

Dynamic Effects of Tax Policy Instruments in West Germany

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I. INTRODUCTION

Over the last two decades computational general equilibrium (CGE) models have become a well established tool for public policy evaluation. They have become especially popular among public finance economists. Although partial equilibrium analysis has proved itself to be a meaningful technique in the field of taxation, the use of a general equilibrium framework seems to be an almost natural application if a coherent description of the full impact of taxation on the private sector is demanded.¹

Recently, increased efforts have been made to incorporate distinctive dynamic features of real world economies into the CGE tax policy models². These attempts are important for at least two reasons. First, there is a wide range of actual tax policy issues that can appropriately be described only within a dynamic framework. The tax treatment of capital income, the taxation of consumer saving, tax reforms attempting to shift the burden of taxes from personal income to personal consumption, and alternative ways of financing the social security system are key issues that all have effects on capital formation and economic growth. Second, a dynamic perspective is also crucial in evaluating the full and

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1. For a survey of the early static applications of the CGE approach to tax policy issues see FULLERTON, HENDERSON, SHOVEN (1984), and SHOVEN, WHALLEY (1984).

2. In formulating dynamic CGE models, two distinct concepts have been employed: a recursive sequence equilibrium approach and an intertemporal equilibrium framework. For a methodological discussion of both approaches see MANNE (1985) and STEPHAN (1989).

lasting impact of tax changes on economic efficiency and individual welfare³. In fact, only CGE models with an explicit dynamic structure are capable of providing a meaningful framework to address short- and long-run effects of particular tax policies simultaneously.

Although the development of dynamic CGE models has provided a much improved theoretical framework for the analysis of several aspects of taxation, dynamic modeling has its own limitations. There are theoretical problems associated with providing an adequate treatment of optimal financial decisions, taking into consideration qualitative differences between capital goods or the modeling of intergenerational links via bequest motives. Also, there are serious limitations with regard to the empirical implementation of such models. The availability of detailed data on individual behavior, on firms and production, on the tax system, and on certain parameters is a limiting factor. Up to now, only few dynamic models have been applied to a rich, actual data set.

So far, only few attempts have been made at developing CGE tax policy models for the Federal Republic of Germany. HIRTE, WIEGARD (1988) and GOTTFRIED, STÖB, and WIEGARD (1990) constructed two small-scale CGE models. By constructing a benchmark data set which incorporates considerable detail on the West German economy, ROSE, KUNGL, and KÜHN (1988) presented for the first time a tax policy model that was applied to actual data. A key drawback of that model results from the fact that it is static and does not even allow investment demand to be satisfied passively by household saving. The only additional contribution has been made by CONRAD, HENSELER-UNGER (1988), who used the framework of a temporary equilibrium model.

The main purpose of this paper is to present a dynamic CGE tax model for the FRG and to calibrate it to actual data. The model here is a less complex variant of a CGE model that is under construction and that will be presented in a later paper. Here, I focus on the general features of such a model. The chosen modeling approach follows in the tradition of contributions made by BALLARD, FULLERTON, SHOVEN, WHALLEY (1985) and GOULDER, SUMMERS (1989). The model contains a multisectoral structure of the West German economy and incorporates in some detail data on household income and expenditure, on intermediate production, on investment, on the government, and on foreign trade. Furthermore, the major instruments of the West German tax system are incorporated. Analytically the basic structure of the model is characterized by assuming forward looking behavior on both the consumption and production side of the economy. As a result intertemporal optimization and allocation processes are fully considered. All plans are formulated in either continuous or discrete time up to an infinite horizon. In particular, it is assumed that the level of consumption is determined by the optimizing behavior of a representative household and that the evolution of investment and production can be derived from the

3. Standing in the tradition of Harberger's analysis of the incidence and efficiency effects of taxes, most of the early static CGE models focussed on potential welfare gains, that could result from the removal of intersectoral distortions. More recently, there is a growing concern with regard to the fact that the elimination of intertemporal distortions may lead to even greater welfare gains, see BOSKIN (1988).

behavior of managers who seek to maximize the value of their firms. Because of the model's rich intertemporal structure, it can be used to study the steady-state impact of tax policy changes as well as their short-run effects. Thereby, it is capable of providing a description of the entire transition path of an economy.

The plan of the paper is as follows. Section 2 lays out the basic structure of the dynamic CGE tax model and describes the household, production, government, and foreign sectors respectively. In section 3 the model's data sources, the adjustment procedures, and the specification of parameters are presented. It contains also some remarks on the solution method. Section 4 reports some preliminary simulation results. The final section of the paper draws some conclusions and suggests avenues for future research.

