Modelling Intertemporal General Equilibrium: An Application to Austrian Commercial Policy

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Abstract

We present a multi–sector CGE model with a rigorous "macro–closure", featuring forward looking investment and savings behavior within an intertemporal optimization framework. This allows the model to capture several of the intertemporal effects of commercial policy that have been stressed by recent literature on the current account adjustment to such policies. We argue that pursuing a simulation approach in addressing these issues is warranted by certain limitations and ambiguities of the analytical literature. In addition to presenting the details of the model structure, the paper addresses calibration issues relating to the intertemporal parameters. The model is calibrated to a 1976 data set for the Austrian economy. Finally, the paper features an application of the model to a simple tariff liberalization scenario.

Zusammenfassung

Das Papier stellt ein multisektorales, rechenbares Gleichgewichtsmodell mit einer in sich geschlossenen makroökonomischen Struktur dar. Das Investitions– und Sparverhalten wird aus einem vorausschauenden, intertemporalen Optimierungskalkül abgeleitet. Das Modell berücksichtigt daher die intertemporalen Auswirkungen der Handelspolitik, wie sie in der neueren Literatur über die dynamische Anpassung der Zahlungsbilanz diskutiert wurden. Die Beschränkungen der analytischen Modelle, welche einige uneindeutige Ergebnisse gezeitigt haben, legen einen Simulationsansatz nahe. Das Papier beschreibt die Erstellung einer mikroökonomisch konsistenten Datenbasis für das Jahr 1976, stellt im Detail die Modellstruktur dar und geht auf die Kalibrierung insbesondere der intertemporalen Parameter ein. Schließlich wird das Modell auf ein einfaches Szenario der Zolliberalisierung angewandt.

Contents

1 Introduction

Providing guidance on the likely positive and normative effects of distortionary policies continues to be among the prime objectives of economic analysis. In pursuing this objective, economists employ a wide variety of different models. For some purposes, highly stylized analytical models may be deemed appropriate, but for others it is desired to go beyond the confines of these models, and to forgo analytical tractability for the sake of incorporating institutional or sectoral detail. For this reason, an increasing number of researchers has started using large scale computable general equilibrium (CGE) models. In using such models for simulation purposes, one hopes to obtain useful information on qualitative and quantitative policy effects in cases where analytical models fail to yield definitive results.

In this paper, we present an intertemporal computable general equilibrium model which is calibrated to Austrian data, and we apply this model to commercial policy issues. The vast majority of CGE models developed so far are single period, static models. This creates an awkward problem, even in cases where the policy issues addressed do not, per se, appear to make the use of multi–period, dynamic models imperative. In calibrating these models, one inevitably encounters investment and savings flows for which, strictly speaking, there is no room in a single period model. Rational agents with a single period time horizon would simply never save nor invest. Because investment and savings are such important parts of the data sets to which CGE models are calibrated, the modellers usually shy away from simply ignoring them. As a result, static models usually treat savings and investment in a more or less ad hoc manner, including some sort of "macro–closure" whose purpose is to ensure the investment–savings identity in the counterfactual analysis. The "closure" problem arises because the presence of savings implies the existence of a store of value (some form of asset). Only if the model explicitly provides for an appropriate relative price mechanism for such assets will it be possible for independent savings and investment decisions to satisfy the fundamental identity. Otherwise the model is overdetermined [see Dewatripont and Michel (1987)]. Instead of incorporating such a price mechanism, static models are usually closed either by relaxing the independence of investment and savings decisions, by allowing some form of non–market–clearing, or by introducing a non–homogeneity into the system through fixing some nominal quantity, thus allowing changes in the price level to affect real variables. The problem with these "closure" rules is that there is hardly any a–priori argument that would allow one to choose among them. Yet, model behavior will be affected by this choice in a very fundamental way.[1]

As pointed out by Dewatripont and Michel (1987, p. 73), the choice of such a closure amounts to a statement as to "which relative prices matter and which do not". While it is conceivable that under some circumstances one or the other of the above mentioned "macro–closures" may in this sense be a reasonable approximation to reality, from a theoretic point of view it is no doubt more satisfactory to extend the behavioral paradigm (optimization) to the intertemporal side of the model, thereby explicitly introducing an intertemporal price structure. In addition to being consistent, such an enrichment of a CGE model will also expand its focus and the range of useful applications.

[1] Adelman and Robinson (1988) discuss alternative "macro–closure" rules and their distributional implications.

Consider, for instance, the current account effect. Many of the closure rules in effect preclude any current account effect of the policy in question. And even if they do, as in some of the non–homogeneity type of "closures", the current account (or trade balance) effects calculated in a counterfactual exercise can be questioned on the grounds that they are not subject to any intertemporal budget constraint. Neglecting current account effects of commercial policy, to take a very prominent candidate of CGE policy analysis, is in sharp contrast to the widespread notion that protection may favorably affect the current account, as witnessed by the fact that bad macroeconomics is usually bad news for trade liberalization [see Dornbusch and Frankel (1987)]. We argue that being able to consistently capture the current account adjustment of an economy should make the effort of constructing intertemporal CGE models worthwile. A related issue is that of adjustment costs. Policy makers often favor a gradual implementation of policy changes. This may be related to the idea, however vague it may be, that adjustment is costly and, therefore, a gradual implementation of a given policy change will set the economy on an adjustment path which is somehow preferable to the one generated by a once–and–for–all policy change. In static models, the question of adjustment costs is usually reduced to the choice of some exogenous degree of factor mobility, whereas in dynamic models adjustment costs can be, and almost always are, made an essential part of the story. Dynamic models allow the calculation of the adjustment paths following alternative ways of implementing a given policy change. Starting from a distorted situation, analytical models often yield rather limited information regarding preferred ways of policy implementation [see, in particular, Mussa (1986)] which certainly constitutes another important advantage of an intertemporal CGE model.

Another area where intertemporal models have a major advantage over single period models is welfare analysis. The desire to quantify welfare effects of certain distortionary policies was, indeed, among the prime motivations behind the CGE program from its very beginning. Yet, it is highly questionable that welfare may be meaningfully measured in a static CGE model incorporating investment and savings. If part of present period output is invested this amounts to a trade off between present and future welfare. Such intertemporal links are missing in a static model, whereas they are explicit in a dynamic model. This problem may not be of equal importance in all instances where static models are applied, but it is potentially troublesome even in cases where the policy in question is not directly oriented towards investment or savings, such as commercial policy. Our particular model additionally allows the computation of intergenerational welfare effects which have almost completely been ignored in all previous CGE models. For lack of space, however, we will not address welfare issues in this paper. They will be taken up in a subsequent paper.

If the essential contribution of intertemporal CGE models is to provide an adequate macroeconomic closure for disaggregate general equilibrium models, one could possibly question the necessity of having any disaggregate structure at all. Such an argument turns the issue on its head, however. The concern is not one of adding sectoral disaggregation to a macro model, but rather the opposite problem of how to adequately "macro–close" a disaggregate model, the use of which for certain purposes is widely accepted to start with. While it may be true that sectoral disaggregation is immaterial for some, maybe many, macro issues, the opposite is not true as we will, in fact, see in our application below. Disaggregate results *are* affected by whether or not a consistent macro closure has been employed, and a given macro–effect, such as for instance an expansionary effect on the capital stock, need not equally hold, even in its sign, for every individual sector.

Many of the policy oriented papers offer only extremely cursury overviews of the applied CGE models which makes it difficult to grasp the main economic forces at work. Furthermore, the reader usually is given only incomplete information regarding the choice of parameters which so importantly influence the numerical results. The prime motivation of the present paper is, therefore, to give a selfcontained presentation of our applied CGE model for Austria. Together with an extended separate appendix it should be possible to reconstruct the model. The appendix covers a detailed analysis of the household sector, a proof of Walras' law and additional information on calibration. It explains the computation of effective tax rates, provides an exhaustive list of parameter values such as elasticities of substitution and share parameters, and finally contains a complete list of variables. The appendix is available upon request. The remainder of the paper is organized as follows. Section 2 provides a general overview of the model structure. In section 3 we concentrate on the intertemporal aspects of our model, dealing mainly with aggregate quantities. Section 4 will then turn to sectoral disaggregation, and section 5 will characterize the equilibrium conditions, both temporary and steady state, as well as some aspects of our solution strategy. In section 6 we turn to the data set and to calibration methods, inasmuch as they go beyond the standard procedures familiar from static models. Section 7 presents an illustrative application of our model to the case of commercial policy, whereby we restrict ourselves to comparative steady state effects, leaving a more detailed counterfactual analysis to a separate paper. Finally, section 8 will close the paper with a few concluding remarks.

2 Overview of the Model Structure

We model an "almost small" open economy taking all import prices as given but facing downward sloping demand curves for its exports. Capital markets provide an important additional link to the world economy which is missing in many static models. The model economy faces a constant real interest rate in terms of imported goods, given exogenously from the rest of the world. It may purchase or sell any amounts of securities bearing this real interest rate on world markets. Net foreign assets, alongside domestic government debt and equity, also serve as a store of value, and we term the total amount of these assets held at any point in time financial wealth.[2] Appropriate arbitrage conditions ensure that households are in fact willing to hold all of these assets in their portfolios.

The economy is populated by an infinite number of overlapping generations facing lifetime uncertainty. Newly borne generations enter the economy without any financial wealth. Each generation is modelled by means of a dynastic family maximizing its expected lifetime utility subject to a dynamic budget constraint,

[2] Our model is close in spirit to the work of Goulder and Eichengreen (1989). Important differences, however, will become evident from the following general characterization.

and it does so by choosing an appropriate time profile of commodity consumption as well as leisure. The model thus features endogenous labor supply which constitutes an important channel for policy effects. Commodity consumption is derived from a multi-level utility nesting as is familiar from static models. The same holds for commodity demands generated by investment and government procurement. In addition to spending on goods, government enacts lump sum income transfers to households. It collects a variety of different taxes, including several commodity and factor taxes as well as a general income tax. Finally, it issues new bonds according to a prespecified path of government debt.

Firms have access to a linearly homogeneous technology and operate in a perfectly competitive environment. Production functions exhibit fixed input–output coefficients with respect to intermediate inputs and a value added product. The value added production function, in turn, allows for substitution between two primary inputs, labor and physical capital. The assumption of convex installation costs for new capital determines forward looking investment behavior in the spirit of the q–theory of investment. Investment is chosen to maximize the present value of the marginally induced cash flows. The installed capital good is identical for all sectors, but once installed, it is immobile across sectors. Thus, reallocation of capital can only take place through accumulation.[3] In modelling trade flows we follow the familiar Armington approach and assume that imports and domestically produced goods are imperfect substitutes in demand. This allows for a certain degree of autonomy of the domestic price system even though import prices are fixed according to the small country assumption. On the export side, however, the economy may not sell arbitrary amounts of its goods on world markets at given prices. This would have destroyed the above mentioned autonomy guaranteed on the import side, unless one assumes some sort of differentiation between domestic sales and sales on the world market.[4] Instead, we simply add to our general equilibrium model a system of partial equilibrium, constant elasticity export demand functions.[5]

The functional forms that we choose guarantee separability properties allowing for multi–stage budgeting. The model may conveniently be thought of as consisting of two parts: the dynamic part concerns the intertemporal allocation of consumption and investment budgets while the static submodel explains how expenditures at any time are channeled through to the sectoral and commodity level. Figure 1 depicts the relationship between these two parts. The notation which will become clear in the course of the model presentation is sufficiently suggestive for a quick understanding of the basic relationships of the model. CD denotes a Cobb–Couglas aggregator, whereas CES denotes a constant elasticity of substitution aggregate. Moreover, square brackets indicate a matrix array whereas an arrow indicates a vector, and adding a vector to a matrix must be thought of as adding it to the row sums of the matrix.

