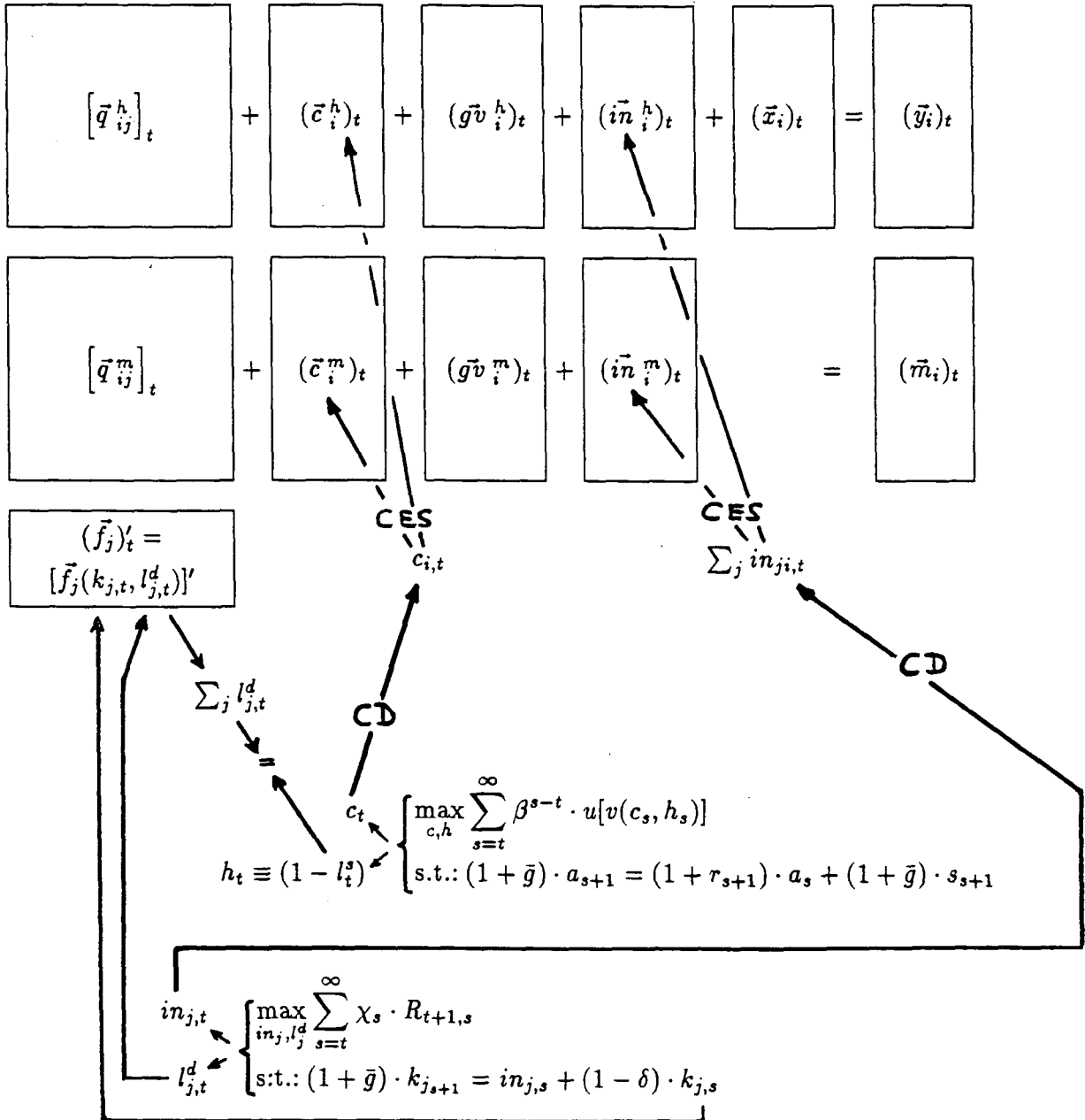
For the time being, we assume that the tax treatment of imports and exports follows an unrestricted destination principle. Incoming imports are subject to all domestic indirect taxes,

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<sup>8</sup>This procedure was first proposed by Armington (1969).

<sup>9</sup>In a second version of the model we assume product differentiation on the supply side as well. This is modeled by means of sectoral transformation functions for home sales and exports, as suggested by de Melo & Robinson (1989). In this second version, we assume infinitely elastic foreign demand for exports, i.e., given world prices for export sales. However, in the present paper we restrict ourselves to the first version described above.

Figure 1: Overview of model structure



**Table 1:**  
**Commodity aggregates for domestic final demand,**  
**and associated prices.**

	Quantity aggregates	Price Indices	Demand functions
<i>Consumption</i>			
<i>Aggregate</i>	$c = c(\bar{c}_i)$	$p^c = p^c(\bar{p}_i^c)$	$c_i = c_i(\bar{p}_i^c, c)$
<i>Sectoral</i>	$c_i = c_i(c_i^m, c_i^h)$	$p_i^c = p_i^c(p_i^{c,m}, p_i^{c,h})$	$c_i^h = c_i^h(p_i^{c,m}, p_i^{c,h}, c_i)$ $c_i^m = c_i^m(p_i^{c,m}, p_i^{c,h}, c_i)$
<i>Investment</i>			
<i>Aggregate</i>	$in = in(\bar{in}_i)$	$p^{in} = p^{in}(\bar{p}_i^{in})$	$in_i = in_i(\bar{p}_i^{in}, in)$
<i>Sectoral</i>	$in_i = in_i(in_i^m, in_i^h)$	$p_i^{in} = p_i^{in}(p_i^{in,m}, p_i^{in,h})$	$in_i^h = in_i^h(p_i^{in,m}, p_i^{in,h}, in_i)$ $in_i^m = in_i^m(p_i^{in,m}, p_i^{in,h}, in_i)$
<i>Government</i>			
<i>Aggregate</i>	$gv = gv(\bar{gv}_i)$	$p^{gv} = p^{gv}(\bar{p}_i^{gv})$	$gv_i = gv_i(\bar{p}_i^{gv}, gv)$
<i>Sectoral</i>	$gv_i = gv_i(gv_i^m, gv_i^h)$	$p_i^{gv} = p_i^{gv}(p_i^{gv,m}, p_i^{gv,h})$	$gv_i^h = gv_i^h(p_i^{gv,m}, p_i^{gv,h}, gv_i)$ $gv_i^m = gv_i^m(p_i^{gv,m}, p_i^{gv,h}, gv_i)$

whereas exports leave the country net of domestic indirect taxes (at a price  $p_i^h$ ) and are subject to the foreign countries' indirect tax system.<sup>10</sup>

Table 1 presents an overview of all final demand aggregates with the associated prices as well as the corresponding demand functions. To avoid excessive notation, we have kept the presentation general. The table is reproduced with the specific functional forms in the appendix.

A few things are worth mentioning. First, it should be noted that  $in_i$  is not investment demand by sector  $i$ , but rather the demand for sector  $i$  output generated by the investment decisions of all sectors taken together. Secondly, as to government procurement we have indicated more substitution in the above table than we actually assume in the model. In particular, there is no substitution in our model between different commodity aggregates within the upper level aggregate  $gv$ . This is meant to reflect the fact, albeit in a stylized way, that government

<sup>10</sup>There will be exceptions to this treatment of exports that will be taken up when dealing with calibration below.

procurement is to a large extent fixed by legal commitments. However, we do assume that within any commodity aggregate  $gv_i$  there is scope for substitution between imported and home produced goods. Finally, while the share parameters of the sectoral aggregates are allowed to vary as between different categories of final demand, they share the same elasticity of substitution between imported and home produced goods (see table A1 of the appendix).

As regards export demand, we employ the following downward sloping export demand functions with constant elasticities:

$$x_i = \bar{x} \left( \frac{p_i^h}{\mathcal{E}} \right)^{\theta_i}, \quad (36)$$

$\theta_i < 0$  is the partial equilibrium elasticity of demand (see previous footnote).

## 5.2 Production and Input Demands

Production is modeled by means of parameterized production functions featuring weak separability and linear homogeneity. This was already implicit in the use of the value added production function above. It is perhaps worth mentioning that the ubiquitous phenomenon of increasing returns to scale does not necessarily interfere all that much with modeling industry output as linearly homogeneous as long as unit cost functions approach near constancy in sufficiently low output ranges, relative to total demand. A related, maybe more worrying, and certainly much more difficult question is that of firm behavior. Following common practice in CGE modeling, we assume perfect competition throughout.<sup>11</sup>

We assume a fixed coefficients production function of the following form:

$$y_i = \min \left\{ \frac{q_{1i}}{a_{1i}}, \frac{q_{2i}}{a_{2i}}, \dots, \frac{q_{ni}}{a_{ni}}, \frac{f_i}{a_{0i}} \right\}, \quad (37)$$

where  $f_i$  is the value added product as introduced above,  $q_{ji}$  is the amount of intermediate inputs of type  $j$  used in the production of good  $i$ , and  $a_{ji}$  is a fixed input-output coefficient.