II. THE MODEL

2.1. The Household Sector

In the context of the CGE approach, life-cycle and infinite horizon models of consumption have extensively been used to build dynamic features into the economic behavior of households⁴. In this chapter I describe a particular version of an infinite horizon model, that can be employed for the determination of aggregate consumption and saving. The entire analysis of the household's consumption decision is conducted in a framework of perfect foresight. Therefore, the households are assumed to base their consumption decisions on correctly projected future factor prices and taxes which will prevail over the entire time horizon under consideration. This implies that these decisions, in the aggregate, generate equilibrium time paths of prices equal to those projected. Thus, there will be no incentives for households to change their behavior in the future and deviate from the optimal path.

The derivation of aggregate utility is based on three major assumptions. First, there exists only a single consumer. By ruling out differences in ages and horizons the need for aggregation is avoided. Furthermore, an interpretation, suggested by BARRO (1974), is to think not of a single infinitely lived individual but of a family or a dynasty of consumers. Therefore, secondly the representative household is assumed to optimize utility over an infinite time horizon, taking into account not only the consumption of its current members but also of its descendants. Finally, for simplicity, the absence of bequests is assumed.

4. Recent discussions started with an widely noticed article by SUMMERS (1981). For CGE models, models which include overlapping generations of life-cycle consumers see e.g. AUERBACH, KOTLIKOFF (1987) and BALLARD, GOULDER (1985). For the second type of model see e.g. ANDERSSON, NORRMAN (1987), BALLARD (1984), BALLARD, GOULDER (1985), and GOULDER, SUMMERS (1989).

The starting point is a simple infinite horizon model with consumption as the only choice variable. The representative household's utility functional is assumed to be additively separable in time:

$$U = \sum_{t=1}^{\infty} \frac{1}{(1+\rho)^{t-1}} U_t(C_t) \quad (1)$$

where C_t is consumption in period t , and ρ is the subjective rate of time discounting, which is assumed to be constant and non-negative⁵. $U_t(\cdot)$ denotes the instantaneous utility or felicity function. The next step is to choose a particular form of the felicity function. A convenient form, commonly chosen, is the iso-elastic form⁶ for which $U'(C) / U''(C)$ is proportional to C , so that:

$$U_t(C_t) = \begin{cases} \frac{C_t^{1-\delta}}{1-\delta} & \text{for } \delta \neq 1 \\ \ln C_t & \text{for } \delta = 1 \end{cases} \quad (2)$$

where δ is the elasticity of marginal utility, which is the inverse of the intertemporal elasticity of substitution. It is defined as:

$$\delta = \frac{-U''(C)}{U'(C)} > 0 \quad \text{all } C \quad (3)$$

Now, the household's lifetime utility can be written, in the non-logarithmic case, as⁷:

$$U = \sum_{t=1}^{\infty} \frac{1}{(1+\rho)^{t-1}} \frac{C_t^{1-\delta}}{1-\delta} \quad (4)$$

Before proceeding with the description of the corresponding constraint of the maximization problem, it is worth pausing to consider the overall consumption in a given period,

5. An argument for assuming a constant rate of time discounting was first provided by STROTZ (1955,56).

6. The iso-elastic form is often chosen as it implies that the optimal path of consumption is simply given by $\frac{\dot{C}}{C} = \frac{(r-p)}{\delta}$, where $\dot{C} = dC / dt$, r denotes the rate of interest and p is the subjective rate of time discounting. See BLINDER (1974,30) for a more detailed discussion.

7. The role of the elasticity of substitution on steady-state capital and on the consumption path is considered in more detail by BLANCHARD (1985).

C_t , in more detail. In each period the representative household purchases several consumer goods. In the model presented here we consider nine specific goods. Thus, the household maximizes an 'intra'temporal utility function in each period, which provides the respective demand functions. Using a Cobb-Douglas form, the overall consumption, C_t , can be expressed as a composite of the consumption of the specific consumer goods according to the fixed Cobb-Douglas expenditure shares. Forming the appropriate indirect utility function and solving for the expenditure function, permits one to create a composite price index, $\bar{p}$, the price of overall consumption, from the individual consumer good prices, p_i . If β_i denotes the Cobb-Douglas expenditure share of consumer good i in overall consumption, the composite price index is⁸:

$$\bar{p} = \prod_{i=1}^9 \left(\frac{p_i}{\beta_i} \right)^{\beta_i} \quad (5)$$