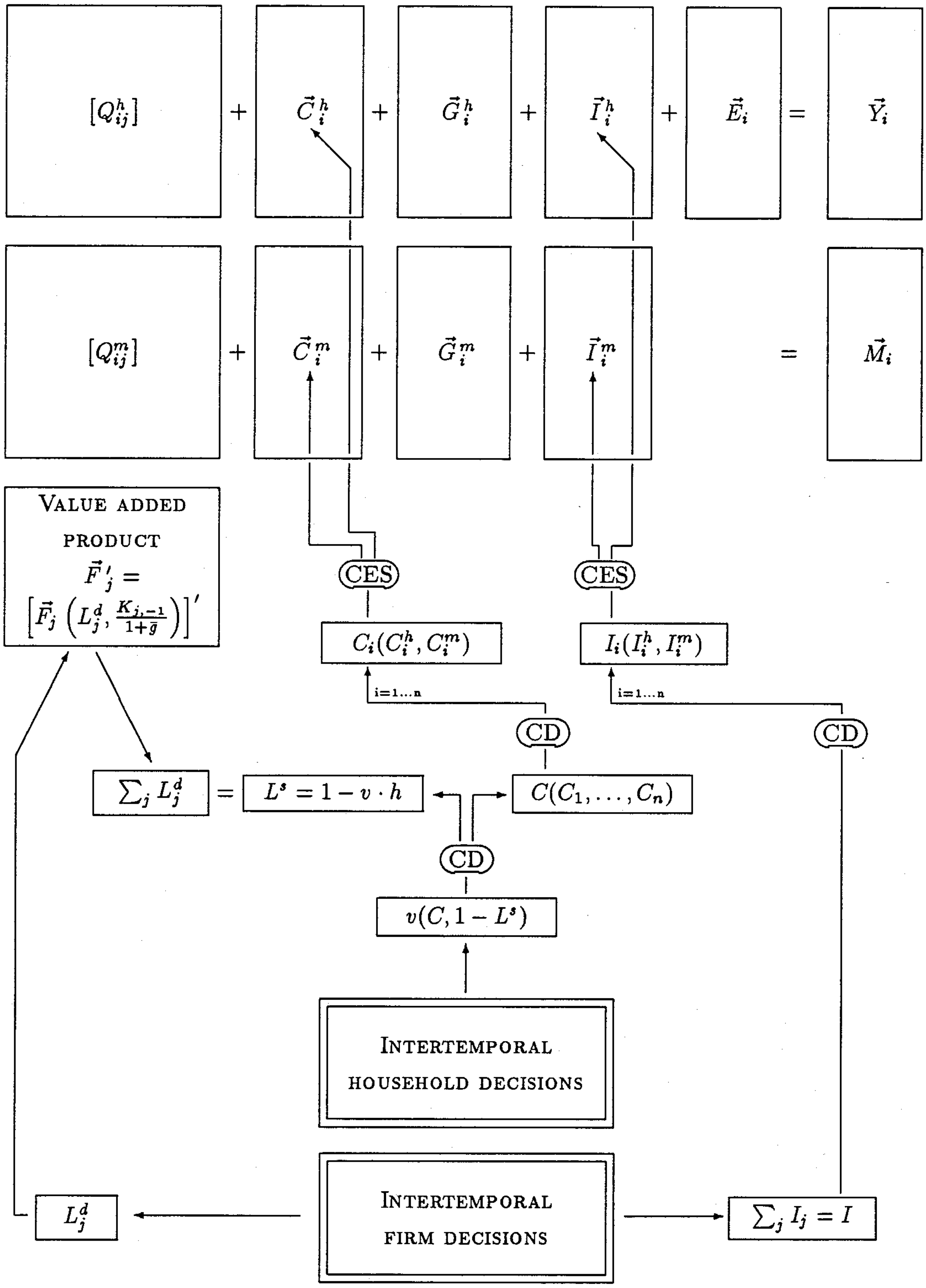
The intertemporal savings and investment decisions are forward looking. Assuming perfect foresight on the part of all agents, they correctly anticipate all future prices and never need to revise their ex-

[3] Except for the facts that there is no reallocation of capital and that adjustment cost are "internal", the production side of the model is very much in the spirit of the classic paper by Mussa (1978).

[4] Such a model specification is suggested by de Melo and Robinson (1989). It requires assigning numerical values to elasticities of transformation between exports and domestic sales. Reliable values for such elasticities are much harder to come by than for traditional price elasticities of export demand.

[5] Whalley and Yeung (1984) discuss the kind of offer curves implied by this specification of trade flows.

Figure 1: Overview of model structure



pectations because of erroneous judgement. Their expectations are continuously borne out by their own decisions, made subject to these expectations. Alternative schemes of expectations formation could be employed in a model like the present one. However, important arguments support the perfect foresight assumption. First, welfare analysis becomes highly problematical if we allow erroneous expectations in an intertemporal model setup. Suppose we were to assume static expectations, and supppose that two alternative distortionary policies yield differing welfare effects as measured by some metric for consumer welfare. Can we conclude that these welfare differences adequately indicate differences in efficiency losses inherent in the respective policies? The answer is no because part of the difference in welfare losses may be due to the fact that the errors involved in static expectations are grossly different in the two situations. But these errors have nothing to do with the inherent efficiency effects of the policies. Second, forward looking expectations allow the model to capture announcement effects. These are precluded in the case of static or backward looking expectations, yet they are undoubtedly a very important aspect of economic policy effects.

3 Intertemporal Optimization

In line with common observation, the model exhibits long–run increases in per capita output and consumption due to labor saving technological progress. The state of technology is captured in an efficiency factor which increases the productivity of labor at an exogenous rate x. In addition, aggregate population grows at rate n. Hence, the effective labor input contains an exogenously given population and productivity trend at rate $\bar{g} = (1+x)(1+n) - 1$. The subsequent model presentation, however, will be such that all variables are stationary in the steady state which is accomplished by suitable detrending.

3.1 Households

Before turning to the decision taken by a representative household, we must agree on the notation used. A variable y as of period t, but pertaining to a generation borne at $t - a$, may be denoted by $y_{t-a,t}$. However, to keep the notation as simple as possible, we denote such a variable by $y_{.}$ whenever we want to indicate an arbitrary generation and an arbitrary time period. $y_{.-1}$ is used to indicate the same variable lagged one period. Upon aggregation, economy wide variables are denoted simply by omitting the generational index. If time indexing is necessary we alternatively use indices s, u, and t.

Our household sector consists of overlapping generations facing lifetime uncertainty with a given, constant probability θ of dying between any two periods.[6] At the beginning of each period, a representative household of any "old" generation faces given financial wealth from the previous period and plans

[6]The basic analytical model of this type was pioneered by Blanchard (1985). A Discrete version was developed by Frenkel and Razin (1987). Our model closely follows Buiter (1988), except that it is in discrete time and additionally features endogenous labor supply. To keep the paper within reasonable length, we have relegated some of the details of the OLG structure to an appendix which is available upon request.

consumption flows for this period, with an associated accumulation of financial wealth until the end of period. Thus, if the household survives beyond this period, we have

$$A_{.} = \frac{(1+r)}{1-\theta}\frac{A_{.-1}}{1+x} + \frac{y_{.}}{\bar{p}} - \frac{M^{v}_{.}}{\bar{p}}. \tag{1}$$

where A denotes real financial wealth expressed in terms of a commodity bundle with a price index $\bar{p}$, y denotes nominal non–wealth income, and M^v is total consumption expenditure, to be described in more detail below. All variables are expressed per efficiency unit, i.e., they are detrended from productivity growth x. The relevant real interest rate r is related to the world real interest rate i^* by the following parity condition:

$$(1+r) = (1+i^*)\bar{p}_{-1}/\bar{p}. \tag{2}$$

This condition states that an asset denominated in terms of a consumption basket with price index $\bar{p}$ earns a real rate of return equal to that of an asset denominated in terms of an arbitrary import commodity whose price remains constant by assumption. Note that lifetime uncertainty increases the effective interest factor for financial wealth. One way to obtain this result is to assume that there is a competitive insurance sector offering reverse life insurance.[7] Moreover, this is the key institutional link between individual lifetime uncertainty and deterministic behavior of aggregate financial wealth.

Subject to this flow constraint and two appropriate boundary conditions, the household chooses a time path of M^v that maximizes expected lifetime utility. We assume a time–separable utility function with exponential discounting, where felicity depends on an index of commodity consumption and leisure. Normalizing time endowment at unity, commodity consumption per efficiency unit C and labor supply L^s contribute to felicity according to $u_{.} = u(XC_{.}, 1-L^s_{.})$, where X is the state of technology (growing at a rate x). To guarantee existence of a steady state in the presence of labor saving technological progress, we have to restrict the elasticity of substitution between the commodity bundle and leisure to unity. The unitary elasticity guarantees that, while the wage rate grows at rate x, consumption per efficiency unit and hours worked remain constant in the steady state. Moreover, linear homogeneity allows a convenient separation between intertemporal decision making and intraperiod allocation, using the principle of multi–stage budgeting. Finally, a constant intertemporal elasticity of substitution γ is required to support a steady state with a constant top level consumption aggregate.[8] Hence, felicity is a linearly homogeneous Cobb–Douglas aggregate nested within a constant intertemporal elasticity of substitution function.

$$U_{.} = X^{\alpha(1-1/\gamma)}u(v_{.}), \qquad u(v_{.}) \equiv \frac{1}{1-1/\gamma}v_{.}^{1-1/\gamma}, \qquad v_{.} \equiv C^{\alpha}_{.}(1-L^s_{.})^{1-\alpha}. \tag{3}$$

Note that $X_s = X_t(1+x)^{s-t}$. Expected utility of an arbitrary generation may then be written as

$$E(U_{.,t}) = \sum_{s=t}^{\infty}[(1-\theta)\beta]^{s-t}u(v_{.,s}), \qquad \text{with} \quad \beta \equiv (1+x)^{\alpha(1-1/\gamma)}(1+\rho)^{-1}, \tag{4}$$

[7] See Frenkel and Razin (1987, p. 287) and Blanchard and Fischer (1989, p. 116) as well as our appendix for more details.

[8] King et al. (1988) discuss the conditions for existence of steady states in optimizing growth models.

where ρ is a subjective disount rate. Individual uncertainty with respect to lifetime is reflected in the additional discounting at rate $(1-\theta)$.

With this specification of utility, total expenditure in any period may be written as $M^v_. = p^v v_.$ where p^v is the exact price index for overall consumption as defined by the unit expenditure function associated with sub–utility $v(\cdot)$:

$$p^v = \min_{\{c,h\}} \{p^c c + w^n h \quad \text{s.t.: } v(c,h) \geq 1\}. \tag{5}$$

Moreover, income $y_.$ equals the value of time endowment, as determined by the net wage rate plus transfers received from the government:

$$y_. = w^n + z_. + d_. t_y, \quad \text{with} \quad w^n = (1-t_y)(1-t_s)w. \tag{6}$$

where w is the market wage rate, t_y is the general income tax rate, t_s is the social security tax rate, and $d_.$ is a lump sum tax deduction by means of which we model an indirectly progessive personal income tax schedule. h and c are compensated (per unit of v) demands for leisure and a commodity aggregate with an exact price index p^c explained below. We will generally use lower case letters for such unit demand functions and capital letters for total demands. Thus, total commodity consumption (per efficiency unit) is equal to $C_. = cv_.$, and labor supply of our household is $L^s_. = 1 - hv_.$. c and h, respectively, are determined by conventional static optimization, whereas $v_.$ is the result of intertemporal decision making.

As detailed in the appendix, a Lagrangean approach can be used to determine the optimal time path of consumption expenditures. Using primed symbols to denote first order derivatives, we have the following Euler equation giving the intertemporal consumption profile:

$$u'(v_{.,s}) = \left[\frac{1+r_{s+1}}{1+x}\frac{p^v_s/\bar{p}_s}{p^v_{s+1}/\bar{p}_{s+1}}\right]\beta u'(v_{.,s+1}). \tag{7}$$

Accordingly, agents equate the marginal utility cost with the discounted utility gain from transferring a unit of consumption from this to the next period. The square bracketed term is the so called consumption based real discount factor.[9] Repeatedly applying this equation and using the functional form of $u(\cdot)$, we can relate the quantities of full consumption in two arbitrary periods s and t by:

$$v_{.,s} = \left\{R^{-1}_{t+1,s}[(1-\theta)\beta]^{s-t}\frac{p^v_t/\bar{p}_t}{p^v_s/\bar{p}_s}\right\}^{\gamma} v_{.,t}, \quad \text{with} \quad R_{t+1,s} \equiv \prod_{u=t+1}^{s}\frac{(1+x)(1-\theta)}{1+r_u}. \tag{8}$$

Having described the time profile of full consumption v, the level of consumption is determined by the intertemporal budget constraint. Solving the dynamic budget constraint in (1) and imposing the transversality condition on financial wealth yields the familiar equality between the value of lifetime consumption and total wealth. Using the Euler equation above to eliminate all future consumption flows,

[9]See Frenkel and Razin (1987, p. 170).

the following consumption function is obtained:

$$\begin{aligned}\frac{p_t^v}{\bar{p}_t}v_{\cdot,t} &= \Omega_t^{-1}\mathcal{W}_{\cdot,t}, \quad \text{with} \quad \Omega_t \equiv \sum_{s=t}^{\infty}[(1-\theta)\beta]^{\gamma(s-t)}\left[\frac{p_s^v/\bar{p}_s}{p_t^v/\bar{p}_t}R_{t+1,s}\right]^{1-\gamma}, \\ \mathcal{W}_{\cdot,t} &\equiv \frac{1+r_t}{(1-\theta)(1+x)}(A_{\cdot,t-1}+H_{\cdot,t-1}), \quad \text{and} \quad H_{\cdot,t-1} \equiv \sum_{s=t}^{\infty}\frac{y_{\cdot,s}}{\bar{p}_s}R_{t+1,s}.\end{aligned} \tag{9}$$