Every intermediate input requirement is defined in terms of a CES aggregate of an imported and a home produced good:

$$q_{ji} = \left[ \psi_{ji}^m q_{ji}^m [(\sigma_j^m - 1)/\sigma_j^m] + (1 - \psi_{ji}^m) q_{ji}^h [(\sigma_j^m - 1)/\sigma_j^m] \right]^{\sigma_j^m / (\sigma_j^m - 1)}. \quad (38)$$

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<sup>11</sup>There are relatively few attempts to model imperfect competition in true CGE models. Examples are Harris (1984), Brown & Stern (1989), Wigle (1988), and Devarajan & Rodrik (1989).

Notice that the share parameters vary both between sectors of destination and sectors of origin, but that we have employed the same elasticity of substitution in the above aggregate as we did for final demand (see table A1 of the appendix).

Producers receive output prices  $p_i^h$  and pay

$$p_j^{q,h} = p_j^h(1 + tx_j^{q,h}) \quad \text{and} \quad (39)$$

$$p_j^{q,m} = \mathcal{E}p_j^m(1 + tx_j^{q,m} + tm_j^q) \quad (40)$$

per unit of home produced and imported inputs, respectively. Since the value added tax is a tax on final demand only, value added tax rates do not appear in the above equations.<sup>12</sup>

The intermediate input demand functions derived from the above aggregate are:

$$\begin{aligned} q_{ji}^h &= \left[ \psi_{ji}^m p_{ji}^q / p_j^{q,h} \right]^{\sigma_j^m} a_{ji} y_i \\ &= a_{ji}^h (p_j^{q,h}, p_j^{q,m}) y_i, \quad \text{and} \end{aligned} \quad (41)$$

$$\begin{aligned} q_{ji}^m &= \left[ (1 - \psi_{ji}^m) p_{ji}^q / p_j^{q,m} \right]^{\sigma_j^m} a_{ji} y_i \\ &= a_{ji}^m (p_j^{q,h}, p_j^{q,m}) y_i, \quad \text{where} \end{aligned} \quad (42)$$

$$p_{ji}^q = \left[ \psi_{ji}^m \sigma_j^m p_j^{q,m(1-\sigma_j^m)} + (1 - \psi_{ji}^m) \sigma_j^m p_j^{q,h(1-\sigma_j^m)} \right]^{1/(1-\sigma_j^m)}. \quad (43)$$

$a_{ji}^h$  and  $a_{ji}^m$  are the resulting input-output coefficients for home produced and imported intermediate goods. These are variable and endogenously determined by the model.

In the chapter on investment decisions we have used a price  $\tilde{p}_i$  for the value added product  $f_i$ . This value added price can now be determined from the zero profit condition:

$$\tilde{p}_i = \left[ p_i^h - \sum_{j=1}^n a_{ji} p_{ji}^q \right] / a_{0i}. \quad (44)$$

Using this value added price, labor input is determined by the usual marginal value product condition as mentioned above. Having determined value added, the fixed coefficients production function in (39) can then be used to calculate gross output  $y_i$ .

<sup>12</sup>Compare (39) and (40) with (34) and (35). Actually, the value added tax is a tax on consumption only, since all value added tax paid on investment goods is deductible as well. However, in our data set there is a significant amount of value added tax attributable to investment purchases. This is due to the fact that some of the investors have been tax exempt which, of course, also precludes tax deduction. More on this below.

### 5.3 Equilibrium conditions

Temporary equilibrium during period  $t$  is conditional on previously accumulated sectoral capital stocks, on previously accumulated financial wealth, and on expectations about future prices as embodied in  $\Omega_t$ ,  $H_t$  and  $v_{1,t}, \dots, v_{n,t}$ . The latter determine aggregate consumption and sectoral investment, as we have seen in our discussion of intertemporal decisions. Using a superscript  $e$  to indicate expected variables, a temporary equilibrium satisfies  $n$  goods market equilibrium conditions of the following forms:

$$c_{i,t}^h(\bar{p}_{i,t}^h, w_t, H_t^e, \Omega_t^e) + g v_{i,t}^h(\bar{p}_{i,t}^h) + \sum_{j=1}^n i n_{ij,t}^h(\bar{p}_{i,t}^h, k_{j,t}, v_{j,t}^e) + x_{i,t}(p_{i,t}) + \sum_{j=1}^n a_{ij}^h(p_{i,t}^h) y_j = y_i(\bar{p}_{i,t}^h, w_t, k_{i,t}), \quad (45)$$

where all but endogenous prices, capital stocks and expected variables have been dropped from the list of arguments, and  $i n_{ij,t}^h$  is investment demand by sector  $j$  for output of sector  $i$ . Furthermore, labor market equilibrium requires

$$l_t^s(\bar{p}_{i,t}^h, w_t, H_t^e, \Omega_t^e) = \sum_{j=1}^n l_j^d(\bar{p}_{i,t}^h, w_t, k_{j,t}). \quad (46)$$

What happens with savings in temporary equilibrium? Household primary savings are equal to the difference between the value of aggregate consumption and net of tax labor income. It can now be shown that, if all goods markets and the labor market are in equilibrium, Walras' Law will ensure that these primary household savings plus total dividends that households receive from firms will be equal to the government primary deficit plus the trade balance.<sup>13</sup> Thus, since we do not want any one of these single balances to be zero we need not enforce any additional temporary equilibrium condition. In particular, there is no need to let the exchange rate variable bring about balanced trade. Indeed, allowing for unbalanced trade and foreign debt accumulation was one of the prime motivations of having an intertemporal model like the one presented. And since all excess demand functions are homogeneous of degree zero in prices and expected variables  $\{H_t^e, v_{j,t}^e\}$ , we can arbitrarily set the exchange rate equal to one (as indicated above) so that our temporary equilibrium will determine all prices relative to the given world prices.

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<sup>13</sup>Substitute (6 - 8) into (5) and use the condition  $a_t = d_t^g + d_t^f + v_t$ .

The equilibrium solution in any period also determines optimal savings and investment decisions by households and firms, respectively. We additionally assume an exogenous savings (or debt) plan by the government.<sup>14</sup> All this implies that successive temporary equilibria are related by the accumulation of stock variables, whereby the latter include sectoral capital stocks as well as government and foreign debt. In a perfect foresight equilibrium, the expected variables must also satisfy certain laws of motion derived in the following section.

#### 5.4 A Note on the Computation of Perfect Foresight Equilibria

Equilibrium in any period  $t$  is conditional on values of the expected variables  $\{H_t^e, \Omega_t^e, v_{j,t}^e\}$  which are nothing but sums of discounted future values. Expected human wealth, for example, is the present value of future wage and transfer incomes. The laws of motion for these forward looking variables are obtained by taking first differences of the sums given in (17), (20) and (26):

$$H_t = w_t^n + z_t + u_t t y_t + \frac{1 + \bar{g}}{1 + r_{t+1}} H_{t+1}^e, \quad (47)$$

$$\Omega_t = 1 + \beta^\gamma \left( \frac{p_{t+1}^v}{p_t^v} \frac{1 + \bar{g}}{1 + r_{t+1}} \right)^{(1-\gamma)} \Omega_{t+1}^e, \quad \text{and} \quad (48)$$

$$v_{j,t} = (\chi_{j,t+1} + v_{j,t+1}^e) \frac{1 + \bar{g}}{1 + r_{t+1}}. \quad (49)$$

We compute perfect foresight equilibria by relying on an iterative procedure described in Keuschnigg (1991). We first take a sequence of guesses of expected variables and compute a corresponding sequence of temporary flow equilibria. Equations (47 – 49) give the corresponding sequence of actual values for  $\{H_t, \Omega_t, v_{j,t}\}$ . If actual values do not coincide with guessed values we may use actual and guessed values to obtain improved new guesses of the expected variables. With such a vector of new guesses we iterate the procedure and compute another sequence of temporary flow equilibria. A perfect foresight equilibrium is obtained as soon as actual and guessed values of the expected variables coincide [see Keuschnigg (1991) for more details].

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<sup>14</sup>While we have imposed restrictions ruling out explosive behavior of financial wealth and firm values, similar restrictions have not been imposed on foreign assets and government debt. To rule out explosive behavior of government debt we specify an exogenous path for government debt in our counterfactual exercises. This then implies that one of the variables appearing in the government balance has to adjust endogenously such that the temporary equilibrium precisely shows the government deficit (or surplus) required for government debt to remain on the specified path. Having thus ruled out explosive behavior of total financial wealth as well as firm values and government debt, the same must then also hold for foreign assets because they are the residual.