Given the specific form of the household's intertemporal utility function, we now specify the basic constraint that governs the maximization. The accumulation of non human wealth can be described by:

$$W_{t+1} = (1 + R_t)W_t + w_t L_t + T R_t - C_t \quad (6)$$

implying that:⁹

$$C_t \leq W_t + R_t W_t + w_t L_t + T R_t \quad (7)$$

where W_t is the nonhuman wealth of the household in period t and R_t is overall rate of return on nonhuman wealth between period t and period $t+1$. We can subdivide nonhuman wealth and the associated flow of earnings by defining W_t and $R_t W_t$ as:

$$W_t = V_t + B F_t + B G_t \quad (8)$$

$$R_t W_t = \text{DIV } B_t + i_t (B F_t + B G_t) \quad (9)$$

8. For a detailed discussion of the construction of the composite price index see BALLARD, FULLERTON, SHOVEN and WHALLEY (1985).

9. The budget constraint as stated in equation (6) does not prevent the household from borrowing to finance its consumption. Thus, to guarantee that the household will not die in debt, an additional constraint is needed: $W_{T+1} \geq 0$.

where V_t is the value of the existing stock of equity, BF_t and BG_t are the value of the stock of bonds issued by firms and by the government, respectively, and i_t is the market rate of interest. Thus, the two characteristic flows associated with nonhuman wealth are dividends and bond payments. Note, that the calculation of bond interest income simply uses the market rate of interest, whereas the computation of the value of corporate equity involves some risk. We assume a constant risk premium on equity in each industry¹⁰.

Now, it is necessary to give a somewhat modified description of labour income and transfers. Although current labor income and current transfers are each known by the household, we assume that their future streams are in some sense regarded as risky. Therefore, the household discounts these streams at a somewhat higher rate than the market rate of interest by adding a constant risk premium, ν . Thus, if we define the rate of discount, r_t , as the market rate of interest net of taxes, future labor income and future transfers are discounted at the rate $\bar{r}_t = r_t + \nu$ ¹¹.

Furthermore, the inclusion of taxes is straightforward. In particular, we consider taxes on labor income, t_w , on interest income, t_R , on dividend income, t_D , on capital gains, t_G , and a value added tax on consumption, t_v .

Given these specifications the household maximizes utility subject to the wealth constraint:

$$\begin{aligned} \sum_{t=1}^{\infty} \bar{p}_t (1 + t_v) C_t \Theta_t &= (V_1 + B F_1 + B G_1) + (1 - t_D) DIV_1 \\ &+ (1 - t_R [i_1(B P_1 + B G_1)] + (1 - t_G) K G_1 \\ &+ \sum_{t=1}^{\infty} (1 - t_w) w_t L_t \bar{\Theta}_t + T R_1 \end{aligned} \quad (10)$$

simplifying yields

$$\sum_{t=1}^{\infty} \hat{p}_t C_t \Theta_t = Y K_1 + \sum_{t=1}^{\infty} Y H_t \Theta_t \quad (11)$$

where KG_1 denotes capital gains in period t and $\hat{p}_t$ denotes the composite price index modified to include the value added tax, which for expositional simplicity is assumed to be a uniform rate. The variables Θ_t and $\bar{\Theta}_t$ are the discounting factors for certain future

10. FULLERTON and GORDON (1983,382) describe a way how to calculate risk premiums within the context of the capital asset pricing model. By using constant risk premiums, which are known to each optimizing agent, we only try to consider the different riskiness of investment in each industry. The assumption of forward looking behavior still prevails.

11. For the construction of such an effective discount rate in case of utility maximizing agents that have finite horizons see GOULDER, SUMMERS (1989) and BLANCHARD (1985).

consumption and uncertain flows of future labor income and transfers, respectively. More precisely, Θ_t , using r_t as discount rate, can be defined as:

$$\Theta_t = \begin{cases} \prod_{s=1}^{t-1} (1 + r_s)^{-1} & \text{for } t > 1 \\ 1 & \text{for } t = 1 \end{cases} \quad (12)$$

Analogous $\bar{\Theta}_t$ is defined with $\bar{r}_t$ as discount rate. Thus, from the wealth constraint, as stated in (10), it follows that the present value of the household's lifetime consumption must be equal to the present value of its resources over the infinite horizon.