This completes the description of how an arbitrary generation decides on the intertemporal allocation of consumption expenditure. To obtain economy wide aggregates, one needs to sum across all generations existing at time t. Note first that $v_{t-a,t}$ is detrended from productivity growth. Thus, multiplying $v_{t-a,t}$ by the size of generation $t-a$ gives total consumption by this generation, and summing over all generations yields total consumption of the economy. Finally, divide by the population size to obtain aggregate per capita consumption in efficiency units [see the separate appendix]

$$v_t = \sum_{a=1}^{\infty}\omega_a v_{t-a,t}, \quad \text{with} \quad \omega_a \equiv \frac{n+\theta}{1+n}\left(\frac{1-\theta}{1+n}\right)^{a-1}. \tag{10}$$

An aggregate consumption function is now obtained by applying aggregation formula (10) to the age specific consumption function derived in (9). Aggregation invokes the law of large numbers to equate the individual probability of dying θ with the fraction of a generation actually dying between any two periods. Thus, population evolves deterministically with a gross birth rate $n+\theta$ and a net birth rate n. Note that the generation wheights ω_{t-a} and, hence, the age distribution of population remain constant, and that $\sum_{a=1}^{\infty}\omega_a = 1$. Moreover, all generations face identical time horizons for the rest of their lives, irrespective of their age.[10] Assuming that they also have identical time endowments, that government transfers are age-independent, and realizing that they face identical prices (and hence discount factors), we conclude that aggregate income and human wealth are equal to individual income and human wealth: $y_{\cdot,t} = y_t$ and $H_t = H_{\cdot,t}$. The only critical step remaining is aggregating over age specific financial wealth. The appendix shows that in the process of aggregating pre-existing real assets $A_{\cdot,-1}(1+r)/(1-\theta)(1+x)$, the death probability vanishes. The reason is that new generations enter the economy without any financial wealth, and because the insurance premiums exchanged between households and the insurance sector essentially cancel out. Hence, aggregate financial wealth evolves deterministically as

$$A_t = \frac{1+r_t}{1+\bar{g}}A_{t-1} + \frac{y_t}{\bar{p}_t} - \frac{p_t^v}{\bar{p}_t}v_t. \tag{11}$$

From (9), the aggregate consumption function then is

$$\frac{p_t^v}{\bar{p}_t}v_t = \Omega_t^{-1}\mathcal{W}_t \quad \text{with} \quad \mathcal{W}_t \equiv \frac{1+r_t}{1+\bar{g}}A_{t-1} + \frac{y_t}{\bar{p}_t} + H_t. \tag{12}$$

Note that the intertemporal consumption decision is governed by forward looking variables like human wealth and the propensity to consume out of wealth. These are essentially present value formulations in

[10] Blanchard and Fischer (1989, p. 115) aptly describe this model feature as perpetual youth.

future prices, and they may equivalently be expressed in difference equations,

$$
\begin{aligned}
&(a) \quad H_{t-1} = \frac{1+\bar{g}}{1+r_t}\frac{1-\theta}{1+n}\left[\frac{y_t}{\bar{p}_t} + H_t\right], \\
&(b) \quad \Omega_{t-1} = 1 + (1-\theta)\beta^{\gamma}\left[\frac{1+x}{1+r_t}\frac{p_t^v/\bar{p}_t}{p_{t-1}^v/\bar{p}_{t-1}}\right]^{1-\gamma}\Omega_t.
\end{aligned}
\tag{13}
$$

3.2 Firms

In this section we characterize the behavior of a representative firm and in doing so we shall omit sectoral indices to avoid cluttered notation. Holding equity must yield the same real rate of return as do foreign assets and government bonds. The return on equity is given by (net of tax) dividends χ plus capital gains on firm values V. Writing all variables per efficiency unit, this implies the following arbitrage condition:

$$
r_t = \frac{\chi_t/\bar{p}_t + V_t - V_{t-1}/(1+\bar{g})}{V_{t-1}/(1+\bar{g})}, \tag{14}
$$

where r is the real interest rate. Firm values are expressed in units of a commodity bundle with price index $\bar{p}$, whereas dividends χ are in nominal terms. This equation describes the time profile of firm values while their levels are determined by value maximization which governs firm behavior. Imposing a transversality condition ruling out eternal speculative bubbles, we obtain the fundamental equation for the ex dividend value of the firm as the forward solution of the arbitrage condition (14):

$$
V_t = \sum_{t+1}^{\infty} \frac{\chi_s}{\bar{p}_s} \prod_{u=t+1}^{s} \frac{1+\bar{g}}{1+r_u} \tag{15}
$$

Dividends are the difference between the value of output and the wage bill plus investment expenditure. Given that production exhibits fixed input–output coefficients for intermediate inputs and the value added input, we may restrict ourselves to the value added product which sells at a price $\tilde{p}$ (defined below), and write net of tax dividends as:

$$
\begin{aligned}
&(a) \quad \chi = (1-t_y)\left[\tilde{p}(F-\Phi) - w^g L^d\right] - (1-et_y)p^I I, \quad \text{where} \\
&(b) \quad F = F(\frac{K_{-1}}{1+\bar{g}}, L^d), \quad \text{and} \quad \Phi = \Phi(\frac{K_{-1}}{1+\bar{g}}, I).
\end{aligned}
\tag{16}
$$

Value added output per efficiency unit, F, is a linearly homogenous function of the capital stock at the beginning of period, expressed per efficiency unit of the current period, and labor demand per capita, L^d. The functional form for $F(\cdot)$ can be found in an appendix table. Firms purchase labor at the gross wage rate w^g which is equal to the market wage rate plus an ad valorem factor tax:

$$
w^g = (1+t_l)w, \tag{17}
$$

where t_l is a sector specific indirect tax on labor use. For gross sectoral investment I, firms purchase an identical composite capital good which sells at a price p^I (see below). The associated installation cost Φ

is linearly homogeneous in investment and capital. Moreover, the installation technology is such that Φ decreases as the capital stock increases, and it is increasing and convex in gross investment. Given that physical capital depreciates at a geometric rate of decay δ, the capital stock evolves according to

$$K_t = I_t + \frac{1-\delta}{1+\bar{g}} K_{t-1}. \tag{18}$$

The appendix table postulates a functional form for $\Phi(\cdot)$ such that adjustment costs vanish in the steady state. This simplifies calibration, but also implies that adjustment costs become negative as net investment turns negative. While it may seem strange at first sight, we argue that it is nevertheless a meaningful way to model the installation technology. Accordingly, a reduction of investment below its steady state value will, ceteris paribus, continue to increase net output. Installation costs reach their minimum if gross investment is half its steady state value and, quite naturally, they are zero again with $I = 0$.

There are several differences between this setup and that of Goulder and Eichengreen (1989). First, the above definition of dividends assumes, for simplicity, that all investment is financed internally by retained earnings meaning that firms do not issue debt. Moreover, they are viewed as mature firms which never issue new equity. Note also that profits are subject to a general income tax at a rate t_y, rather than a corporate tax rate. At the same time, a fraction e of investment expenditures may be deducted from the tax base. For this reason, there is no additional taxation of dividends in the arbitrage condition.[11] Finally, the model ignores capital gains taxes and equity does not bear any risk premium over the return of interest bearing securities. These simplifications, especially the ones relating to the tax structure, are primarily dictated by data restrictions.

At any point in time, the capital stock is predetermined and labor demand is governed by the familiar equality between the value marginal product of labor and the gross wage rate:

$$\tilde{p} F_L\left(\frac{K_{-1}}{1+\bar{g}}, L^d\right) = w^g \tag{19}$$

Firms decide on investment so as to maximize the cum dividend value of the firm subject to the definition of dividends, the equation of motion for the capital stock, an initial condition $K_{t-1} = K_0$, and non-negativity conditions for the capital stock throughout, $K_s > 0$ for $s = t, \ldots, \infty$. The Lagrangean of this problem is

$$\mathcal{L}_t = \sum_{s=t}^{\infty} \left\{ \frac{\chi_s}{\bar{p}} + q_s \left[I_s + \frac{1-\delta}{1+\bar{g}} K_{s-1} - K_s \right] \right\} \prod_{u=t+1}^{s} \frac{1+\bar{g}}{1+r_u}, \quad \text{where} \prod_{u=t+1}^{t} \frac{1+\bar{g}}{1+r_u} \equiv 1,$$

and χ is defined in (16). The necessary conditions for a maximum value are (18) plus

[11] Our model thus does not capture the double taxation feature of a separate corporate tax in addition to a personal income tax. See also the chapter on calibration.

$$
\begin{aligned}
&(a) \quad q_s = (1-t_{y,s})\frac{\tilde{p}_s}{\bar{p}_s}\Phi_{I,s} + (1-e_s t_{y,s})\frac{p_s^I}{\bar{p}_s}, \\
&(b) \quad q_{s-1}(1+r_s) = (1-t_{y,s})\frac{\tilde{p}_s}{\bar{p}_s}(F_{K,s}-\Phi_{K,s}) + (1-\delta)q_s, \quad \text{and} \\
&(c) \quad \lim_{T\to\infty} K_T q_T \prod_{u=t+1}^{T} \frac{1+\bar{g}}{1+r_u} = 0,
\end{aligned} \tag{20}
$$

where $F_{K,s}$ is the marginal productivity of capital during period s, and $\Phi_{K,s}$ and $\Phi_{I,s}$ are the partial derivatives of the installation cost function with respect to its arguments. The first equation states that investment is carried out to the point where the marginal cost of investment (marginal cost of obtaining the capital good plus the marginal installation cost) equals the shadow value of an additional unit of capital stock. The second equation (Euler) determines how the shadow value of the marginal capital stock evolves over time, and the third equation states that the shadow value of the terminal capital stock must asymptotically vanish, giving bounded solutions. Using this transversality condition in the forward solution of the Euler equation allows the marginal shadow value of capital to be expressed as the present value of future net earnings created by an additional unit of capital stock installed at time t:

$$
q_t = \sum_{s=t+1}^{\infty} \frac{1-t_{y,s}}{1-\delta}\frac{\tilde{p}_s}{\bar{p}_s}(F_{K,s}-\Phi_{K,s}) \prod_{u=t+1}^{s} \frac{1-\delta}{1+r_u}. \tag{21}
$$

Inserting this expression into condition (20a) gives an implicit investment function. Notice that investment, like aggregate consumption, is determined by future prices. Hayashi's (1982) theorem relates the value of the firm to the shadow value of new capital and the existing capital stock: $V_t = q_t K_t$. After replacing q_t by V_t/K_t in the optimal investment condition (20a), written for time t, and using the equation of motion for the capital stock to replace K_t, one obtains an investment function $I_t = I(\vec{p}_t, K_{t-1}, V_t)$ by solving

$$
\Phi_I(\frac{K_{t-1}}{1+\bar{g}}, I_t) = \left[\frac{V_t}{I_t + (1-\delta)K_{t-1}/(1+\bar{g})} - (1-e_t t_{y,t})\frac{p_t^I}{\bar{p}_t}\right]\frac{\bar{p}_t}{(1-t_{y,t})\tilde{p}_t}. \tag{22}
$$

The specific functional form can be found in appendix table A2.

4 Sectoral Disaggregation

The preceding analysis has repeatedly referred to aggregate quantities and associated price indices. In particular, C and I have been interpreted as aggregate consumption and investment demand, respectively, with associated price indices p^c and p^I. We shall now discuss how these aggregate consumption and investment demands translate into demands for individual domestic and imported commodities. Moreover, we will introduce government demand for commodities as well as export demand. In addition to the demand price indices we will now explicitly define the value added price $\tilde{p}$. Besides sectoral disaggregation, this section will also present the details of commodity taxation. We will generally use i and j as sectoral indices, and the number of sectors is denoted by n. To avoid cluttered notation, we abstain from time–indexing.

4.1 Final Demand

For reasons outlined in detail in Kohler (1990), we assume that imported goods and domestic goods within any sector i are imperfect substitutes, and we employ Armington's (1969) procedure to model this. Any demand for a commodity of sector i 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. For the time being, we do not further differentiate imports by their country of origin. These sector specific aggregates enter a second level of aggregation leading to the consumption aggregates C and I. Thus, the full nesting of our felicity finally reads as $u = u\big[v\big\{C[C_1(C_1^h, C_1^m), \ldots, C_n(C_n^h, C_n^m)], 1 - L^s\big\}\big]$, where $v(\cdot)$ and $C(\cdot)$ as well as all $C_i(\cdot)$ are linearly homogenous and strictly quasiconcave.[12] This somewhat restrictive (but common) assumption is for tractability and allows static household optimization to be carried out in separate stages, in the same way that we have separated static from dynamic optimization. In a perfectly analogous fashion, the investment aggregate must be read as $I = I\big[I_1(I_1^h, I_1^m), \ldots, I_n(I_n^h, I_n^m)\big]$. Finally, multi–stage budgeting also applies to government procurement. Quasi–preferences for the government of the form $G = G\big[G_1(G_1^h, G_1^m), \ldots, G_n(G_n^h, G_n^m)\big]$ determine government demand for individual commodities. Consumers and firms as well as the government are assumed to minimize the expenditure necessary to obtain a given level of the aggregate C, I, and G, respectively. In doing so, they all face the same market prices p_i^h and p_i^m for a home produced and imported good of sector i, but they face different effective indirect tax treatment.Our modelling of the tax system allows for a value added tax rate t_v, an excise tax rate t_x, and a tariff rate t_m. All these tax rates vary between sectors as well as between different categories of demand. Thus, the price gross of indirect taxes that final demand of category $n \in \{C, I, G\}$ has to pay for a home produced and an imported commodity i, respectively, is

$$\begin{aligned} (a) \quad p_i^{n,h} &= p_i^h(1 + t_{v,i}^{n,h} + t_{x,i}^{n,h}), \\ (b) \quad p_i^{n,m} &= p_i^m(1 + t_{v,i}^{n,m} + t_{x,i}^{n,m} + t_{m,i}^{n}). \end{aligned} \tag{23}$$

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 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. Note that there is no exchange rate variable appearing in the above equation for import prices. We have thus implicitly assumed p_i^m to be in the same dimension as domestic prices. Since our economy is small on the import side, all equilibrium prices will be relative to the given world prices p_i^m, which are all set equal to one in the process of calibration. This is nothing but an arbitrary normalization of the price system. We could, in fact, have chosen any other normalization and then let an exchange rate variable guarantee the equilibrium relationship between domestic prices and world prices. Since there is no a–priori argument in favor of any particular normalization, we have decided on the above normalization on the grounds of simplicity.