## 6 Empirical Implementation

The model presented above was calibrated to a 1976 benchmark data set, and this section describes the most important aspects of this calibration exercise. As is well known, calibration involves the use of extraneous information on elasticity parameters and the calculation of other parameters, especially share parameters, subject to these elasticity values and certain unit conventions, such that the model will replicate the benchmark data set as an equilibrium solution. For this purpose, the data set has to be adjusted in several parts so that it becomes micro-consistent. We will briefly describe the adjustments that we have applied to the raw data below.

A special feature of the present calibration is that the benchmark equilibrium has to be a steady state equilibrium of the above model. This generates new problems that were absent in the calibrations of static CGE models. With all the intertemporal structure to it, the model has a number of parameters which are impossible to calibrate from the data sets usually employed for the empirical implementation of a general equilibrium model. For want of more reliable information we specify informed guesses for certain intertemporal parameters, and we calibrate the rest from the steady state requirement which we want to be fulfilled in the benchmark equilibrium. Details on this procedure will follow below.

### 6.1 Data and Data Adjustments

We have used several data sources, the most important of which is the 1976 input-output table for Austria.<sup>15</sup> Data pertaining to this input-output table were available to us on three different levels of aggregation: 175, 48, and 31 sectors. To keep the calculations within reasonable limits, we have decided to aggregate the data still further, and we presently vary the number of sectors between 3 and 19, depending on the purpose at hand. Tables A2 and A3 of the appendix give detailed information on the 31 sector and the 19 sector classification as well as the concordance between them and a shorthand expression used in subsequent tables.<sup>16</sup> The other principal data

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<sup>15</sup>We wish to express our thanks to Josef Richter, Federal Chamber of Commerce, Josef Schwarzl, Austrian Central Statistical Office, and Gottfried Tappeiner, University of Innsbruck, for invaluable help in supplying and interpreting the data used.

<sup>16</sup>Actually, we alternatively use five different levels of aggregation leading to 3, 5, 8, 11 and 19 sectors, respectively. But we use the 3 and 5 sector versions only for a demonstration of certain dynamic properties of the model. According to our judgement, 8 is the minimum number of sectors that should be used for the simulation results to be of any empirical significance.

set that we have used is the national accounts statistics.

Our general strategy is as follows. All transactions pertaining to the input-output table originally evaluated net of value added tax, but including all other indirect taxes. Our first step is to purge the data from all other indirect commodity taxes so that we can determine values for the sectoral user cost of capital in a meaningful manner. We then calculate effective indirect tax rates for all three categories of taxes and for all types of demand to obtain total expenditures. In doing so we use effective tax rates for private consumption and aggregate information on indirect taxes attributable to other categories of demand. Next we start calibrating investment share parameters leading to a certain benchmark value of demand for the capital (or investment) aggregate. For this demand to be consistent with both the steady state and the user cost of capital observed in the data set, the intertemporal parameters of the model have to fulfil certain restrictions. These as well as informed guesses on certain parameters are used to calibrate the intertemporal parameters.

Our data set comprises the following categories of final demand:

1. private consumption,
2. government consumption,
3. foreign tourists' expenditure,
4. expenditure on gross capital formation,
5. inventory investments, and
6. exports of goods and services.

For items 1 through 5 we have separate figures for domestic goods and imports (gross of import duties). The same holds true for intermediate input demand. As regards indirect taxes, we have disaggregate information on import duties, excise taxes and value added tax paid on private consumption, and import duties on intermediate imports, and we have aggregate information on indirect taxes attributable to the other categories of demand. We use the implicit tax rates for all three types of indirect taxes (value added tax, excise tax, and import duties) in order to distribute across sectors the known tax aggregates for the other categories of demand. These derived tax vectors were then used to calculate the corresponding effective indirect tax rates referred to in

equations (34), (35), (39) and (40) above.<sup>17</sup> Tables A7 through A9 give the calculated effective indirect tax rates for private consumption, investment demand and government demand.

We have added foreign tourists' expenditures to exports. This may seem like a straightforward thing to do, but it entails a contradiction to the principle mentioned above that there are no indirect taxes on exports. Because part of these "enlarged" exports are now in fact consumed within the domestic economy, this part is also fully subject to the domestic excise as well as the value added tax.

Government purchases in 1976 were exempt from value added tax, so we have set  $tv^{gv}$  equal to zero. In principle, value added taxes on investment purchases are deductible from value added tax liabilities, but because some of the firms are not subject to the value added tax in the first place the data show a significant amount of value added tax being paid on investment purchases. This treated just like all other value added tax payments but for obvious reasons the resulting effective tax rates are much lower for investment than for consumption.

A further adjustment was made regarding inventory investment. Since there is no scope within our model for inventory investment (inventory behavior is simply not explained by our model), we have decided to distribute these flows across private consumption, government consumption, and exports within every sector. We have not included fixed capital formation because inventories clearly do not add to fixed capital.

We now calculate the values of total outputs as the row sums of the matrix of domestic intermediates plus all final demands for domestic commodities, all net of indirect taxes (at producers' prices). Sectoral value added is then calculated residually by deducting the column sums of the matrices of imported and domestic intermediates, *inclusive* of indirect taxes.<sup>18</sup> Finally, gross wages paid to employed labor plus indirect taxes on labor use<sup>19</sup> are deducted from this value added figure to obtain the user cost of physical capital installed in each sector.

Denoting the benchmark figure net of indirect commodity taxes by superscript 0, the procedure can be summarized by figure 2, which already makes use of the unit convention underlying our calibration: Units are chosen such that market prices for all goods as well as for labor are equal to unity. I.e., we have  $p_i^{h,0} = p_i^{m,0} = 1$  for all  $i$ , and  $w^0 = 1$  as well.  $p_i^m$  remains equal to 1

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<sup>17</sup>A fully detailed description of this procedure can be obtained upon request.

<sup>18</sup>Indirect taxes paid on intermediate products used in production are part of the costs that sum up to the value of output at producers' prices.

<sup>19</sup>These are employer contributions to social security, and wage dependent indirect taxes.

throughout all counterfactual calculations because we assume a small country. A square bracket indicates a square matrix, and  $uc_j^0$  denotes the benchmark user cost of capital (see below).

From the national accounts statistics we took aggregate figures on social security tax and income tax paid by private households as well as taxes paid by enterprises (comprising corporate income tax, business tax and property tax). Since there is no information whatsoever on the sectoral breakdown of the latter, we have decided to add this tax category to the income tax bill (see also the remarks made above regarding our definition of the intertemporal decision problem for firm behavior). An aggregate figure for government transfer to private households was similarly taken from the national accounts statistics, as was income accruing to private households and the government from property and enterprise. The latter was treated in total as benchmark dividends (gross of income tax) received by households.

## 6.2 Elasticities

For a calibration of the model we need information on four types of elasticities, and we follow common practice in using extraneous information on all of these.

Guided by empirical work on intertemporal consumption patterns we have set  $\gamma$ , the intertemporal elasticity of substitution for full consumption, equal to 0.7.

The second type of elasticity we need to know is the sectoral elasticity of substitution between labor and physical capital in the production of the value added product. In line with Kohler (1991), we have taken our elasticities from the compilations by Mansur & Whalley (1984), Harrison (1986), and Deardorff & Stern (1986). We have experimented with two sets of elasticities, one on the lower end and the other one on the higher end, and we finally used the lower elasticity values. Table A6 gives the values used in addition to the components of value added.

Another set of elasticities on which we take extraneous information relates to the substitution between imports and domestic goods. We use five different sources of information: Harrison, Rutherford & Wooton (1991), Shiells, Deardorff & Stern (1986), Deardorff & Stern (1986), Lächler (1985), and Harris (1986). Table A4 gives the elasticity values reported by these studies, whereby a zero entry in the table should be interpreted as no value being given on that sector in the respective source. The final column gives the elasticity value used for the present model which is obtained as follows. In view of the similarity between the Austrian and the German economies, the elasticity obtained by Lächler (table 5) is preferred if it is statistically significant. In all other cases we take an unweighted average of the different values given by the various

Figure 2: Overview of benchmark data construction

$$\begin{array}{c}
 \boxed{\left[ \bar{q}_{ij}^{h,0} \right]} + \boxed{\bar{c}_i^{h,0}} + \boxed{g\bar{v}_i^{h,0}} + \boxed{i\bar{n}_i^{h,0}} + \boxed{\bar{x}_i^0} = \boxed{\bar{y}_i^0} \\
 + \\
 \boxed{\left[ \bar{q}_{ij}^{m,0} \right]} + \boxed{\bar{c}_i^{m,0}} + \boxed{g\bar{v}_i^{m,0}} + \boxed{i\bar{n}_i^{m,0}} = \boxed{\bar{m}_i^0} \\
 + \\
 \boxed{\begin{array}{l} (t\bar{x}_j^{q,h})' \left[ \bar{q}_{ij}^{h,0} \right] + \\ (t\bar{x}_j^{q,m} + \\ t\bar{m}_j^q)' \left[ \bar{q}_{ij}^{m,0} \right] \end{array}} \\
 + \\
 \boxed{(tl_j \bar{l}_j^{d,0})'} \\
 + \\
 \boxed{(\bar{l}_j^{d,0})'} \\
 + \\
 \boxed{\begin{array}{l} (\bar{p}_j^0 f_k(l_j^{d,0}, k_j^0) k_j^0)' \\ \equiv uc_j^0 k_j^0 \end{array}} \\
 = \\
 \boxed{(\bar{y}_j^0)'}
 \end{array}$$

sources. For the services sectors (25 – 30) we arbitrarily use a value of 0.1 on the grounds that we would expect the elasticity to be „rather low“ in these cases. The value for sector 31 is immaterial since there are no imports in this sector. Finally, for our computational model, the elasticities so obtained for the 31 sector classification are aggregated to 19 sectors using total imports as weights.