To solve the household's maximization problem, we combine the equations (4) and (11) and write the Lagrangean function as:

$$L = \frac{1}{1-\delta} \sum_{t=1}^{\infty} \frac{C_t^{1-\delta}}{(1+\rho)^{t-1}} + \lambda \left\{ Y K_1 + \sum_{t=1}^{\infty} [Y K_t \bar{\Theta}_t - \hat{p}_t C_t \Theta_t] \right\} \quad (13)$$

Taking the derivatives of (13) with respect to C_t and C_{t-1} , yields first-order conditions for a maximum in the periods t and $t-1$. Dividing the equations for the first-order conditions by each other generates an equation that describes the evolution of the household's consumption in any two adjacent periods of the optimal lifetime consumption path. Recursive computation of this equation of motion yields an expression for first(base) period consumption:

$$\frac{C_t}{C_1} = \left[\frac{\hat{p}_t}{\hat{p}_1} (1+\rho)^{t-1} \theta_t \right]^{\frac{1}{\delta}} = \left[\frac{\hat{p}_1}{\hat{p}_t} \frac{(1+\rho)^{1-t}}{\theta_t} \right]^{\frac{1}{\delta}} \quad (14)$$

By substituting equation (14) into the wealth constraint (11) and by solving the modified constraint for C_1 , the determination for the households's consumption in period one follows in a straightforward manner¹².

12. A detailed description of this result is given by BALLARD, GOULDER (1985).

Thus the expression (14) states that the household's optimal lifetime consumption is a function of the prices of consumption and three key parameters, the rate of time preference, the rate of return, and the elasticity of marginal felicity. Let g represent the steady-state growth rate of the economy. In the steady-state only certain combinations of r , ρ , and δ exist, which are consistent with a given steady-state growth rate. It can be shown that¹³:

$$\frac{r - \rho}{\delta} \equiv g \quad (15)$$

Before leaving the household sector it may be useful to consider briefly some of the problems associated with such a modeling approach. Although this type of modeling provides a consistent framework for an examination of tax-policy induced changes in consumption, it is obvious at the theoretical level, that it is based on several restrictive assumptions. Thus, to give a more realistic description of the household's consumption the simple model needs to be extended. In particular, the assumption of a fixed and exogenously determined labor supply could be abandoned by incorporating a labor-leisure choice. A second important departure from the simple formulation is the possibility that the household's maximization of lifetime utility incorporates bequests¹⁴. Finally, much of the recent literature on consumer behavior emphasizes not wealth but rather liquidity as a binding constraint¹⁵.

In addition, the restrictive formulation of the household's problem has some uncomfortable implications when it is used for numerical simulations. The equations (14) and (15) show that there is a strong implicit relation between the steady-state growth rate of consumption and the growth rate of the entire economy on the one hand, and the key parameter of consumer behavior on the other hand. In particular, it is obvious that if the growth rate is determined in accordance with actual data and the rate of return is fixed exogenously, then the rate of time preference and the intertemporal substitution elasticity must change in inverse proportion to each other. A second related weak feature, as stressed by BALLARD (1989), is the high degree of intertemporal responsiveness inherent in such

13. This result can be easily obtained by formulating the household's maximization problem in continuous time. Solving this problem yields $\dot{C} = (r - \rho)U'(C) / -U''(C)$ (see also footnote 6). Therefore, consumption steadily increases (decreases) if $r > \rho$ ($p > r$). This result was first reached by STROTZ (1955,56) and in a more general form by YAARI (1964).

14. For the incorporation of bequest behavior in life-cycle models of consumption and in CGE models see BLINDER (1974), BALLARD (1984) and AUERBACH, KOTLIKOFF (1987).

15. Liquidity constrained households are not able to borrow any amount they choose at an interest rate that is equal to the rate of return on their financial assets. For a general discussion see HAYASHI (1987). For the effects of liquidity constraints on tax policy-related changes in consumption see HUBBARD and JUDD (1986).

a modeling approach, which is mainly due to the chosen form of the additively separable lifetime utility function. But there are ways to alter the model's intertemporal responsiveness. One could try, as BALLARD, GOULDER (1985) did, to distinguish between discretionary and non-discretionary, i.e. minimum 'required' consumption. Thereby, an element of complementarity across time would be added to the model, that may help to keep the degree of substitution across periods in reasonable limits¹⁶. But such modifications are not without their own problems, as they refer to ad hoc formulations.