Price indices on the sectoral and the aggregate level are obtained as unit expenditure functions

[12] The functional forms are found in the appendix table.

associated with the corresponding sub–utilities:

$$
\begin{aligned}
&(a) \quad p_i^c = \min_{\{c_i^h, c_i^m\}} \left\{ p_i^{c,h} c_i^h + p_i^{c,m} c_i^m \quad \text{s.t.: } C_i(c_i^h, c_i^m) \geq 1 \right\}, \\
&(b) \quad p^c = \min_{\{c_i, \ldots, c_n\}} \left\{ \sum_{i=1}^{n} p_i^c c_i \quad \text{s.t.: } C(c_i, \ldots, c_n) \geq 1 \right\}, \quad \text{and} \\
&(c) \quad p^v = \min_{\{c,h\}} \{ p^c c + wh \quad \text{s.t.: } v(c,h) \geq 1 \},
\end{aligned}
\tag{24}
$$

where the last equation has been reproduced from section 3 above. As is evident from above, c_i^h, c_i^m, c_i, and c are compensated demands. Total consumption demand for the home produced and imported good of sector i is obtained as

$$C_i^h = c_i^h c_i c v, \quad \text{and} \quad C_i^m = c_i^m c_i c v. \tag{25}$$

where v is determined as in section 3. The functional forms of all price indices and unit demand functions are found in the appendix table.

As regards investment demand, we first note that there are n sectors in which firms determine their demands for the composite capital good by intertemporal optimization. Using an index j to denote the sector where investment demand originates, we obtain total demand for the composite capital good as $I = \sum_{j=1}^{n} I_j$ (see figure 1). Perfectly analogous to consumption demand, this now translates into demands for home produced and imported commodities of individual sectors. The appendix table gives the specific functional forms for price indices and unit demand functions relating to investment. As to government procurement, we assume the top level of $G(\cdot)$ to be Leontief. This is meant to reflect the fact, albeit in a stylized way, that government procurement is to a large extent fixed by legal commitments. The lower utility nest, however, allows for cost-minimizing substitution between imported and home goods. The modelling of final demand is now completed by adding a system of partial equilibrium export demand functions:

$$E_i = E_i(p_i^h), \quad \text{with} E_i' < 0. \tag{26}$$

For convenience, we have chosen a constant elasticity form for these equations.[13]

4.2 Production and Input Demands

We have already mentioned above that the sectoral production functions feature fixed input–output coefficients in terms of intermediate inputs and the value added product. In perfect analogy to the preceding subsection, we now specify that every intermediate input requirement is defined in terms of an aggregate good composed of an imported and a home produced variety. We have

$$Y_i = \min \left\{ \frac{Q_{1i}}{a_{1i}}, \frac{Q_{2i}}{a_{2i}}, \ldots, \frac{Q_{ni}}{a_{ni}}, \frac{F_i - \Phi_i}{a_{0i}} \right\}, \quad \text{where} \quad Q_{ji} = Q_{ji}(Q_{ji}^h, Q_{ji}^m), \tag{27}$$

[13]See Whalley and Yeung (1984) and Kohler (1990) for some implications of this "trade closure" of the model.

and F_i is the value added product introduced in section 3. $a_{ji}(j = 0, \ldots n)$ are fixed input–output coefficients. Producers receive output prices p_i^h, and they pay

$$\begin{aligned} (a) \quad & p_{ji}^{Q,h} = p_j^h(1 + t_{x,ji}^{Q,h}), \\ (b) \quad & p_{ji}^{Q,m} = p_j^m(1 + t_{x,ji}^{Q,m} + t_{m,ji}^{Q}) \end{aligned} \tag{28}$$

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 these equations. For any given intermediate input requirement, producers minimize the necessary expenditure by an appropriate mix between imported and home produced inputs. The unit expenditure function defines the relevant input price:

$$p_{ji}^{Q} = \min_{\{q_{ji}^h, q_{ji}^m\}} \left\{ p_{ji}^{Q,h} q_{ji}^h + p_{ji}^{Q,m} q_{ji}^m \quad \text{s.t.: } Q_{ji}(q_{ji}^h, q_{ji}^m) \geq 1 \right\}. \tag{29}$$

Again, q_{ji}^h and q_{ji}^m are compensated demands, and we can define the corresponding input–output coefficients for home produced and imported inputs, respectively, as

$$a_{ji}^h = q_{ji}^h a_{ji}, \quad \text{and} \quad a_{ji}^m = q_{ji}^m a_{ji}. \tag{30}$$

Notice that, while a_{ji} is fixed, a_{ji}^h and a_{ji}^m depend on prices. Now the price $\tilde{p}_i$ for the value added product of sector i is defined,

$$\tilde{p}_i = [p_i^h - \sum_{j=1}^{n} a_{ji} p_{ji}^Q] / a_{0i} , \tag{31}$$

which is a modified version of the net price familiar from the effective protection literature. In the present context, it states that the gross output price p_i^h must exactly match the minimum costs of producing a unit of good i, the usual zero profit condition. We can write it with equality, because our assumptions guarantee that equilibrium outputs are positive for all goods.

5 General Equilibrium

We have argued in the introduction that one of the crucial motivations behind the construction of a model like the present one is the desire to compute the adjustment path that the economy will take once disturbed by some policy change. Such a path is nothing but a sequence of temporary equilibria. We have a group of forward looking, expected variables which we conveniently denote by $\mathcal{E} \equiv \{V_1, \ldots, V_n, \Omega, H\}$. A group of backward looking, state variables are predetermined at any point in time, and are denoted by $\mathcal{K} \equiv \{K_1, \ldots, K_n, D^G, D^F\}$. Any temporary equilibrium is conditional on these historic variables. Similarly, a temporary equilibrium is conditional on expectations of future prices as embodied in the forward looking variables. As we have repeatedly indicated above, we employ the assumption of perfect foresight during the adjustment path. Hence, successive temporary equilibria are interconnected in two ways. Previous equilibria have contributed to the historic variables that agents face at any given point in time as initial conditions. Future equilibria determine expectations and, thus, all forward looking variables drive the agents' present behavior. In addition to market clearing, a sequence of temporary equilibria will have to satisfy, under perfect foresight, the laws of motion of all the dynamic variables, both the predetermined as well as the expected variables. More precisely, the predetermined variables must satisfy, in addition to (18),

$$\begin{aligned}
(a)\quad D^G &= \left(\frac{1+i^*}{1+\bar{g}}\right)D^G_{-1} + S^G,\\
(b)\quad D^F &= \left(\frac{1+i^*}{1+\bar{g}}\right)D^F_{-1} + S^F,\\
(c)\quad \bar{p}A &= \left(\frac{1+i^*}{1+\bar{g}}\right)\bar{p}_{-1}A_{-1} + S^H.
\end{aligned} \tag{32}$$

Primary balances plus interest on previously accumulated stocks add to existing wealth to give the desired wealth at the end of the period. From (11), (6) and (5), primary household sector savings out of non-capital income is $S^H = w^n L^s + z + t_y d - p^c C$. The primary government surplus is $S^G = z + p^G G - T$ where T denotes total tax revenues. The trade balance is $S^F = \sum_i \left[p_i^h E_i - p_i^m \left(C_i^m + G_i^m + \sum_j I_{ij}^m + \sum_j a_{ij}^m Y_j\right)\right]$. Solving these equations forward in time one obtains the intertemporal budget constraints which restrict the present value of future excess spending to the amount of existing wealth. In the opposite case of outstanding debt, the intertemporal constraint requires an equally large present value of future surpluses.

Equilibrium in spot markets requires that excess demands in any period are zero, $\zeta_t(\vec{p}_t, \mathcal{K}_{t-1}, \mathcal{E}_t) = 0$,

$$\begin{aligned}
(a)\quad & \zeta_i^C \equiv C_i^h + G_i^h + \sum\nolimits_j I_{ij}^h + E_i + \sum\nolimits_j a_{ij}^h Y_j - Y_i, \qquad i,j = 1\ldots n,\\
(b)\quad & \zeta^L \equiv \sum\nolimits_j L_j^d - L^s,\\
(c)\quad & \zeta^G \equiv \bar{D}^G - \frac{1+i^*}{1+\bar{g}}\bar{D}^G_{-1} - S^G,\\
(d)\quad & \zeta^K \equiv \sum\nolimits_j \bar{p}V_j + D^G + D^F - \bar{p}A.
\end{aligned} \tag{33}$$

The public sector's "excess demand" ζ_t^G follows from the assumption of a prespecified path of government debt. The government budget, therefore, endogenously determines transfers z. To compute a temporary equilibrium, we need to solve only for the zeros of (33a–c) by iterating domestic commodity prices, the wage rate and government transfers, $\vec{p} = \{p_1, \ldots, p_n, w, z\}$. In equilibrium, capital market clearing is implied by Walras' Law. To see this, add up (32a,b) as well as firm values in (14). Note the fact that financial wealth in the previous period was $\bar{p}_{-1}A_{-1} = D^F_{-1} + D^G_{-1} + \sum_j \bar{p}_{-1}V_{j,-1}$, and use (32c) to obtain desired household wealth $\bar{p}A$. As a result,

$$\zeta^K = D^F + D^G + \sum\nolimits_j \bar{p}V_j - \bar{p}A = S^F + S^G - \sum\nolimits_j \chi_j - S^H. \tag{34}$$

In the separate appendix we prove the following: if commodity and labor markets are cleared and the government satisfies its flow constraint ($\zeta_i^C = \zeta^L = \zeta^G = 0$), then the capital market is in equilibrium too ($\zeta^K = 0$). The flow condition for capital market equilibrium is a statement of the macroeconomic savings investment identity in primary balances. To obtain the more usual flow identity, define $\nabla D \equiv$

$D - D_{-1}/(1+\bar{g})$. Note that investment is financed by retained earnings $R = p^I I$. Use this to expand the flow condition (34) and eliminate the primary balances by (32a,b) to obtain

$$\nabla D^G + \nabla D^F + p^I I = S + R, \tag{35}$$

where total savings out of labor plus capital income is $S = S^H + \sum_j \chi_j + i^*(D^G_{-1} + D^F_{-1})/(1+\bar{g})$. Hence, private sector savings from households and firms must cover gross investment, government deficits and the current account imbalance.

The computation of temporary equilibria, $\zeta_t(\vec{p}_t, \mathcal{K}_{t-1}, \mathcal{E}_t) = 0$, is conditional on predetermined and expected variables. While the predetermined variables $\mathcal{K}_{t-1}$ result from previous equilibria, the expected variables $\mathcal{E}_t$ are present values of variables determined in future equilibria. Hence, expected variables are not yet known when computing period t temporary equilibrium, and must be guessed. Given such a guess, the computation of a temporary equilibrium yields the initial conditions for the next period's equilibrium by evaluating the accumulation relationships. At the same time, given a guess $\mathcal{E}_t$, computation of the current equilibrium yields all the prices necessary to obtain revised values for the last period's values $\mathcal{E}_{t-1}$ by evaluating the updating relations (13) and (14). The procedure to compute perfect foresight equilibria requires to start with an initial guess of expected variables, $\mathcal{E}^0$, over the entire transition path. Next, one computes the corresponding sequence of temporary equilibria and, thereby, obtains a sequence of "actual" values $\mathcal{E}^1$ to replace the initial guesses for the next iteration. Hence, the perfect foresight solution requires repeated computations of sequences of temporary equilibria until "actual" and guessed values of the expected variables converge.[14]

The solution for the transition paths requires knowledge of the terminal values of the expected variables, and these are generated by independant computation of the final steady state. This is justified since the final steady state is the terminal point of the adjustment path consisting of a sequence of temporary equilibria. When computing the steady state, both expected and predetermined variables are unknown and must be determined endogenously. Since in a steady state prices are time invariant, expected variables are obtained by directly evaluating the present value formulas. Additionally, one must ensure that the equations of motions are stationary. The separate appendix presents the details.