The elasticity of substitution between imported and home goods is closely related to the price elasticity of import demand. Some authors use the convention of equating the negative of the substitution elasticity to the own price elasticity of import demand [see for instance Lächler (1985) and Harrison, Rutherford & Wooton (1991)]. Others, such as Shiells, Deardorff & Stern (1986) relate the elasticity of substitution to the cross price elasticity of demand for the imported good. We use these three sources for extraneous information on the price elasticities of export demand (see table A5 of the appendix). We take the german values reported by Lächler to be representative for the price elasticities of demand for Austrian exports to Europe and the US elasticities reported by Shiells et al. to be representative for exports to non-European countries, and we use a weighted average of these two values for every sector, with regional shares for merchandise exports serving as weights. If any one of the two sources reports a missing or positive value, the corresponding value is taken from Harrison et al., and where no information was available at all we arbitrarily choose a value of 1.5.

We are well aware of the fact that the above procedure of assigning parameter values to factor substitution and trade elasticities is very problematical. Obtaining more reliable, authentic information for the Austrian economy to which the model is calibrated must indeed be one of the most important points on the agenda for future research to improve on the present situation. For now, the crucial question really seems to be whether using extraneous information as indicated above is any better than just using random numbers within a “meaningful” interval. Without being able to give any rigorous justification for our own judgement, we nevertheless feel that the answer to this question is affirmative.

### 6.3 Calibration

The model is calibrated such that  $\sum_{j=1}^n l_j^{d,0} = l^{s,0}$ . But since  $l^s$  is labor supply per capita it would have to be somewhere between zero and one. Hence, all data have to be scaled down to a per capita basis. However, we chose a somewhat modified “per capita” basis for calibration because we don’t want the numbers to become too small. Instead of a true per capita basis

we decided to scale the whole data set down to a total benchmark labor supply of  $l^{s,0} = 100$ . We (arbitrarily) assume that the benchmark labor supply amounts to a use of 60 percent of total time available:  $L^{s,0} = 0.6 \cdot N^0$ . This implies a transformed “per capita population size” of  $n^0 = 100/0.6$  and, assuming labor market equilibrium for the benchmark situation, the scaling factor by which we divide all data is  $(\sum_{j=1}^n l_j^{d,0})/100$ . Notice that with this normalization  $h^0$  becomes  $(n^0 - l^{s,0})$  with  $l^{s,0} = 100$ .

As regards prices, we have already mentioned that all market prices, including the wage rate, are taken to be equal to one by an appropriate choice of units. We next apply the effective tax rates for all indirect commodity taxes and all categories of demand to calculate gross commodity prices, and we calibrate all remaining parameters of the aggregates mentioned above such that the quantities shown in figure 2 above will result from these gross prices under optimizing behavior. For the specific functional forms and the parameter notation, see table A1 of the appendix.

We will now demonstrate the procedure for the aggregate capital good in some detail, other parameters are calibrated analogously. We know from table A1 of the appendix that the capital good is a Cobb–Douglas aggregate of sectoral quantities that are themselves CES aggregates of imported and home produced goods. From our data set we have  $in_i^{h,0}$  and  $in_i^{m,0}$  as well as  $p_i^{in,h,0} = 1 + tv_i^{in,h} + tx_i^{in,h}$  and  $p_i^{in,m,0} = 1 + tv_i^{in,m} + tx_i^{in,m} + tm_i^{in}$ . If the sectoral quantity aggregate  $in_i$  is “produced” at minimum cost, we have from the corresponding first order conditions that

$$\frac{p_i^{in,h,0}}{p_i^{in,m,0}} = \frac{(1 - \kappa_i^m) (in_i^{h,0})^{-1/\sigma_i^m}}{\kappa_i^m (in_i^{m,0})^{-1/\sigma_i^m}}. \quad (50)$$

This equation can be solved for the share parameter  $\kappa_i^m$  as follows:

$$\kappa_i^m = \left[ 1 + p_i^{in,h,0} (in_i^{h,0})^{1/\sigma_i^m} / p_i^{in,m,0} (in_i^{m,0})^{1/\sigma_i^m} \right]^{-1}. \quad (51)$$

Notice that  $\kappa_i^m = 0$  if  $in_i^{m,0} = 0$ . Now that we know  $\kappa_i^m$ , we can also calculate the benchmark price index  $p_i^{in,0}$  associated with the aggregate  $in_i$ . The precise formula can be taken from table A1 of the appendix and need not be reproduced here. As a final step,  $in_i^0$ , the benchmark quantity of the sectoral aggregate, is obtained as

$$in_i^0 = \frac{in_i^{m,0} \cdot p_i^{in,m,0} + in_i^{h,0} \cdot p_i^{in,h,0}}{p_i^{in,0}}. \quad (52)$$

This completes calibration at the bottom level of aggregation, and we can now proceed to the top level. This is very easy since Cobb–Douglas implies constant expenditure shares:

$$\kappa_i = \frac{p_i^{in,0} \cdot in_i^0}{\sum_{i=1}^n p_i^{in,0} \cdot in_i^0}. \quad (53)$$

The price of the aggregate capital good is then

$$p^{in,0} = \prod_{i=1}^n \left( \frac{\kappa_i}{p_i^{in,0}} \right)^{-\kappa_i} \quad (54)$$

This completes calibration of the parameters pertaining to investment demand (for results see table A8 of the appendix).

Since other parameters are obtained in a perfectly analogous way, a similarly detailed description of the procedure can be omitted. For results on private consumption and government demand, see tables A7 and A9 of the appendix. What is perhaps worth reiterating is that we allow the share parameters of the aggregates  $q_{ji}(\cdot)$  to vary both between sectors of origin and sectors of use.

Having determined the benchmark quantities  $q_{ji}^0$  in an analogous way, we next calibrate the parameters of the production function as

$$a_{ji} = \frac{q_{ji}^0}{y_i^0} \quad \text{and} \quad (55)$$

$$a_{0i} = \frac{\bar{p}_i^0 f_i^0}{y_i^0}. \quad (56)$$

Notice that this implies unitary prices for all value added products in the benchmark equilibrium,  $\bar{p}_i^0 = 1$  for all  $i$ , because  $a_{0i}$  is, of course, a ratio of *quantities*. This is ensured by an appropriate calibration of the scale parameter of the value added production function  $f_i(\cdot)$  (see below).

The above procedure implies a certain aggregate demand for the capital good for the benchmark equilibrium. The next step is to ensure that this is consistent with a steady state. This can be done by an appropriate calibration of certain intertemporal parameters. As we have already mentioned above, this procedure does not uniquely determine all intertemporal parameters, so that we still have to rely on informed guesses. To see how we have proceeded, we first recall the first order conditions for the intertemporal firm problem (investment behavior). Omitting time indices to denote steady state values, we have from the Euler equation:

$$(r + \delta)q = (1 - ty)\tilde{p}(f_k - \Phi_k). \quad (57)$$



Substituting from the installation cost function and the first order condition for investment, we get the following expression:

$$\bar{p}_i f_k(k_i, l_i^d) = \frac{r + \delta_i}{1 - ty} [(1 - ty)\bar{p}_i \psi_i (\bar{g} + \delta_i) + (1 - e_i ty) p^{in}] - \bar{p}_i \psi_i (\bar{g} + \delta_i)^2. \quad (58)$$

The right hand side of the above equation is the steady state user cost of capital. Notice that although adjustment costs vanish in the steady state, the derivatives of  $\Phi(\cdot)$  do matter for the steady state user cost of capital.