2.2. The Production Sector

At the beginning of this chapter we roughly outline the interindustrial production structure that underlies the model presented here. We then develop a simple q-theory model of investment to illustrate the basic features of the firms' behavior. Finally, by taking into account taxes and the financial behavior of firms we improve upon this simple formulation to give a more realistic description of producer behavior¹⁷. It will be convenient to describe the model in discrete time.

The model of the West German industry includes seven profit-maximizing producer good sectors and uses a 7 x 7 fixed coefficient input-output matrix (see appendix A, table 1 and 2). Each industry uses two primary factors of production - labor and capital - in a constant elasticity of substitution (CES) value-added function. With capital stocks given, minimization of labor costs in each industry yields the labor input necessary to produce a value-added composite. Thus, by using a fixed coefficient technology with respect to the value-added composite and intermediate inputs, the gross output of each industry is derived. Proceeding from here, consumer goods demanded by the representative household are derived from the producer good outputs of the seven industries through a fixed-coefficient transition matrix¹⁸. Furthermore, the seven producer good outputs go into a composite investment commodity in fixed proportions. It can be interpreted as a composite of newly produced capital goods. Finally, the underlying input-output framework results in characteristic end uses of the producer good outputs. They are either delivered as inputs to each of the seven industries according to their technical production requirements, or, they are used to meet the demand for final goods by government and the demand for exports.

Assuming a representative firm in each of the seven industries the description of producer behavior starts by considering the employment and investment decisions of

16. The idea of introducing a non-discretionary consumption floor goes back to STARRETT (1982), see the quotation by BALLARD, GOULDER (1985,280).

17. For the construction of CGE tax models based on the q-theory of investment, see ANDERSSON, NORRMAN (1987), AUERBACH, KOTLIKOFF (1987), BOVENBERG (1983, 1985), GOULDER, SUMMERS (1989), and GOULDER, EICHENGREEN (1988).

18. The construction and use of such a transition matrix is described by BALLARD, FULLERTON, SHOVEN and WHALLEY (1985).

firms in a simplified environment without taxes, and in the absence of financing via new issues of shares and via debt. The major objective for each of these firms is to maximize the present value of its net cash flow, CASH, over an infinite horizon. Let $Y(K_t, L_t, M_t)$ be a production function, where K_t denotes the capital stock, L_t the amount of labor employed, and M_t a vector of intermediate inputs at time t . By simply multiplying the firm's output by the output price p_t , we obtain the the firm's gross profit. Thus, the cash flow at time t is:

$$CASH_t = p_t Y(K_t, L_t, M_t) - w_t L_t - p_{M_t} M_t - k_t I_t - c\left(\frac{I_t}{K_t}\right) \quad (16)$$

where w_t is the wage rate, p_{M_t} is a vector of intermediate input prices, k_t is the price of investment goods, and I_t is the firm's gross investment, all at time t . By introducing adjustment costs the firm's investment expenditure is the sum of the purchase costs of investment goods and the costs due to the installation of the new capital goods. Thus, k_t can be interpreted as the price of uninstalled capital goods and $c(I_t/K_t)$ is the adjustment costs function which is on-negative and is convex in the rate of investment¹⁹. It is convenient to think of the adjustment costs as internal to the firm, so that a certain amount of the firm's resources is required to compensate the costs of installing the new capital goods. This implies that the firm's output is separable between factor inputs, intermediate inputs and installation costs. Although the adjustment-costs concept still introduces an ad-hoc element into the analysis of investment decisions, it is a reasonable attempt to incorporate the path of adjustment into the firm's maximization problem²⁰.

Now, let V_t be the value of the firm at time t and r_t be the real rate of interest at time t , and define Θ_u to be the discount factor that discounts net cash flows at time s back to time t , then the firm's maximization problem can be written:

$$\begin{aligned} \max \quad & V_t = \sum_{s=t}^{\infty} CASH_s \cdot \Theta_u \\ \text{s.t.} \quad & K_{t+1} - K_t = I_t - \delta^R K_t \\ \text{with} \quad & \Theta_u = \prod_{u=t}^s (1 + r_u)^{-1} \end{aligned} \quad (17)$$

19. The concept of adjustment costs was introduced by LUCAS (1967) and GOULD (1968). Slightly different adjustment costs functions are being used in tax policy analysis see e.g. ABEL (1979,1983), AUERBACH, KOTLIKOFF (1987) and CHIRINKO (1987).

20. For a critical discussion of the ad-hoc features of the adjustment-costs concept see STEPHAN (1989).

Whereas the level of the capital stock, K_t , is considered as an initial condition, the firm can choose the level of employment and investment at each point in time. The common constraint of the firm's problem is the equation of motion of the capital stock, where δ^R denotes the rate of economic depreciation.