6 Empirical Implementation

This section addresses the most important aspects of calibrating the model to a 1976 benchmark data set for Austria. Calibration involves the use of extraneous information on elasticity parameters. Subject to these elasticity values and certain unit conventions, other parameters, especially share parameters, are calculated such that the model replicates the benchmark data set as an equilibrium solution. Since the data stem from several different sources and are available for a single period only, they have to be adjusted in several parts to be consistent with steady state general equilibrium.

[14] The algorithm is described in detail in Keuschnigg (1991).

6.1 Data and Data Adjustments

The model merges several data sources, the most important of which is the 1976 input–output table for Austria.[15] Data pertaining to this input–output table were available on three different levels of aggregation: 175, 48, and 31 sectors. To keep the calculations within reasonable limits forced us to aggregate the data still further, and we presently vary the number of sectors between 3 and 19, depending on the purpose at hand. Table 6.1 gives the 19 sector classification with the shorthand expressions used in subsequent tables.[16] The other main source is the national accounts statistics. In addition to intermediate input demand, the raw data comprise the following categories of final demand: private consumption, government consumption, foreign tourists' expenditure, expenditure on gross fixed capital formation, inventory investments, and exports of goods and services.

Except for exports, separate figures for spending on domestic goods and imports (gross of import duties) are available. The same holds true for intermediate input demand. All transactions are evaluated net of value added tax, but include all other indirect taxes. Hence, the first step is to separate the indirect commodity taxes from the data. Then we calculate effective indirect tax rates for all three categories of taxes and for all types of demand to obtain total expenditures. While we have disaggregate information on value added taxes, excise taxes and import duties paid on private consumption, and import duties on intermediate imports, we have only aggregate information on all indirect taxes attributable to the other categories of demand. We use the effective tax rates of private consumption 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 are then used to calculate the corresponding effective indirect tax rates referred to in equations (23) and (28) above.[17]

Government purchases in 1976 were exempt from value added tax, hence t_v^G is set equal to zero. In principle, value added tax on investment purchases is deductible from value added tax liabilities. Some of the firms, however, are not subject to the value added tax in the first place giving a significant amount of value added taxes in the investment data. For obvious reasons the resulting effective tax rates are much lower for investment than for consumption. Foreign tourists' expenditures are treated like exports. Although it seems straightforward to do so, it entails a contradiction to the principle that exports bear no indirect taxes. Part of these "enlarged" exports are in fact consumed within the domestic economy and, therefore, are fully subject to domestic excise as well as value added taxes. A further adjustment was made regarding inventory investment. Since the model simply does not explain inventory behavior, these flows needed to be distributed across final demand categories. Since inventories clearly do not add to fixed capital formation, the inventory data were distributed to private consumption, government consumption, and exports.

[15] We appreciate the help of Josef Richter, Federal Chamber of Commerce, Josef Schwarzl, Austrian Central Statistical Office, and Gottfried Tappeiner, University of Innsbruck, in supplying and interpreting the data used.

[16] A separate appendix provides more detailed information on the concordance between the 19 sector and the 31 sector classification. It is available upon request.

[17] The separate appendix provides detailed information on effective indirect tax rates for all categories of demand.

Table 6.1: Sector Classification

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

We now calculate the values of total outputs by adding the row sums of the matrix of domestic intermediates plus 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, from gross outputs.[18] Finally, gross wages paid to employed labor plus indirect taxes on labor use[19] are deducted from this value added figure to residually obtain the share of capital income in each sector. Calibration is simplified by choosing units of all goods as well as labor such that prices are equal to unity in the benchmark equilibrium: $p_i^{h,0} = p_i^{m,0} = 1$ for all i, and $w^0 = 1$. Thus, the benchmark data are directly interpreted as quantities.

The national accounts statistics give 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. An aggregate figure for government transfers 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. The separate appendix presents the national accounts containing the benchmark data on aggregate income flows.

[18] Indirect taxes on intermediate products are part of the costs that sum up to the value of output at producers' prices.

[19] These are employer contributions to social security, and wage dependent indirect taxes.

Table 6.2: Value Added Components and Factor Substitution Elasticities							
Sector		Value Added	Wages	Wage Tax	Cap. Income	K_i^0	μ_i
1	Agr/For	10.579	1.245	0.161	9.174	6.059	0.607
2	Min/Quar	1.211	0.802	0.170	0.239	0.158	0.500
3	Food	6.769	4.035	0.844	1.890	1.248	0.775
4	Tex/Clot	5.238	3.536	0.782	0.920	0.608	0.983
5	Wood	4.349	2.587	0.555	1.207	0.797	0.851
6	Paper	4.210	2.596	0.546	1.068	0.705	0.868
7	Chemic	5.708	3.166	0.662	1.879	1.241	0.827
8	Petrol	0.939	0.535	0.107	0.297	0.196	0.500
9	Nonferr	3.916	2.112	0.462	1.342	0.886	0.992
10	MetProd	5.428	3.564	0.780	1.084	0.716	1.091
11	MetProc	21.403	12.271	2.628	6.504	4.296	0.581
12	Energy	6.461	2.252	0.450	3.759	2.483	0.360
13	Constr	18.145	9.105	2.092	6.948	4.589	0.324
14	Trade	27.581	11.919	2.280	13.383	8.839	0.970
15	Hot/Cat	5.504	2.241	0.524	2.739	1.809	0.970
16	Trans	10.452	6.708	2.072	1.671	1.104	0.970
17	RealEst	17.606	4.877	0.850	11.879	7.846	0.970
18	OthSer	11.060	5.983	1.055	4.022	2.656	0.970
19	Public	28.152	20.467	2.112	5.573	3.681	0.970
20	Total	194.710	100.000	19.131	75.579	49.918	0.794

6.2 Elasticities

Calibration of the model requires information on four types of elasticities. Following common practice, we use extraneous information. Econometric estimates of the intertemporal elasticity of substitution γ range from near zero to above unity and tend to be inconclusive. Such is the evidence from the work of Mankiw (1985), Mankiw, Rotemberg and Summers (1985), Hall (1988a,b) and Eichenbaum, Hansen and Singleton (1988) to take a few examples. We assign a base case value of 0.8. Given the importance for the model's comparative static behaviour and the wide range of estimates, this parameter will be a prime candidate for sensitivity analysis.

In line with Kohler (1991a,b), the sectoral elasticities of substitution between labor and physical capital in value added production are taken from the compilations by Mansur and Whalley (1984), Harrison (1986), and Deardorff and Stern (1986). Table 6.2 gives the elasticity values in addition to the components of value added. Another set of elasticities on which we take extraneous information relates to trade flows: the elasticities of substitution between imports and domestic goods as well as the price elasticities of export demand. We use five different sources of information on international trade elasticities: Harrison, Rutherford and Wooton (1991), Shiells, Stern and Deardorff (1986), Deardorff and Stern (1986), Lächler (1985), and Harris (1986). For shortage of space, we relegate all details on how we have constructed our elasticities from this set of extraneous information to the separate appendix which is available upon request.

6.3 Calibration

The model was formulated with detrended variables which requires an appropriate scaling of the benchmark data. The whole data set is scaled to give a total benchmark labor supply of $L^{s,0} = 100$. This implies a benchmark population size of $N^0 = 100/0.6$ as we assume that each agent is endowed with one unit of time and chooses to allocate 60 percent for work in the benchmark equilibrium. Accordingly, the factor by which we scale the data, is $\left(\sum_{j=1}^{n} L_j^{d,0}\right)/100$.

Calibration comprises static and dynamic aspects. Static calibration is largely standard and we can, accordingly, be very brief. Given the unit price convention and the effective indirect tax rates, expenditures are split into quantities and prices of all categories of demand on the bottom level of aggregation. We take elasticity values for imported and home goods substitution from the literature (see above) and use the first order condition for minimum unit expenditure to solve for the corresponding share parameters.[20] In the case of investment, for instance, one obtains values for import shares $\xi_i^{I,m}$. This allows to calculate the benchmark unit expenditure $p_i^{I,0}$ which can, in turn, be used to determine the associated benchmark quantity index $I_i^{I,0}$. These values enter calibration on the second level of aggregation for the composite capital good, which determines $p^{I,0}$ and I^0. A similar procedure identifies $p^{c,0}$ as well as C^0, the benchmark price and quantity indices for aggregate commodity consumption. Calibration of the full consumption aggregate $v(\cdot)$ which is the argument of momentary felicity uses prices and quantities of leisure and of the commodity index. Aggregate consumption of leisure is $N^0 - \sum_{i=1}^{n} L_i^{d,0}$, i.e. total time endowment less the amount of time spent at work. The price of leisure is the net wage rate or, equivalently, the amount of income foregone by not working. The net wage is obtained from the unit convention and the benchmark social security and income tax rates (see below). Calibrating the share of consumption in full income, α, is straightforward, and the price index $p^{v,0}$ of the full consumption index is readily obtained. The present model implementation denominates financial assets in units of the commodity bundle for private consumption, $\bar{p} \equiv p^c$.

The static calibration of the value added production parameters requires knowledge of capital stocks which at the same time must satisfy certain dynamic relationships. The data set does not allow a unique calibration of all intertemporal parameters which forces one to rely on informed guesses in addition to "hard facts". As regards dynamic calibration of investment and capital stocks, the crucial point is that I^0 has to be consistent with the steady state restrictions on the equation of motion for capital stocks and the Euler condition for optimal accumulation. Omitting time indices to denote steady state values, the necessary conditions in (20) imply $(r+\delta)q_i\bar{p} = (1-t_y)\tilde{p}_i(F_{iK} - \Phi_{iK})$. Substituting from the installation cost function and the first order condition for investment gives

[20] See Mansur and Whalley (1984) or Ballard et al. (1985) for a detailed description of this procedure. Other categories of demand are calibrated in a perfectly analogous way. Appendix table A1 gives specific functional forms while tables 6.2 and 6.3 contain various calibrated share parameters.

Table 6.3: Share Parameters							
Sector		$\xi_i^{c,m}$	$\xi_i^{I,m}$	$\xi_i^{G,m}$	κ_i^c	κ_i^I	κ_i^G
1	Agr/For	0.348	0.170	0.207	0.062	0.006	0.004
2	Min/Quar	0.655	0.000	0.263	0.004	0.001	0.002
3	Food	0.050	0.000	0.024	0.165	0.000	0.004
4	Tex/Clot	0.446	0.131	0.431	0.100	0.003	0.002
5	Wood	0.351	0.026	0.276	0.032	0.045	0.004
6	Paper	0.527	0.000	0.428	0.015	0.001	0.008
7	Chemic	0.558	0.022	0.498	0.025	0.007	0.020
8	Petrol	0.167	0.133	0.145	0.041	0.000	0.006
9	Nonferr	0.474	0.026	0.231	0.004	0.028	0.002
10	MetProd	0.587	0.418	0.314	0.007	0.015	0.003
11	MetProc	0.542	0.560	0.436	0.109	0.314	0.023
12	Energy	0.000	0.000	0.000	0.025	0.017	0.016
13	Constr	0.000	0.000	0.000	0.014	0.456	0.036
14	Trade	0.000	0.000	0.000	0.165	0.065	0.042
15	Hot/Cat	0.000	0.000	0.001	0.038	0.001	0.003
16	Trans	0.000	0.000	0.000	0.039	0.017	0.032
17	RealEst	0.000	0.000	0.000	0.084	0.000	0.020
18	OthSer	0.000	0.000	0.000	0.056	0.023	0.132
19	Public	0.000	0.000	0.000	0.016	0.002	0.640

$$\begin{aligned}
&(a) \quad \tilde{p}_i F_{iK}\left(\tfrac{K_i}{1+\bar{g}}, L_i^d\right) = uc_i(\cdot), \quad \text{where} \\
&(b) \quad uc_i(r,\psi,\delta,x,n,t_y,e) \equiv \tilde{p}_i \Phi_{iK} + (r+\delta)\left[\tilde{p}_i \Phi_{iI} + \frac{1-et_y}{1-t_y} p^I\right].
\end{aligned} \tag{36}$$

uc_i is the *steady state* user cost of capital which must be equal to the marginal value product of capital in every sector. Even though adjustment costs vanish in the steady state, the derivatives of $\Phi(\cdot)$ do matter for the *steady state* user cost of capital. The steady state derivatives, however, depend only on the stationary investment to capital ratio equal to $\bar{g}+\delta$. ψ is an installation cost parameter determining the sensitivity of investment demand with respect to Tobin's q. The appendix table A2 gives the specific functional form of uc_i. Moreover, $p^{I,0}$ results from static calibration. By the unit price convention, $\tilde{p}_i^0$ is unity. Hence, sectoral capital stocks have to satisfy the following equation with the right hand side given by the benchmark data:

$$uc_i(\cdot) K_i^0 = \tilde{p}_i^0 F_{iK}^0 K_i^0. \tag{37}$$

The parameters in the argument of $uc_i(\cdot)$ have not yet been specified. Setting their values determines user costs and, therefore, sectoral capital stocks. However, through n equations of the form (18), these capital stocks must also be consistent with steady state sectoral investment demands. Summing across all sectors gives the aggregate demand for the composite capital good I^0 which is given from static calibration:

$$I^0 = \sum_{i=1}^{n} (\bar{g}+\delta) K_i^0. \tag{38}$$

One of the seven parameters $r, \psi, \delta, x, n, t_y, e$ is used up to ensure that the two restrictions for stationary capital stocks hold simultaneously. Hence, six degrees of freedom are left for further use. Their choice is partly determined by considerations on the dynamic calibration of the household sector. Some of them are assigned values that were judged to be plausible. Given these other choices, x is then calibrated to satisfy the steady state restrictions on capital stocks. Table 6.4 lists the base case parameterization. The numerical value for ψ corresponds to the estimates of Summers (1981). Notice that the parameters satisfy $\bar{g} < r$ which is the condition for dynamic efficiency. Given capital stocks, calibration of the remaining parameters on the production side is straightforward. Extraneous information yields values for the substitution elasticities while the unit convention together with the benchmark data yields labor demands, gross wage rates and the quantity of sectoral value added output. Next, take the ratio of the marginal productivity conditions (19) and (36a) to calculate the share parameter of the value added production function $F(\cdot)$. Finally, the output computed by the value added function must be identical to the value added product implied by the data which determines the scale parameter. The only remaining parameters relating to the production technology are the input–output coefficients of the top level production function. By the unit price convention, revenues and intermediate costs are identical to output and intermediate input quantities. Hence, the input–output coefficients are easily obtained by deviding intermediate inputs Q_{ji}^0 and the value added product F_i^0 by gross outputs Y_i^0.