Our data set gives sectoral values for  $\bar{p}_j^0 f_k(l_j^{d,0}, k_j^0) k_j^0 \equiv uc_j^0 k_j^0$  (see figure above). We write  $uc_i = uc_i(\delta_i, r, ty, \psi_i, x, n, e_i, \bar{p}_i, p^{in})$  for the user cost of capital (the right hand side of the above equation). Note that the price index  $p^{in}$  has already been calculated in the process of calibrating investment demand parameters, and that we calibrate the scale parameter of  $f_i(\cdot)$  such that  $\bar{p}_i$  is equal to 1 in the benchmark equilibrium. Suppose we knew all the remaining parameters of  $uc_i(\cdot)$ . We could then calibrate the benchmark capital stocks as

$$k_i^0(\delta_i, r, ty, \psi_i, x, n, e_i, \bar{p}_i^0, p^{in,0}) = \frac{\bar{p}_j^0 f_k(l_j^{d,0}, k_j^0) k_j^0}{uc_i(\delta_i, r, ty, \psi_i, x, n, e_i, \bar{p}_i^0, p^{in,0})}. \quad (59)$$

For the benchmark equilibrium to be a steady state equilibrium, sectoral investment demands would have to be  $(\bar{g} + \delta)k_i^0$ . But we have already calibrated total investment demand above. Hence, we have two seemingly independent approaches to determine total demand for the investment aggregate. These can be made mutually consistent by an appropriate choice of the the parameters  $\delta_i, r, ty, \psi_i, x, n$ , and  $e_i$  such that

$$\sum_{i=1}^n (\bar{g} + \delta_i) k_i^0(\delta_i, r, ty, \psi_i, x, n, e_i, \bar{p}_i^0, p^{in,0}) = \sum_{i=1}^n p_i^{in,0} i n_i^0 / p^{in,0} \quad (60)$$

Seen from the present stage of our calibration exercise, this is a nonlinear equation in 7 unknowns. This leaves us with six degrees of freedom which we have used to more or less arbitrarily specify what we thought are sensible values for all parameters except  $x$  which we calibrate, given these other choices, to fulfil the above condition. Table A10 of the appendix gives the results obtained. Little more than intuition can be invoked to justify these parameter choices. Notice, however, that  $g < r$ . This is important for the calculation of steady state stocks of assets from flow balances carried out below. As regards the tax rate, it must be emphasized that it only determines part of the tax system in our model. The second part is the tax deduction value  $u$ , which we calibrate, given our choice of  $ty$ , as described below.

We can now proceed to calibrate the share parameters of the sectoral value added productions functions,  $\eta_i$ , as follows. Our unit convention allows the indirect tax rate on labor,  $tl_i$ , to be

calculated directly from the data set, and this leads to a benchmark value for the gross wage rate  $w_i^{g,0} = 1 + tl_i$ . Applying the procedure explained above, we obtain for the share parameter  $\eta_i$ :

$$\eta_i = \left[ 1 + w_i^{g,0} \left( l_i^{d,0} \right)^{1/\mu_i} / uc_i^0 \left( k_i^0 \right)^{1/\mu_i} \right]^{-1}. \quad (61)$$

Since we have treated the total value added figures of our benchmark data set as quantities of value added, we now have to specify the remaining parameter of the value added production function,  $\phi_i$ , such that the quantity of the value added product is equal to this value added figure:

$$\phi_i = \left( \bar{p}_j^0 f_j^0 \right) \left[ \eta_i l_i^{d,0(\mu_i-1)/\mu_i} + (1 - \eta_i) k_i^{0(\mu_i-1)/\mu_i} \right]^{-\mu_i/(\mu_i-1)}. \quad (62)$$

Calibrating the share parameters pertaining to consumption demand at the lower levels of aggregation follows the above procedure. A brief comment regarding the share parameter of the full consumption aggregate  $v(\cdot)$  is perhaps warranted. Lower level calibration will yield a quantity  $c^0$  and an associated price index  $p^{c,0}$ . The other part of the aggregate is leisure, which was defined to be  $(1 - l^s)$  *per capita* in the model presentation. But notice that we have chosen a modified “per capita” basis for calibration leading to a benchmark value for leisure equal to  $w^{n,0}(n^0 - \sum_{i=1}^n l_i^{d,0})$ , where  $w^{n,0}$  is derived from an aggregate social security tax figure, utilizing the unit convention, plus the specified income tax rate (see above). Accordingly, the share parameter is (see table A10 for its value):

$$\alpha = p^{c,0} c^0 \left[ p^{c,0} c^0 + w^{n,0} \left( n^0 - \sum_{i=1}^n l_i^{d,0} \right) \right]^{-1}. \quad (63)$$

Finally, we need to calibrate the scale parameters of the export demand equations from the benchmark export values and the corresponding price elasticities (see above). Again, we use the unit convention to derive effective indirect tax rates.<sup>20</sup> The scale parameters are:

$$\bar{x}_i = x_i^0 / \left( p_i^{h,x,0} \right)^{\theta_i}, \quad (64)$$

where the exchange rate variable has been set equal to one according to our previous remarks on the role that the exchange rate plays in the temporary equilibrium.

Calibration is now completed by calculating the benchmark primary balances for the foreign sector and the government sector and deriving the implicit steady state values of the corresponding assets. The results can be found in tables A11 through A15 of the appendix which

<sup>20</sup>See the above explanation for the appearance of indirect taxes on exports when trade flows have, in fact, been assumed to be treated according to the destination principle.

present all primary income accounts, with primary balances (if any) being carried over into separate accounts of asset-related flows. As we have detailed above, there are three types of assets constituting financial wealth and all financial wealth is held by households. Accordingly, it must now be possible to consolidate the flows relating to government debt, firm values and foreign debt with the primary household balance.

Starting with the government sector (table A12), we must note that income tax includes tax on interest income generated by government debt. This must be deducted from the income tax bill to obtain the primary government balance which can then be used to calibrate benchmark government debt from the equation of motion (6) by letting  $d_t^g = d_{t-1}^g = d^{g,0}$ :

$$d^{g,0} = \frac{1 + \bar{g}}{r - \bar{g}} b^{g,0} \left[ 1 + \frac{1 + \bar{g}}{r - \bar{g}} ty \cdot i \right]^{-1}. \quad (65)$$

If debt per efficiency unit remains constant in the steady state, new debt must be issued in every period if  $\bar{g} < 0$ . This shows up in the residual of the asset-related flow account. In interpreting this residual, one has to be careful to express all items on a comparable „per-efficiency-unit basis“. Newly issued debt per efficiency unit of the initial period  $t - 1$  is  $\bar{g} \cdot d_t^g = r \cdot d_{t-1}^g - (1 + \bar{g}) \cdot b_t^g$ , whereas per efficiency units of the subsequent period  $t$  it is  $\bar{g} \cdot d_t^g / (1 + \bar{g}) = r \cdot d_{t-1}^g / (1 + \bar{g}) - b_t^g$ , where for both cases  $d_t^g = d_{t-1}^g = d^{g,0}$  in the steady state. The residual of the asset-related flow account is thus equal to new debt issue (per efficiency unit of the initial period  $t - 1$ ) plus  $\bar{g} \cdot b^{g,0}$ . These two terms must find corresponding entries in the household account of wealth related flows, where the former contributes to the increase in household financial wealth.

Analogous interpretations hold for equity related flows (table A13) and foreign debt related flows (table A14). Note that dividends is an equity related flow rather than a primary income flow to households. Moreover, since enterprise taxes have been lumped together with the personal income tax (see above), the profit-tax is treated as primary income to households who, in turn, pay all direct taxes. As regards foreign sector balance, we assume that existing foreign debt is serviced at the given net interest rate  $r$ .

We may finally note that steady state financial wealth increases by  $\bar{g}(d^{g,0} + v^0 + d^{f,0}) = 6.70$ , measured again in efficiency units of time  $t - 1$ .

There is only one final step remaining, which is calculating the benchmark value of income tax deduction,  $u$ , such that the benchmark value of the direct tax bill plus the benchmark value of the tax base is consistent with the marginal tax rate of  $ty = 0.3$  as specified above (see table A10). These two values completely specify the progressive income tax schedule of our model economy.

## 7 Final Remarks

The model presented above was primarily motivated against the background of trade protection and/or trade liberalization issues and certain shortcomings of “first generation” CGE models with which these issues have traditionally been addressed. Accordingly, we close this presentation with a brief indication of the kind of simulation exercise that we plan to carry out with our model.

Empirical studies on the economic effects of Austrian tariff protection (or its removal) are relatively few in number. Breuss & Tesche (1991) simulate certain kinds of tariff liberalization (including preferential trading arrangements) using a 7 sector, static, single country model. Kohler (1991a) uses a static, completely production oriented, specific-factors model comprising 48 sectors to analyse pre- and post-Tokyo-round tariff protection, and Kohler (1991b) uses the well-known multi-country model developed by Deardorff & Stern (1986) (the so-called Michigan Model) to investigate how the Austrian economy was affected by the multilateral tariff reductions of the Tokyo-round and might be affected by certain scenarios of further multilateral trade liberalization. The model presented here should constitute an improved basis for further simulations in that it is specifically geared towards the dynamic adjustment to such policy changes by focusing on sectoral capital formation (combined with sector-specificity of installed capital) and forward looking savings behavior. It thus allows to capture current account effects of trade policies which play a significant role in policy debates on these policies, as we have emphasized at the outset. These features were absent in the above mentioned studies on Austrian tariff protection. Yet, experience with other countries indicates that they might be very important [see Goulder & Eichengreen 1989b)]. Specifically, we plan to compare the effects of a tariff reduction of the order agreed upon in the Tokyo-round or a removal of post-Tokyo-round tariff protection, if introduced once and for all, with the effects of the same reduction being phased in over a period of several years, as was actually the case with the Tokyo-round.<sup>21</sup> It should also be very interesting to see what difference it makes, for a given policy change, whether the simulation model used incorporates intertemporal decision making or not. These are issues that we plan to take up in due course using the model that we have presented here.

We are well aware of the fact that there is ample scope for improvement of our model. For instance, analysing scenarios of multilateral tariff reductions requires more model structure regarding the “rest of the world” than the present version of our model provides. The same holds

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<sup>21</sup>The Tokyo-round of the GATT was concluded in 1979, and the tariff cuts agreed upon were phased in over 7 years beginning 1980.

true for preferential trading arrangements which presently appear to command more interest than the traditional GATT principle of multilateral trade liberalization. In addition, there is a general presumption that non-tariff trade barriers are at least as important, quantitatively, as are tariffs. Incorporating these requires more empirical information than we presently have. Needless to say that there are also several other shortcomings on the data side. It would, for instance, be highly desirable to use sector-specific information on the commodity composition of physical capital, and on capital decay as well as capital installation costs, not to mention the desirability of a lower level of aggregation.

Notwithstanding future improvements on the model structure as well as the available data, the present paper should serve as a convenient source of reference for subsequent work. It is to be hoped that the omission of some of the details presented here will make future reports somewhat easier to digest.

**Table A.1: Commodity aggregates and prices on the demand side: specific functional forms**

	Quantity aggregates	Prices	Demand functions
<i>Consumption</i>			
<i>Aggregate</i>	$c = \prod_{i=1}^n c_i^{\xi_i}, \sum_{i=1}^n \xi_i = 1$	$p^c = \prod_{i=1}^n (p_i^c / \xi_i)^{\xi_i}$	$c_i = (\xi_i / p_i^c) p^c c$
<i>Sectoral</i>	$c_i = \left[ \xi_i^m c_i^m [(\sigma_i^m - 1) / \sigma_i^m] + (1 - \xi_i^m) c_i^d [(\sigma_i^m - 1) / \sigma_i^m] \right]^{\frac{\sigma_i^m}{\sigma_i^m - 1}}$	$p_i^c = \left[ \xi_i^m \sigma_i^m p_i^{c,m(1-\sigma_i^m)} + (1 - \xi_i^m) \sigma_i^m p_i^{c,h(1-\sigma_i^m)} \right]^{\frac{1}{1-\sigma_i^m}}$	$c_i^m = \left[ \xi_i^m p_i^c / p_i^{c,m} \right]^{\sigma_i^m} c_i$ $c_i^h = \left[ (1 - \xi_i^m) p_i^c / p_i^{c,h} \right]^{\sigma_i^m} c_i$
<i>Investment</i>			
<i>Aggregate</i>	$in = \prod_{i=1}^n in_i^{\kappa_i}, \sum_{i=1}^n \kappa_i = 1$	$p^{in} = \prod_{i=1}^n (p_i^{in} / \kappa_i)^{\kappa_i}$	$in_i = (\kappa_i / p_i^{in}) p^{in} in$
<i>Sectoral</i>	$in_i = \left[ \kappa_i^m in_i^m [(\sigma_i^m - 1) / \sigma_i^m] + (1 - \kappa_i^m) in_i^h [(\sigma_i^m - 1) / \sigma_i^m] \right]^{\frac{\sigma_i^m}{\sigma_i^m - 1}}$	$p_i^{in} = \left[ \kappa_i^m \sigma_i^m p_i^{in,m(1-\sigma_i^m)} + (1 - \kappa_i^m) \sigma_i^m p_i^{in,h(1-\sigma_i^m)} \right]^{\frac{1}{1-\sigma_i^m}}$	$in_i^m = \left[ \kappa_i^m p_i^{in} / p_i^{in,m} \right]^{\sigma_i^m} in_i$ $in_i^h = \left[ (1 - \kappa_i^m) p_i^{in} / p_i^{in,h} \right]^{\sigma_i^m} in_i$
<i>Government</i>			
<i>Aggregate</i>	$gv = \min \left\{ \frac{1}{\gamma_1} gv_1, \frac{1}{\gamma_2} gv_2, \dots, \frac{1}{\gamma_n} gv_n \right\}$	$p^{gv} = \sum_{i=1}^n p_i^{gv} \cdot \gamma_i$	$gv_i = \gamma_i gv$
<i>Sectoral</i>	$gv_i = \left[ \gamma_i^m gv_i^m [(\sigma_i^m - 1) / \sigma_i^m] + (1 - \gamma_i^m) gv_i^h [(\sigma_i^m - 1) / \sigma_i^m] \right]^{\frac{\sigma_i^m}{\sigma_i^m - 1}}$	$p_i^{gv} = \left[ \gamma_i^m \sigma_i^m p_i^{gv,m(1-\sigma_i^m)} + (1 - \gamma_i^m) \sigma_i^m p_i^{gv,h(1-\sigma_i^m)} \right]^{\frac{1}{1-\sigma_i^m}}$	$gv_i^m = \left[ \gamma_i^m p_i^{gv} / p_i^{gv,m} \right]^{\sigma_i^m} gv_i$ $gv_i^h = \left[ (1 - \gamma_i^m) p_i^{gv} / p_i^{gv,h} \right]^{\sigma_i^m} gv_i$

Table A2: Sector Classification and Concordance: 31 Sectors

No.	Sector	Shorthand	Concordance
1	Agriculture a. Forestry	Agr/For	1
2	Mining	Min/Quar	2
3	Petroleum	Petrol	8
4	Stones, Clay a. Cement	Stones	9
5	Glass	Glass	9
6	Foodstuff	Foodst	3
7	Tobacco	Tobacc	3
8	Textiles	Text	4
9	Clothing	Cloth	4
10	Leather and Shoes	Leath/Sh	4
11	Chemicals (excl. Petroleum)	Chem	7
12	Iron a. Steel Production	Iron/St	10
13	Machinery, Steel and Metal Constr.	Machin	11
14	Casting	Cast	10
15	Non-ferrous Metals	Nonferr	10
16	Iron a. Metal Products, Precision Mech.	MetProd	11
17	Electric Machinery	ElMach	11
18	Vehicles Constr. a. Repair	Vehic	11
19	Sawing	Sawing	5
20	Wood Processing	WoodPr	5
21	Paper Production	Paper	6
22	Paper Processing	PaperPr	6
23	Construction	Constr	13
24	Energy and Water Supply	En/Wat	12
25	Commerce	Comm	14
26	Transport a. Communication	Transp	16
27	Banking a. Insurance	Bank/In	17
28	Hotels a. Restaurants	Hot/Cat	15
29	Other Services	Oth/Ser	18
30	Real Estate Services	RealEst	17
31	Public Services	Public	19

**Table A3: Sector Classification and Concordance: 19 Sectors**

No.	Sector	Shorthand	Concordance
1	Agriculture a. Forestry	Agr/For	1
2	Mining	Min/Quar	2
3	Foodstuff	Food	6,7
4	Textiles a. Clothing	Tex/Clot	8,9,10
5	Wood a. Wood Processing	Wood	19,20
6	Paper a. Paper Processing	Paper	21,22
7	Chemicals (excl. Petr.)	Chemic	11
8	Petroleum	Petrol	3
9	Non-ferrous Minerals	Nonferr	4,5
10	Basic Metals	MetProd	12,14,15
11	Metal Processing	MetProc	13,16,17,18
12	Energy and Water Supply	Energy	24
13	Construction	Constr	23
14	Commerce	Trade	25
15	Hotels a. Restaurants	Hot/Cat	28
16	Transport a. Communication	Trans	26
17	Banking, Insurance a. Real Estate	RealEst	27,30
18	Other Services	OthSer	29
19	Public Services	Public	31



Table A4: Imported-home goods substitution elasticities ( $\sigma_i^m$ )