Consider next the dynamic aspects of household sector calibration. In models with an infinitely lived consumer, the subjective discount rate ρ immediately follows from the steady state restriction on the household consumption profile once the world interest rate i^* has been chosen. The OLG structure, however, precludes such a strategy for the simple reason that the steady state restriction need not apply for individual generations.[21] Instead, we infer the parameters from the aggregate consumption function. Evaluate the propensity to consume (13b) in a steady state, substitute into (12) and compute

$$\beta = \left[\left(1 - \frac{p^v v}{\bar{p}\mathcal{W}}\right) \left(\frac{1+r}{1+x}\right)^{1-\gamma} \frac{1}{1-\theta} \right]^{1/\gamma}. \tag{39}$$

At this stage, the benchmark values for $p^v, v, \bar{p}, r, x$ are known from previous calibration results while γ as well as θ are exogenously specified. Absent any more precise information, $\theta = .06$ is considered a plausible value, and this parameter, too, is an important candidate for sensitivity analysis. All that remains is to calculate the benchmark value of total wealth $\mathcal{W}$. From equation (12b), $\mathcal{W}^0$ can easily be related to the benchmark flow magnitudes by using the steady state versions of (11) and (13a). Once the factor β is calculated, the subjective discount rate ρ follows from the definition in (4). The next step is to calculate the benchmark value of the income tax deduction d. Given the income tax rate which was fixed at $t_y = 0.2$, and the model definition of the tax base, the deduction is chosen to yield the benchmark value of the direct tax bill.

The scale parameters of the export demand functions are calculated such that benchmark exports follow from the prespecified export demand elasticities. Calibration is completed by calculating net

[21] See also Engel and Kletzer (1990, p. 75).

Table 6.4: Intertemporal Parameters			
Basic Parameters		Value	Method
Productivity growth rate	x	0.025	calibrated
Population growth rate	n	0.010	specified
Total growth rate	$\bar{g}$	0.035	calculated
Subjective discount rate	ρ	0.004	calibrated
Probability of death	θ	0.060	specified
Discount factor	β	0.989	calculated
Intertemp. subst. elasticity	γ	0.800	specified
Top level consumption share	α	0.722	calibrated
Real interest rate	r	0.055	specified
Depreciation rate	δ	0.150	specified
Adjustment cost parameter	ψ	10.000	specified
Investment expensing rate	e	0.400	specified
Income tax rate	t_y	0.200	specified
Personal tax deduction	d	16.599	calibrated

foreign assets and government debt as implied by the benchmark flow data. This step relies on the steady state versions of the relevant equations of motions given in (32). We present the details of this procedure in the form of several accounts in the separate appendix. In the wealth related flows, i denotes the interest rate gross of income tax. Notice also that all variables are expressed per efficiency unit of the current period. Thus, since interest is being paid on a stock inherited from the previous period, gross interest payments on benchmark government debt per contemporaneous efficiency units are $iD^G/(1+\bar{g})$. Similarly, new debt issue per current efficiency unit is $D^G - D^G/(1+\bar{g}) = \bar{g}D^G/(1+\bar{g})$ and is calculated from the flow data. Similar remarks hold for all other assets. As a final point, note that foreign debt and government debt are expressed in nominal terms, whereas firm values and total financial wealth are in real terms, hence $D^{F,0} + D^{G,0} + V^0\bar{p}^0 = A^0\bar{p}^0$.

Having completed calibration, we would like to add a few methodological remarks. Calibration of an intertemporal CGE model amounts to effectively interpreting a given historical situation as a steady state equilibrium. Needless to say that such an interpretation of data is a rather delicate thing. It must be emphasized that the whole procedure is not meant to imply that the real world economy was anywhere near such an equilibrium in the benchmark year. How, then, should our computational model be interpreted? In our view, it is essential to point out that models like the present one can claim to be empirical models only to a limited extent. They can perhaps be seen as taking a position somewhere inbetween stylized analytical models and truly empirical work. The difference to the former is that CGE models incorporate much detail which would inevitably be missing if analytical tractability were to be retained and which is arguably an essential ingredient of real world policy effects. At the same time they take recourse to empirical information. The most important difference to econometric work is that the model is not subject to any empirical test. As a result of this, the policy effects calculated should not, in our view, be regarded as anything like econometric forecasts. The CGE approach gives an enriched neoclassical model that is capable of reproducing certain features of a real world economy. It may be used to simulate possible consequences of alternative policy scenarios and to evaluate the attractiveness of rivaling policy options on the basis of household sector welfare.

7 An Application to Commercial Policy

We now proceed to an illustrative application of our model to the case of commercial policy. For shortage of space, we restrict ourselves to comparative steady state computations and focus on a very simple scenario: a reduction of all tariff rates from their benchmark values to zero. A more detailed analysis of commercial policy scenarios, including adjustment paths and welfare effects under different implementation scenarios will follow in a separate paper.

7.1 On the Macroeconomics of Commercial Policy

Before going into the details of the numerical results we put our simulation exercise into perspective by looking at the relevant analytical literature. Since one of the most important aspects of our model is its rigorous "macro–closure" and since the static micro effects of tariffs are much better understood, we concentrate on the macroeconomics of protection (or liberalization). The traditional literature has largely focussed on the Harberger–Laursen–Metzler effect to show how a tariff affects output and the trade balance within a Keynesian model featuring unemployed resources and rigid nominal prices. Krugman (1982) has surveyed this literature which appears to conclude that with a flexible exchange rate protection is contractionary. The clue to this result, which some people have found "counterintuitive" or "almost inconceivable", lies with the fact that a currency appreciation will over–compensate the terms of trade deterioration caused by a tariff, thus leading to an increase in hoarding (Harberger–Laursen–Metzler effect) with a depressing effect on output.[22]

Our model takes a view which is different from this traditional one in almost all important aspects. First, any expansionary or contractionary effect reported below does not rest on the questionable Harberger–Laursen–Metzler effect but on intertemporal optimization instead. Second, tariff effects do not depend on any form of price rigidity and associated unemployment. This point is related to the fact

[22] It should be noted, however, that there are other channels in addition to the Harberger–Laursen–Metzler effect, operating through the money market, which reinforce the contractionary effect of tariffs in Keynesian models [see Chan (1978), Eichengreen (1981), and Krugman (1982)]. On the other hand, introducing portfolio balance considerations into such models does generate a certain expansionary potential of a tariff. In Eichengreen (1981), this is shown to be restricted to the short–run, whereas in the long–run the depressing effect prevails.

that there is no monetary sector and the exchange rate does not play any role in our model.[23] Finally, we have a whole structure of protection rather than a single tariff rate and the expansionary/contractionary effect of removing this structure of protection is different, even in its direction, in different sectors. Thus, contrary to the view taken by Krugman (1982), an expansionary effect of tariff liberalization in the present context does not mean increased output by using previously unemployed resources at unchanged nominal prices. Instead, expansion takes place through an increase in the sectoral physical capital stocks which is the result of investment decisions reacting towards changes in relative prices, and by using more labor, the supply of which is similarly called forth by changes in relative prices. This difference cannot be overemphasized when interpreting our results. In particular, there is no relationship, whatsoever, between the contractionary/expansionary effects reported below and the notion of aggregate demand management through commercial policy which is quite frequently maintained in developed as well as developing countries. Our model economy is one in which any such notion would simply never be maintained since all prices are perfectly flexible and output is not demand determined.

There is widespread agreement that assuming an absolute nominal price rigidity is unsatisfactory. Accordingly, some of the traditional literature, such as for instance Eichengreen (1981), has weakened this assumption by introducing price stickiness (instead of absolute rigidity) along the lines suggested by Dornbusch. This allows a distinction between the short– and the long–run which is arguably very important for policy analysis. Models of this type involve the notion of some exogenous full employment, or natural, level of real output. Again, our model is different in that this full employment level of (sectoral) output is endogenously determined. At the same time the present assumption of complete price flexibility does not preclude the distinction between short–run and long–run effects. In our case, this distinction rests on intertemporal decision making subject to the existence of installation costs for physical capital, and on an explicit treatment of the relationships between assets and corresponding flows.

Of course, our model setup which essentially combines macroeconomics with intertemporal microeconomics under completely flexible prices, is by no means new. Indeed, during the past decade, the traditional literature of the Keynesian kind has been supplemented, and to some extent supplanted, by a whole strand of new analytical models focussing on dynamic adjustment to terms of trade changes or tariffs within an intertemporal optimization framework. Our model evidently draws on this literature, and a brief review of the most important analytical results may add to the motivation for our simulation approach and help interpreting our results.

The analytical study coming closest to our simulation model is Sen and Turnovsky (1989), henceforth called ST. They assume an infinitely lived household instead of an OLG structure, but otherwise their model is a highly stylized version of ours. The household consumes two goods, an exportable and an imported good, and the domestic economy is completely specialized on the exportable, with a downward sloping export demand function. As in our model, firms maximize the present value of future profits subject to convex installation costs for investment, but capital consists of the home produced good

[23]Nominal price rigidities play an important role in the dynamic model of Eichengreen (1981), where it takes the form of a fixed or sticky nominal wage rate.

only. ST linearize the model and obtain thereby a system of differential equations describing the local deviations of the economy from an initial stationary equilibrium. Their analytical solutions show the current account effect to be theoretically ambiguous. Given the restrictiveness of the model, this is quite remarkable, and it clearly establishes a case for pursuing a simulation approach.[24] On the other hand, ST establish an unambiguous contractionary effect of a tariff on the capital stock, thus reinforcing the "almost inconceivable" results of the Keynesian literature. It must be emphasized, however that the ST contractionary effect comes about through an entirely different channel, the crucial point of which is a decrease in labor supply caused by substitution away from commodity consumption towards leisure. The question then remains whether this effect will hold up in every sector if sectoral disaggregation is introduced into the model. Our results reveal that this is not the case which gives a further reason for going into simulation studies.

The ST model squarely puts the emphasis on macroeconomic effects by assuming that the home economy produces only one good.[25] Gavin (1991) has pointed out that microeconomic, or reallocation effects play a very important role for the current account adjustment to the imposition or removal of a tariff. He emphasizes that, whenever the reaction of the production side of the economy (reallocation) to a permanent tariff takes time and recources, consumption smoothing driven by intertemporal optimization on the part of households will have temporary current account effects with an associated change in steady state foreign assets.[26] In addition, if relative prices are endogenous, any difference between the short–run and the long–run response of the production sector to a permanent tariff will cause changes in relative prices during the adjustment path which, in turn, will induce intertemporal substitution on the part of the consumer. This establishes a further channel through which a change in tariffs may cause temporary current account effects and, thus, affect the steady state level of foreign assets.[27] For a model without any factor accumulation and only two goods produced domestically, Gavin (1991) shows that the imposition of a tariff will lead to a temporary current account surplus and an increase in the steady state level of foreign assets. However, with a richer production structure as in our computational model, the intertemporal relative price effects are no longer unambiguous. Furthermore, while the effects pointed out by Gavin are undoubtedly very important, abstracting from accumulation is a disturbing restriction. Foregoing analytical tractability for the sake of simulation allows us to have both, the Gavin effects as well as the accumulation effects stressed by ST. Our model, however, is different from Gavin (1991) in that reallocation of capital does not take place along the lines first suggested by Mussa (1978) but through sectoral depreciation and investment instead. Still, costly and time consuming adjustment, the essential ingredient of the Gavin effects, is a prominent feature of our model.