Sector	Harrison et al.	Shiells et al.	Deardorff & Stern	Laechler	Harris	Present
1 Agr/For	2.000	0.000	1.139	0.000	1.100	1.413
2 Min/Quar	0.500	0.000	0.000	0.053	1.100	0.551
3 Petrol	2.000	-0.340	2.359	0.112	1.100	1.046
4 Stones	1.300	2.110	2.784	-0.765	2.480	1.582
5 Glass	1.300	4.290	1.628	0.932	0.000	1.630
6 Foodst	0.500	0.460	1.133	0.797	1.280	0.797
7 Tobacc	0.000	-16.190	1.133	0.797	1.100	0.797
8 Text	2.000	2.580	1.147	1.361	1.100	1.361
9 Cloth	2.000	1.620	4.269	-0.465	4.070	2.299
10 Leath/Sh	6.800	3.150	1.810	0.998	1.710	0.998
11 Chem	2.000	9.850	2.612	1.065	2.200	1.065
12 Iron/St	0.500	3.050	1.446	2.841	2.010	2.841
13 Machin	0.500	3.340	1.022	-0.469	1.100	1.099
14 Cast	0.500	3.050	1.446	0.000	0.000	0.999
15 Nonferr	0.000	0.810	1.430	1.218	0.000	1.218
16 MetProd	2.000	1.540	3.674	4.911	4.220	4.911
17 ElMach	1.300	7.460	2.110	1.362	1.100	1.362
18 Vehic	0.000	2.010	3.585	0.818	4.840	0.818
19 Sawing	1.900	0.260	1.757	0.787	1.100	0.787
20 WoodPr	1.900	12.130	3.096	1.014	3.110	1.014
21 Paper	1.100	1.800	1.585	0.063	1.310	1.172
22 PaperPr	1.100	2.720	3.013	2.191	3.230	2.191
23 Constr	0.000	0.000	0.000	0.000	1.100	1.100
24 En/Wat	0.340	0.000	0.000	0.000	0.100	0.440
25 Comm	0.000	0.000	0.000	0.000	0.000	0.100
26 Transp	2.000	0.000	0.000	0.000	0.100	0.100
27 Bank/In	0.000	0.000	0.000	0.000	0.000	0.100
28 Hot/Cat	0.000	0.000	0.000	0.000	0.000	0.100
29 Oth/Ser	0.000	0.000	0.000	0.000	0.000	0.100
30 RealEst	0.000	0.000	0.000	0.000	0.000	0.100
31 Public	0.000	0.000	0.000	0.000	0.000	0.100

Table A5: Export demand elasticities ( $\theta_i$ )

Sector	Harrison et al.	Shiells et al.	Laechler	Present
1 Agr/For	-2.000	0.000	0.000	-2.000
2 Min/Quar	-0.500	0.000	-0.053	-0.155
3 Petrol	-2.000	-0.790	-0.112	-0.135
4 Stones	-1.300	-1.370	0.765	-1.311
5 Glass	-1.300	-2.860	-0.932	-1.628
6 Foodst	-0.500	-0.700	-0.797	-0.769
7 Tobacc	0.000	-7.570	-0.797	-1.144
8 Text	-2.000	-1.410	-1.361	-1.374
9 Cloth	-2.000	-0.520	0.465	-1.761
10 Leath/Sh	-6.800	-2.010	-0.998	-1.333
11 Chem	-2.000	-6.820	-1.065	-2.741
12 Iron/St	-0.500	-2.280	-2.841	-2.756
13 Machin	-0.500	-0.880	0.469	-0.651
14 Cast	-0.500	-2.280	0.000	-0.927
15 Nonferr	0.000	-0.670	-1.218	-1.094
16 MetProd	-2.000	-0.940	-4.911	-3.760
17 ElMach	-1.300	-3.080	-1.362	-1.895
18 Vehic	0.000	-1.240	-0.818	-0.946
19 Sawing	-1.900	-1.320	-0.787	-0.854
20 WoodPr	-1.900	-9.560	-1.014	-2.861
21 Paper	-1.100	-1.800	-0.063	-0.464
22 PaperPr	-1.100	-1.460	-2.191	-2.023
23 Constr	0.000	0.000	0.000	-1.500
24 En/Wat	-0.340	0.000	0.000	-0.340
25 Comm	0.000	0.000	0.000	-1.500
26 Transp	-2.000	0.000	0.000	-1.500
27 Bank/In	0.000	0.000	0.000	-1.500
28 Hot/Cat	0.000	0.000	0.000	-1.500
29 Oth/Ser	0.000	0.000	0.000	-1.500
30 RealEst	0.000	0.000	0.000	-1.500
31 Public	0.000	0.000	0.000	-1.500

**Table A6: Value added components and and primary factor substitution elasticities**

Sector	wage bill	ind. wage tax	capital income	value added	$k_i^0$	$\mu_i$
1 Agr/For	1.245	0.161	9.174	10.579	6.123	0.607
2 Min/Quar	0.802	0.170	0.239	1.211	0.160	0.500
3 Food	4.035	0.844	1.890	6.769	1.262	0.775
4 Tex/Clot	3.536	0.782	0.920	5.238	0.614	0.983
5 Wood	2.587	0.555	1.207	4.349	0.806	0.851
6 Paper	2.596	0.546	1.068	4.210	0.713	0.868
7 Chemic	3.166	0.662	1.879	5.708	1.255	0.827
8 Petrol	0.535	0.107	0.297	0.939	0.198	0.500
9 Nonferr	2.112	0.462	1.342	3.916	0.896	0.992
10 MetProd	3.564	0.780	1.084	5.428	0.723	1.091
11 MetProc	12.271	2.628	6.504	21.403	4.341	0.581
12 Energy	2.252	0.450	3.759	6.461	2.509	0.360
13 Constr	9.105	2.092	6.948	18.145	4.637	0.324
14 Trade	11.919	2.280	13.383	27.581	8.933	0.970
15 Hot/Cat	2.241	0.524	2.739	5.504	1.828	0.970
16 Trans	6.708	2.072	1.671	10.452	1.116	0.970
17 RealEst	4.877	0.850	11.879	17.606	7.929	0.970
18 OthSer	5.983	1.055	4.022	11.060	2.685	0.970
19 Public	20.467	2.112	5.573	28.152	3.720	0.970
20 Total (A)	100.000	19.131	75.579	194.710	2.655	0.794

**Table A7: Effective indirect tax rates and share parameters ( $\xi_i$ ) for private consumption**

Sector	VAT (dom.)	VAT (imp.)	Excise (dom.)	Excise (imp.)	Tariff	$\xi_i^m$	$\xi_i$
1 Agr/For	0.102	0.104	0.039	0.040	0.082	0.348	0.062
2 Min/Quar	0.088	0.102	0.000	0.000	0.072	0.655	0.004
3 Food	0.113	0.095	0.132	0.043	0.074	0.050	0.165
4 Tex/Clot	0.177	0.182	0.000	0.000	0.068	0.446	0.100
5 Wood	0.168	0.175	0.000	0.000	0.032	0.351	0.032
6 Paper	0.130	0.121	0.000	0.000	0.025	0.527	0.015
7 Chemic	0.132	0.140	0.000	0.000	0.046	0.558	0.025
8 Petrol	0.209	0.216	0.667	0.714	0.153	0.167	0.041
9 Nonferr	0.149	0.175	0.000	0.000	0.059	0.474	0.004
10 MetProd	0.054	0.145	0.000	0.000	0.010	0.587	0.007
11 MetProc	0.181	0.172	0.000	0.000	0.033	0.542	0.109
12 Energy	0.080	0.080	0.000	0.000	0.000	0.000	0.025
13 Constr	0.096	0.000	0.000	0.000	0.000	0.000	0.014
14 Trade	0.136	0.000	0.000	0.000	0.000	0.000	0.165
15 Hot/Cat	0.125	0.000	0.071	0.000	0.000	0.000	0.038
16 Trans	0.057	0.000	0.000	0.000	0.000	0.000	0.039
17 RealEst	0.071	0.000	0.021	0.000	0.000	0.000	0.084
18 OthSer	0.121	0.121	0.000	0.000	0.000	0.000	0.056
19 Public	0.067	0.000	0.000	0.000	0.000	0.000	0.016

**Table A8: Effective indirect tax rates and share parameters ( $\kappa_i$ ) for investment demand**

Sector	VAT (dom.)	VAT (imp.)	Excise (dom.)	Excise (imp.)	Tariff	$\kappa_i^m$	$\kappa_i$
1 Agr/For	0.040	0.041	0.001	0.001	0.092	0.170	0.006
2 Min/Quar	0.040	0.000	0.000	0.000	0.000	0.000	0.001
3 Food	0.036	0.000	0.001	0.000	0.000	0.000	0.000
4 Tex/Clot	0.073	0.073	0.000	0.000	0.066	0.131	0.003
5 Wood	0.070	0.072	0.000	0.000	0.037	0.026	0.045
6 Paper	0.066	0.000	0.000	0.000	0.000	0.000	0.001
7 Chemic	0.055	0.056	0.000	0.000	0.053	0.022	0.007
8 Petrol	0.054	0.055	0.065	0.066	0.111	0.133	0.000
9 Nonferr	0.072	0.073	0.000	0.000	0.044	0.026	0.028
10 MetProd	0.051	0.037	0.000	0.000	0.032	0.418	0.015
11 MetProc	0.072	0.072	0.000	0.000	0.026	0.560	0.314
12 Energy	0.031	0.000	0.000	0.000	0.000	0.000	0.017
13 Constr	0.038	0.000	0.000	0.000	0.000	0.000	0.456
14 Trade	0.054	0.000	0.000	0.000	0.000	0.000	0.065
15 Hot/Cat	0.046	0.000	0.001	0.000	0.000	0.000	0.001
16 Trans	0.022	0.000	0.000	0.000	0.000	0.000	0.017
17 RealEst	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18 OthSer	0.048	0.048	0.000	0.000	0.000	0.000	0.023
19 Public	0.026	0.000	0.000	0.000	0.000	0.000	0.002

**Table A9: Eff. indir. tax rates and share parameter for government demand**

Sector	Excise (dom.)	Excise (imp.)	Tariff	$\gamma_i^m$	$\gamma_i$
1 Agr/For	0.001	0.001	0.069	0.207	0.004
2 Min/Quar	0.000	0.000	0.062	0.263	0.002
3 Food	0.001	0.001	0.062	0.024	0.004
4 Tex/Clot	0.000	0.000	0.056	0.431	0.002
5 Wood	0.000	0.000	0.028	0.276	0.004
6 Paper	0.000	0.000	0.023	0.428	0.008
7 Chemic	0.000	0.000	0.040	0.498	0.020
8 Petrol	0.060	0.060	0.081	0.145	0.006
9 Nonferr	0.000	0.000	0.043	0.231	0.002
10 MetProd	0.000	0.000	0.024	0.314	0.003
11 MetProc	0.000	0.000	0.024	0.436	0.023
12 Energy	0.000	0.000	0.000	0.000	0.016
13 Constr	0.000	0.000	0.000	0.000	0.036
14 Trade	0.000	0.000	0.000	0.000	0.042
15 Hot/Cat	0.001	0.001	0.000	0.001	0.003
16 Trans	0.000	0.000	0.000	0.000	0.032
17 RealEst	0.031	0.000	0.000	0.000	0.020
18 OthSer	0.000	0.000	0.000	0.000	0.132
19 Public	0.000	0.000	0.000	0.000	0.640

Parameter	Value	Method
$\delta_i$	0.15000	specified (for all i)
$\psi_i$	0.80000	specified (for all i)
$r$	0.04000	specified
$e_i$	0.40000	specified (for all i)
$n$	0.01000	specified
$x$	0.02322	calibrated
$\rho$	0.00645	calibrated
$\beta$	0.99370	calibrated
$\gamma$	0.70000	specified
$\bar{g}$	0.03345	calculated
$ty$	0.30000	specified
$u$	63.97360	calibrated
$\alpha$	0.74823	calibrated

Expenditure		Revenue	
Domestic intermediates	129.02	Domestic intermediates	129.02
Taxes on dom. int.	0.98	Private consumption demand	85.18
Imported intermediates	35.21	Government purchases	37.00
Taxes on imp. int.	1.18	Investment demand	44.43
Wage bill	100.00	Export demand	65.46
Ind. wage tax	19.13		
Capital income	75.58		
<b>Total</b>	<b>361.10</b>	<b>Total</b>	<b>361.10</b>

Table A12: Government accounts			
Primary Income and Expenditure			
Expenditure		Revenue	
Domestic purchases	37.00	Indirect comm. taxes	26.61
Taxes on dom. purch.	0.04	Profit tax + income tax	27.14
Purchase of imports	2.00	Social security tax	11.99
Taxes on imp. purch.	0.07	Indirect wage tax	19.13
Transfers	39.99	Inc. tax on interest paid on gov. debt	-4.21
Primary government balance	1.56		
Total	80.66	Total	80.66
Debt related flows ( $d\bar{g}^0 = 245.70$ )			
Expenditure		Revenue	
Interest payments ( $i \cdot d\bar{g}^0$ )	14.04	Primary balance ( $b\bar{g}^0$ )	1.56
		Tax on interest ( $i \cdot ty \cdot d\bar{g}^0$ )	4.21
		$\bar{g} \cdot d\bar{g}^0$ (new debt) + $\bar{g} \cdot b\bar{g}^0$	8.27
Total	14.04	Total	14.04

Table A13: Enterprise accounts			
Primary Income and Expenditure			
Expenditure		Revenue	
Imported investment goods	10.45	Capital income	75.58
Taxes on imp. inv. goods	1.01		
Domestic investment goods	44.43		
Taxes on dom. inv. goods	2.12		
Profit tax	15.71		
Dividends	1.86		
Total	75.58	Total	75.58
Equity related flows ( $v^0 = 292.93$ )			
Expenditure		Revenue	
Return on equity ( $r \cdot v$ )	11.72	Dividends ( $\chi^0$ )	1.86
		$\bar{g} \cdot v^0$ (growth of firm values) + $\bar{g} \cdot \chi^0$	9.86
Total	11.72	Total	11.72

Table A14: Foreign sector accounts			
Primary Income and Expenditure			
Expenditure		Revenue	
Exports	65.46	Private consumption imports	18.25
Ind. tax on exports	2.59	Investment imports	10.45
		Government imports	2.00
		Imported intermediates	35.21
		Foreign sector balance	2.14
Total	68.05	Total	68.05
Foreign Debt related flows ( $d^{f,0} = -338.32$ )			
Expenditure		Revenue	
Foreign sector balance ( $b^{f,0}$ )	2.14	Interest payments ( $-r \cdot d^{f,0}$ )	13.53
$-\bar{g} \cdot d^{f,0}$ (Growth of for. debt) + $\bar{g} \cdot b^{f,0}$	11.39		
Total	13.53	Total	13.53

Table A15: Household accounts			
Primary Income and Expenditure			
Expenditure		Revenue	
Consumption of domestic goods	85.18	Wage income	100.00
Ind. tax on dom. cons.	14.45	Profit tax	15.71
Consumption of imported goods	18.25	Transfer income	39.99
Ind. tax on imp. cons.	4.19		
Social security payments	11.99		
Income tax + profit tax	27.14		
Tax on interest income on gov. debt	-4.21		
Primary household balance	-1.27		
Total	155.71	Total	155.71
Wealth related flows ( $a^0 = 200.31$ )			
Expenditure		Revenue	
Tax on interest ( $i \cdot ty \cdot d^{g,0}$ )	4.21	Interest payments ( $i \cdot d^{g,0}$ )	14.04
Interest paid on for. debt ( $r \cdot d^{f,0}$ )	13.53	Net return on equity ( $r \cdot v^0$ )	11.72
Primary balance	1.27	New foreign debt ( $\bar{g} \cdot d^{f,0}$ )	11.32
New government debt ( $\bar{g} \cdot d^{g,0}$ )	8.22	$\bar{g} \cdot b^{f,0}$	0.07
Growth of firm values ( $\bar{g} \cdot v^0$ )	9.80		
$\bar{g} \cdot b^{g,0}$	0.05		
$\bar{g} \cdot \chi^0$	0.06		
Total	37.15	Total	37.15

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**WORKSHOP ON**  
**ISSUES IN INTERNATIONAL ECONOMICS: QUESTIONS TO AND ANSWERS FROM**  
**COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS**

**JULY 8-9, 1991**  
**UNIVERSITY OF KONSTANZ**

**MONDAY, JULY 8, 1991**

10.00 Opening Address

Wolfgang Franz (Dean, University of Konstanz)

Bernd Genser (University of Konstanz)

"General Equilibrium Economics: Computation and Application"

John Whalley (University of Western Ontario)

**11.00 Session 1: International Taxation**

"Value-Added Tax Harmonization in the EC"

Wolfgang Wiegard/Hans Fehr/Christoph Rosenberg (University of Regensburg)

"Commodity Tax Reform under the Restricted Origin Principle"

Andreas Haufler (University of Konstanz)

**14.30 Session 2: Factor Supply**

"Simulation Models of Labour Supply"

Alan Duncan (Institute for Fiscal Studies, London)

"An Intertemporal General Equilibrium Model for Austria with Application to Foreign Trade"

Christian Keuschnigg (University of Bonn)/Wilhelm Kohler (University of Innsbruck)

**17.00 Session 3: Environment**

"CGE Modelling of International Public Goods: Air Quality and Global Warming"

John Piggott (University of New South Wales)

**TUESDAY, JULY 9, 1991**

**09.00 Session 4: Imperfect Competition and Growth**

"AGE Models in International Economics with Special Reference to Imperfect Competition and Increasing Returns to Scale"

Albert Schweinberger (University of Konstanz)

Growth and International Capital Movement: A Simulation Study

Karl-Josef Koch (University of Konstanz)

(presentation cancelled due to accident)

**10.45 Round Table: "The Payoff of Investment in CGE - Modelling"**

Chair: Bernd Genser

Introductory Statements:

John Chipman (University of Minnesota)

Friedrich Schneider (University of Linz)

Closing Address: Bernd Genser