[24] One of the reasons for this indeterminacy is that the ST model endogenizes the relative price of the exportable. Relative price effects of this kind also play an important role in our simulation model.

[25] So does Eichengreen (1981), which is more in the Keynesian tradition inasmuch as price stickiness rather than intertemporal optimization is the driving force behind the expansionary/contractionary effect of a tariff.

[26] This effect has also been stressed by O'Rourke (1989). Razin and Svensson (1983) have pointed out that, in the absence of such time consuming adjustment of the production side of an economy, current account effects of a permanent tariff can only be caused by intertemporal non–homotheticicities of consumer preferences.

[27] This channel is also a key aspect in Gavin's (1990) analysis of the adjustment to a terms of trade disturbance.

Sen and Turnovsky as well as Gavin model household behavior by means of dynastic preferences, i.e., by assuming an infinitely lived representative household. By way of contrast, our model features overlapping generations with uncertain lifetimes. Recent literature has pointed out that additional intertemporal effects of a tariff are present in models with overlapping generations. These effects operate via income distribution changes such as might be brought about by the well known factor price effects of protection or by a particular redistribution scheme for the government revenues from tariffs. Engel and Kletzer (1990), henceforth called EK, investigate intergenerational income distribution channels under overlapping generations with uncertain lifetimes in a two goods model without any accumulation where current account effects are equal to savings effects. They show that, in the simplest possible case where there is no home production of the importable, a tariff can be viewed as a tax on total wealth whereas a lump sum redistribution of the tariff revenue is equivalent to a subsidy on human wealth only. In models like ours with a perfectly competitive insurance sector, the tax on wealth is capitalized by the presently living generations to a much greater extent (if financial wealth is positive) than are future income transfers because the latter have to be shared with generations that are not yet borne. Formally, this difference can be seen by the fact that financial wealth A and human wealth H follow different laws of motion [equations (11) and (13a)]. Hence, on balance, tariffs redistribute income from present towards future generations. Present generations see their wealth decreased as a result of the tariff and, consequently, spend less. The current account improves [see Engel and Kletzer (1990, pp. 78–83)].

In addition to the revenue distribution effect of a tariff, EK also point out an intertemporal effect of factor price changes which are usually attendant upon a tariff in a general equilibrium model of diversified economies. Ever since the famous paper by Stolper and Samuelson, indeed ever since Ricardo's "Principles", the impact of protection on factor incomes has been at the heart of the theory of protection. But while in Ricardo's times the interest was on the growth effects of changes in income distribution, the modern theory of protection has restricted its attention to the static effects and its consequences for the political process. Why, then, should changes in factor incomes have current account effects in an intertemporal optimization framework? In intertemporal models spending is driven by changes in total wealth but factor price changes feed differently into the labor and non–labor components. Because of the insurance sector, future non–labor income is capitalized with a lower discount rate than is future labor income. As with future transfers due, for instance, to lump sum redistribution of tariff revenues, future increases in labor income resulting from factor price changes will only partially be reflected by an increase in human wealth of present generations. The reason is that part of future labor income will be received by generations not yet borne and, thus, cannot contribute to human wealth of presently living generations. By way of contrast, any increase of future dividends will be fully capitalized by an increase in firm values held by presently living generations. The presence of a competitive insurance sector allows individuals with uncertain lifetimes to fully transfer claims on tangible wealth into present command over resources. As a result of all this, any increase in the real wage rate will also redistribute wealth from presently living to future generations. If this is a pure redistribution effect, i.e., if it is not combined with the introduction or removal of a distortion changing the overall level of wealth, then there will be an unambiguous improvement of the current account. However, whether the imposition or removal of a tariff will increase or decrease the real wage rate depends on the details of the production structure, such as the degree of factor mobility as well as such parameters as primary factor substitution elasticities and factor intensities.[28] From the present perspective, then, the intertemporal factor price effect of a tariff is ambiguous which provides further motivation for the simulation approach pursued in this paper.

An important parallel between our model and many analytical models such as, for instance, Sen and Turnovsky (1989) and Eichengreen (1981) is the assumption that imported goods are not produced domestically. Consequently, tariffs do not constitute a production distortion. No potential for production gains may be reaped in removing tariffs or, for that matter, of introducing "large" tariffs. This is in sharp contrast to the traditional theory of protection and, quite obviously, it is rather important for welfare considerations which will be the subject of a subsequent paper. If production is assumed to be diversified, analytical models often rule out production distortions by assuming that a "small" tariff is introduced starting from a zero tariff initial equilibrium (in which case any distortionary effects are of second order). By way of contrast, our analysis starts with a protection situation and investigates "large" tariff reductions. We regard this as an important advantage. Investigating "large" tariff reductions appears to be more relevant, empirically, than focussing on the imposition of a "small" tariff starting from a free trade equilibrium.

7.2 Numerical Results: Steady State Effects

The scenario that we report in the present paper is a complete tariff liberalization. Column one of table 7.1 reports the benchmark values of tariff rates. Following Frenkel and Razin (1987, chapter 6), we set $\bar{p} = p^c$ to express all real variables in terms of the consumption basket C. Furthermore, the policy keeps the real value of initial government debt constant. Our results complement the existing evidence on the economic effects of Austrian tariff protection derived from static approaches [see Kohler (1991a,b), and Breuss and Tesche (1991)].

Even in complex models with a rich economic structure, the numerical solutions consistently reflect the host of simultaneous interdependencies involved. While this is undoubtedly a strength of the numerical approach, the complexity also makes interpretation of the results somewhat tricky. It should be possible, however, to identify the main channels for policy effects and to provide an intuition for the results. We try to do so in a stepwise procedure by first focussing on the various substitution effects on the demand and the supply side under notionally unchanged dynamic variables, and then looking at the intertemporal effects operating through changes in dynamic variables. The distinction is artificial and serves only to disentangle different aspects of the long-run adjustment of the economy.

As regards the immediate price effects on demand, note first that the tariff recuction increases prices of home goods relative to their competing imports, thereby inducing substitution effects towards imports within all categories of demand. Consumption, for example, is modelled via a multi-level utility nesting.

[28]For a similar line of argument, see Matsuyama (1988) where the intertemporal effect of factor price changes is accentuated by the fact that individuals face certain lifetimes.

Table 7.1: Demand and Price Effects of Tariff Reductions (in %)							
Sector		$t^0_{m,i}$ (aver.)	C^d_i	C^m_i	I^d_i	I^m_i	p_i
1	Agr/For	6.758	-1.520	5.527	0.099	9.518	-2.048
2	Min/Quar	1.280	0.082	2.512	0.220	0.000	-1.923
3	Food	5.384	-0.752	2.534	0.472	0.000	-2.169
4	Tex/Clot	4.922	-1.616	3.770	0.369	6.547	-2.169
5	Wood	2.648	-0.907	-0.380	0.382	1.654	-2.081
6	Paper	3.316	-0.706	-0.785	0.570	0.000	-2.265
7	Chemic	2.261	-1.156	1.010	0.206	3.424	-1.913
8	Petrol	1.751	-1.914	4.993	-0.633	8.361	-1.128
9	Nonferr	2.911	-1.742	2.831	0.301	3.561	-2.006
10	MetProd	1.720	-0.576	-2.504	-0.353	2.233	- 1.787
11	MetProc	2.536	-1.325	-0.022	0.113	0.764	-1.977
12	Energy	0.000	-1.164	-1.974	0.147	0.000	-1.852
13	Constr	0.000	-0.951	0.000	0.342	0.000	-2.043
14	Trade	0.000	-0.928	0.000	0.366	0.000	-2.066
15	Hot/Cat	0.000	-0.932	0.000	0.362	0.000	-2.062
16	Trans	0.000	-1.068	0.000	0.224	0.000	-1.928
17	RealEst	0.000	-0.936	0.000	0.000	0.000	-2.058
18	OthSer	0.000	-0.974	-1.177	0.092	-0.113	-2.029
19	Public	0.000	-0.872	0.000	0.423	0.000	-2.122

This preference structure implies that the bottom level price effects just mentioned also feed into upper level price indices. This, in turn, causes upper level quantity effects that look like income effects if viewed from the bottom level. Tariff reductions will ultimately affect labor supply by making the top level commodity bundle cheaper relative to leisure. Holding total wealth as well as the nominal wage rate constant for the moment, the immediate effect of tariff reductions will be to increase the real price of full consumption $p^v/\bar{p}$ since price indices always decrease less at higher levels of aggregation than at lower levels (remember, $\bar{p} = p^c$). Since the marginal propensity to consume is constant across steady states, full consumption v decreases by this reason. The reduction in full consumption operates like a negative income effect at the next lower level and depresses commodity consumption as well as leisure. In the case of labor supply the top level income effect and the lower level substitution effect reinforce each other whereas they are of opposite directions in the case of commodity consumption. Hence, the effect on aggregate commodity consumption, C, is a–priori indeterminate. Our results show that, in all sectors except mining/quarrying, the aggregate consumption effect is not sufficient to fully compensate for the bottom level substitution effect away from home produced to imported goods (see table 7.1). Similar reasoning applies, ceteris paribus, to other categories of demand. Columns 4 and 5 report effects on investment demand.[29] Thus, the initial demand effects of tariff reductions generate an excess supply of domestic goods and labor. Consider, next, the supply response. Assuming, for the moment, unchanged capital stocks and unchanged domestic prices (including the nominal wage rate), lower intermediate

[29]Table 7.1, however, gives general equilibrium results including the dynamic effects that we neglect momentarily.

Table 7.2: Production Effects of Tariff Reductions (in %)							
Sector		K_i	L_i^d	F_i	Y_i	V_i	q_i
1	Agr/For	-0.176	-0.153	-0.173	-0.173	0.176	0.3520
2	Min/Quar	1.230	1.249	1.245	1.245	1.581	0.3515
3	Food	-0.218	-0.188	-0.197	-0.197	0.129	0.3471
4	Tex/Clot	0.663	0.701	0.695	0.695	1.013	0.3494
5	Wood	1.278	1.312	1.302	1.302	1.631	0.3523
6	Paper	0.948	0.982	0.973	0.973	1.299	0.3510
7	Chemic	2.450	2.483	2.472	2.472	2.807	0.3568
8	Petrol	-0.171	-0.152	-0.158	-0.158	0.177	0.3476
9	Nonferr	0.622	0.661	0.648	0.648	0.973	0.3506
10	MetProd	2.489	2.532	2.524	2.524	2.845	0.3559
11	MetProc	1.417	1.440	1.433	1.433	1.770	0.3530
12	Energy	0.242	0.256	0.248	0.248	0.593	0.3512
13	Constr	0.291	0.304	0.299	0.299	0.641	0.3497
14	Trade	0.168	0.205	0.187	0.187	0.518	0.3501
15	Hot/Cat	1.695	1.734	1.715	1.715	2.051	0.3556
16	Trans	0.523	0.561	0.555	0.555	0.872	0.3487
17	RealEst	0.079	0.117	0.092	0.092	0.431	0.3514
18	OthSer	-0.141	-0.104	-0.118	-0.118	0.207	0.3481
19	Public	-0.044	-0.006	-0.014	-0.014	0.303	0.3471

input costs (due to cheaper imported inputs) raise the value added price, $\tilde{p}_i$, and hence the marginal value product of labor. Firms will expand their labor demand and sectoral outputs. Demand and supply effects together unambiguously point to a depressing effect on domestic commodity prices (see last column of table 7.1) and, ultimately, on value added prices $\tilde{p}_i$.

Thus far, we have not considered any change in dynamic variables such as capital stocks. A look at the steady state version of the dynamic optimality conditions [equations (36) above] reveals that the sectoral capital labor ratio is determined, across steady states, by movements of $p^I/\tilde{p}_i$. With unchanged tax rates, the real steady state user cost of capital, $uc_i/\tilde{p}_i$, is entirely dominated by movements of $p^I/\tilde{p}_i$ because Φ_{iK} as well as Φ_{iI} only depend on $(\bar{g}+\delta)$ and, hence, do not change across steady states. $uc_i/\tilde{p}_i$ increases with $p^I/\tilde{p}_i$, and so does the marginal product of capital. Hence, the capital labor ratio falls. In our case the capital labor ratio falls throughout all sectors (compare column one of table 7.3 with the change in p^I reported in table 7.4). Capital stocks, however, need not necessarily be lowered. The majority of sectors, to the contrary, feels an expansionary effect driven by the labor market which is sufficient to allow a decrease in the capital labor ratio being accompanied by an increase in the capital stock. This expansionary effect is precisely the one pointed out by Sen and Turnovsky (1989). However, the effects differ quite substantially across sectors. Indeed, a few sectors experience a contraction (see columns one through 4 of table 7.2). From tables 3 and 4 we infer that both price ratios on the right hand side of (20a) increase. Therefore, the shadow value of capital rises as well. Column 5 of table 7.2 shows, interestingly, that it rises suffiently for firm values to increase throughout, even in contracting sectors.

Table 7.3: Value Added Effects of Tariff Reductions (in %)						
Sector		$\tilde{p}_i$	$\tilde{p}_i F_i$	χ_i	$L_i^d w^g$	$p^I I_j$
1	Agr/For	-2.096	-2.265	-2.264	-2.278	-2.263
2	Min/Quar	-2.122	-0.903	-0.893	-0.907	-0.887
3	Food	-2.119	-2.311	-2.310	-2.313	-2.304
4	Tex/Clot	-2.122	-1.443	-1.448	-1.443	-1.441
5	Wood	-2.119	-0.844	-0.845	-0.845	-0.839
6	Paper	-2.120	-1.167	-1.168	-1.168	-1.162
7	Chemic	-2.117	0.303	0.303	0.301	0.308
8	Petrol	-2.117	-2.272	-2.263	-2.278	-2.258
9	Nonferr	-2.116	-1.482	-1.487	-1.482	-1.481
10	MetProd	-2.122	0.349	0.340	0.349	0.347
11	MetProc	-2.118	-0.715	-0.708	-0.720	-0.703
12	Energy	-2.107	-1.864	-1.857	-1.878	-1.853
13	Constr	-2.115	-1.822	-1.810	-1.832	-1.805
14	Trade	-2.111	-1.928	-1.931	-1.928	-1.926
15	Hot/Cat	-2.110	-0.432	-0.435	-0.432	-0.431
16	Trans	-2.123	-1.580	-1.585	-1.580	-1.578
17	RealEst	-2.103	-2.014	-2.016	-2.014	-2.013
18	OthSer	-2.115	-2.230	-2.234	-2.231	-2.229
19	Public	-2.122	-2.135	-2.140	-2.135	-2.134

Table 7.3 combines the quantity effects on value added with the price effect and shows that, due to lower value added prices, value added in nominal terms has fallen in all but the two most expansionary sectors. Thus, we see that focussing on value added gives a picture which is entirely different from that of table 7.2 where the focus is on quantities. Table 7.3 also gives changes in the different uses of value added.

We have seen above that the commodity price effects cause increased labor supply as well as increased aggregate labor demand. The general equilibrium effect on the wage rate is shown to be negative in table 7.4 but less so, proportionally, than the commodity price index. Hence, the real wage rate $w/\bar{p}$ increases slightly. However, in our model consumption is not determined by the real wage but by real wealth. By the definition of labor income in (6a), human wealth is determined not only by real wages but also by government transfers. The latter, in turn, depend on the loss of tariff revenue and on how price changes affect government expenditure. In addition, any decrease in $\bar{p}$ will increase real government debt which we want to be the same in the final as in the initial equilibrium. As is apparent from the decrease in government transfers in table 7.4, lower prices for a constant aggregate government procurement cannot fully compensate for the price effect on real government debt plus the loss of tariff revenue. We observe a significant fall in real disposable labor income $y/\bar{p}$ as a result of tariff reductions. The steady state version of (13a) immediately shows that, in a small open economy with fixed interest rates, human wealth must decrease by the same proportional amount as does real disposable income. Moreover, it can be shown that financial wealth A, the real full consumption basket $M^v/\bar{p}$, and the consumption aggregate C as well as leisure all change by the same proportion. Thus, we conclude that the "second round" effect of

Table 7.4: Aggregate Effects of Tariff Reductions (in %)		
wage rate	w	-2.129
commodity price index	$p^c = \bar{p}$	-2.436
full consumption price index	p^v	-2.351
price of capital aggregate	p^I	-2.091
government transfers	z	-5.703
disposable income	$y/\bar{p}$	-0.553
human capital	H	-0.553
financial capital	A	-0.553
primary household savings	S^H	-0.553
real full consumption	$M^v/\bar{p}$	-0.553
labor supply	L^s	0.576
firm values	$\sum_j V_j$	0.742
real foreign debt	$D^F/\bar{p}$	4.506
real trade balance	$S^F/\bar{p}$	4.506

tariff reductions, based on the dynamic features of our intertemporal model, is depressive on commodity consumption and, at the same time, reinforcing the "first round" expansionary effect on labor supply. The depressing effect on commodity consumption even leads to decreased import demand within some sectors (see table 7.1), and it also reinforces the tendency of domestic goods prices to decline.

In the light of the discussion in the previous subsection, we finally investigate the effects of tariff reductions on the trade balance and foreign debt. As is evident from table 7.2, the economy accumulates capital stocks on average, although not in every sector individually. Even though the present model differs on the household side, our empirical result is in line with Sen and Turnovsky (1989). ST, however, find an ambiguous effect on the foreign asset position. The present simulation exercise suggests that tariff liberalization increases real foreign indebtedness, see table 7.4. That the new steady state level of real foreign indebtedness must be higher than the old one can also be inferred from the fact that real firm values increase while financial wealth as a whole falls in real terms. Since real government debt was held constant by virtue of our policy design, the stock of foreign assets (which was already negative in the benchmark equilibrium to begin with) is run down in real terms. We abstain in this paper from characterizing the adjustment path in any depth, but we can nevertheless conclude from the change in foreign debt that there must be extended periods of current account deficits during the adjustment path. Hence, the Gavin effects mentioned in the preceding subsection are confirmed even though our computational model incorporates additional features that are not present in the Gavin model. Finally, table 7.4 shows that an increased level of foreign indebtedness requires an increased trade balance to service new debt in the long–run equilibrium.

8 Concluding Remarks

Researchers using disaggregate empirical general equilibrium models to estimate the quantitative effects of commercial policy scenarios tended to downplay the impacts of these policies on savings and investment flows. Potential effects on the current account and foreign indebtedness were largely ignored and put into the realm of macroeconomics where they usually were analysed within Keynesian type models. CGE modellers emphased microeconomic effects and, accordingly, tended to view the "macro–closure" issue as a nuisance more than an integral part of the problem under investigation. More recently, however, macroeconomics experienced a shift in paradigm and increasingly adopted intertemporal optimization as a behavioral hypothesis. With investment and savings flows being modelled by means of intertemporal optimization, new channels have been explored through which such policies as the introduction or removal of tariffs might affect the current account and the level of foreign assets under capital mobility. The incorporation of the intertemporal approach into large scale simulation models has, however, been somewhat slow which is surprising in face of the renewed interest in macroeconomic effects of trade liberalization. Given the restrictiveness of the analytical models available and the ambiguities of their results, empirical simulation models seem to be a welcome tool to complement purely analytical techniques.

The paper presented a multi–sector CGE model incorporating forward-looking savings and investment decisions derived from intertemporal optimization. The model, thus, incorporates a rigorous "macro–closure" which enables it to capture the intertemporal aspects of commercial policies. We laid down the structure of the model including a detailed description of the short– and long–run equilibium conditions and commented on the solution strategy employed in the simulation exercises. Furthermore, we explained in the necessary detail how the model is calibrated to Austrian data. When applying the model to commercial policy we restricted ourselves to the steady state effects of complete tariff liberalization. A more detailed analysis of alternative policy scenarios including adjustment paths and welfare analysis will follow in a separate paper.

The most important aspects of our results are the following. Although tariff liberalization has an overall expansionary effect on capital stocks, labor supply and sectoral outputs, marked differences occur across sectors with some sectors actually experiencing a contraction. This is particularly important because it shows that expansionary/contractionary effects as pointed out by analytical models need not hold up in all sectors individually. Such diverse sectoral implications create a strong case for pursuing a simulation approach to complement the purely analytical analysis of stylized theoretical models. Moreover, the expansionary effect is linked in a crucial way to endogenous labor supply. Interestingly enough, firm values are shown to be increasing in all sectors including those experiencing a fall in output and capital stocks. Furthermore, we discussed that stylized analytical models find the effects of tariff liberalization on the current account to be theoretically ambiguous. Our simulation study creates evidence for increased foreign indebtedness. Capital accumulation requires increased investment, and this, together with the substitution effects towards imports in all categories of demand plus intertemporal smoothing of consumption demand, causes extended periods of current account deficits during the adjustment path.

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9 Appendix: Functional Forms

Table A1: Functional Details of Final Demand

Bottom Level: Imports versus Home Goods	
Sub–Utility (Sub–Aggregate)	$C_i = \left[\xi_i^{c,m} C_i^{m[(\sigma_i^m-1)/\sigma_i^m]} + (1-\xi_i^{c,m}) C_i^{h[(\sigma_i^m-1)/\sigma_i^m]}\right]^{\sigma_i^m/(\sigma_i^m-1)}$
Unit Expenditure Function	$p_i^c = \left[\xi_i^{c,m} p_i^{c,m(1-\sigma_i^m)} + (1-\xi_i^{c,m}) p_i^{c,h(1-\sigma_i^m)}\right]^{1/(1-\sigma_i^m)}$
Unit Demand Functions	$c_i^h = \left[(1-\xi_i^{c,m}) p_i^c / p_i^{c,h}\right]^{\sigma_i^m}; \quad c_i^m = \left[\xi_i^{c,m} p_i^c / p_i^{c,m}\right]^{\sigma_i^m}$
For investment and government procurement, simply substitute I and G, respectively, for c. (Notice that the elasticity of substitution does not vary between categories of demand)	
Upper Level: Allocating Consumption and Investment Expenditure across Sectors	
Sub–Utiliy (Aggregate)	$C = \prod_{i=1}^n C_i \kappa_i^c$
Unit Expenditure Function	$p^c = \prod_{i=1}^n (p_i^c/\kappa_i^c)^{\kappa_i^c}$
Unit Demand Function	$c_i = (\kappa_i^c/p_i^c) p_i$
For investment demand, simply substitute I for c.	
Upper Level: Allocating Government Expenditure across Sectors	
Government Preferences	$G = \min\left\{\frac{1}{\kappa_1^G} G_1, \ldots, \frac{1}{\kappa_n^G} G_n\right\}$
Unit Expenditure Function	$p^G = \sum_{i=1}^n p_i^G \kappa_i^G$
Unit Demand Function	$g_i = \kappa_i^G$
Top Level: Allocating Household Budget to Commodities and Leisure	
Sub–Utility	$v = C^\alpha (1-L^s)^{(1-\alpha)}$
Unit Expenditure Function	$p^v = \left(\frac{p^c}{\alpha}\right)^\alpha \left(\frac{w^n}{1-\alpha}\right)^{1-\alpha}$
Unit Demand Functions	$c = \left(\frac{\alpha}{p^c}\right) p^v; \quad h = \left(\frac{1-\alpha}{w^n}\right) p^v$ with $L^s = 1 - vh$

Table A2: Functional Details of Production

Bottom Level: Imported versus Home Produced Intermediate Inputs	
Input Aggregate	$Q_{ij} = \left[\xi_{ij}^{Q,m} Q_{ij}^{m[(\sigma_i^m-1)/\sigma_i^m]} + (1-\xi_{ij}^{Q,m}) Q_{ij}^{h[(\sigma_i^m-1)/\sigma_i^m]}\right]^{\sigma_i^m/(\sigma_i^m-1)}$
Unit Expenditure Function	$p_i^Q = \left[\xi_{ij}^{Q,m} p_i^{Q,m(1-\sigma_i^m)} + (1-\xi_{ij}^{Q,m}) p_i^{Q,h(1-\sigma_i^m)}\right]^{1/(1-\sigma_i^m)}$
Input–Output Coefficients	$a_{ij}^h = \left[(1-\xi_{ij}^{Q,m}) p_i^Q / p_i^{Q,h}\right]^{\sigma_i^m} a_{ij}; \qquad a_{ij}^m = \left[\xi_{ij}^{Q,m} p_i^Q / p_i^{Q,m}\right]^{\sigma_i^m} a_{ij}$
Bottom Level: Value Added	
Value Added Product	$F_j = \phi_j \left[\eta_j L_j^{d[\mu_j-1)/\mu_j]} + (1-\eta_j)[\frac{K_{j,-1}}{1+\bar{g}}]^{[(\mu_j-1)/\mu_j]}\right]^{\mu_j/(\mu_j-1)}$
Value Added Loss due to Installation Cost	$\Phi_j = \psi \left[\frac{I_j}{K_{j,-1}/(1+\bar{g})} - (\bar{g}+\delta)\right] I_j$
Investment and User Cost of Capital	
Investment Function	$2\psi \frac{1+\bar{g}}{K_{j,-1}} I_j^2 - \left[\psi(\bar{g}+\delta) - 2\psi(1-\delta) - \frac{1-et_y}{1-t_y}\frac{p^I}{\tilde{p}}\right] I_j = \frac{\bar{p}}{(1-t_y)\tilde{p}} V + \left[\psi(\bar{g}+\delta) - \frac{1-et_y}{1-t_y}\frac{p^I}{\tilde{p}}\right] \frac{1-\delta}{1+\bar{g}} K_{j,-1}$
Steady State User Cost of Capital	$uc_j = \tilde{p}_j \psi(\bar{g}+\delta)^2 + (r+\delta)\left[\tilde{p}_j \psi(\bar{g}+\delta) + \left(\frac{1-et_y}{1-t_y}\right) p^I\right]$