The firm's maximization problem can be expressed as a standard problem in optimal control²¹. The Lagrangian function can be defined as:

$$L = \sum_{s=t}^{\infty} \{CASH_s + q_s [I_s + (1 - \delta^R) K_s - K_{s+1}]\} \Theta_u$$

Substituting (17) into (18) and differentiating L with respect to L_t , K_t and I_t , respectively, yields the system of canonical equations. It follows, that the firm chooses a level of employment such that the marginal revenue product of labor is equal to the wage rate. By solving the maximization problem the constate variable q_t can be interpreted as the shadow price of new capital goods. This price is equal to the present value of the discounted stream of marginal cash flow, generated by an additional unit of capital installed at time t . Thus, q_t can be viewed the price at which a unit of installed capital can be purchased or sold. As HAYASHI (1982) has shown, the shadow price of new capital goods or 'marginal q ' implies, along with certain conditions, that 'average Q ' can be defined as $Q_t \equiv V_t/K_t$. Thus, an observable counterpart for the shadow price of investment is obtained. From the first order condition for investment at time t , $\partial L/\partial I_t = 0$, the optimal path of investment can be derived. Assuming that the price of uninstalled capital goods is equal to one, q_t can be derived as:

$$q_t = 1 + c + c_I \left(\frac{I_t}{K_t} \right) \quad (19)$$

where c_I indicates the partial derivative of the adjustment costs function with respect to the rate of investment. Furthermore, assuming that the form of the adjustment costs function is given by:

$$c_I \left(\frac{I}{K} \right) = \frac{\beta}{2} \left(\frac{I}{K} - \alpha \right)^2 \left(\frac{I}{K} \right)^{-1} \quad (20)$$

21. As a standard reference for the application of optimal control theory to problems of intertemporal optimization see INTRILIGATOR (1971) and KAMIEN, SCHWARTZ (1981).

yields a simple and observable relation between the rate of investment and the Q-variable,

$$\frac{I_t}{K_t} = \frac{1}{\beta} (q_t - 1) = \alpha + \frac{1}{\beta} (Q) \quad (21)$$

where α and β are parameters of the adjustment costs function which can be estimated. Thus, in a world without taxes, and firms constrained to finance new capital goods out of retentions, investment would simply be a function of 'average Q'.

Now, the formulation above is extended by introducing debt and new issues of shares as additional financial instruments that are available to the firm. Let D_t be the firm's nominal debt, BN_t be the value of new bond issues and let VN_t be new share issues, then the fundamental cash flow identity in each period is given by:

$$DIV B_t + I E_t = EARN_t + B N_t + V N_t \quad (22)$$

where IE_t is total investment expenditure by the firm including the adjustment costs associated with the installation of new capital goods, and $EARN_t$ is firm's stream of earnings net-of-taxes. Although the firm's financial behavior can be treated as an element of the firm's general optimization problem, it is assumed here, that the firm maintains a constant debt-capital ratio, b , and pays dividends equal to a constant fraction, a , of its after-tax earnings net of depreciation. Let p_{K_t} denote the replacement price of capital goods, then we can define:

$$D_t = bp_{K_t} K_t \quad (23)$$

$$B N_t = D_{t+1} - D_t \quad (24)$$

$$DIV B_t = a(EARN_t - \delta^R p_{K_t} K_t) \quad (25)$$

This specification implicitly supports the so-called 'old' view of dividend behavior, i.e. at the margin new capital goods are financed through new share issues.²²

22. As an alternative to the 'old' or 'traditional' view of dividend taxes, the 'new' view is based on the notion of tax capitalization. These two views can be derived from different assumptions about the firms' financial margin. In contrast to the 'traditional' view, there is no impact on corporate investment decisions by changes in the dividend tax rate suggested by the 'new' view. For a detailed discussion of both views see KING (1974), POTERBA and SUMMERS (1983, 1985).

The next step is to describe the taxes that are imposed on the firm. As the model incorporates the major components of the West German tax system, we can distinguish several characteristic type of taxes that interfere with the firm's employment and investment decisions. In particular, social security contributions paid by, firms, which are modeled as ad valorem taxes on each firm's use of labor, taxes on business capital (Gewerbekapitalsteuer) and business property, which are modeled as ad valorem taxes on each firm's use of capital, production taxes that are levied on the value of gross output of each firm, and capital income taxes which can be divided in two major parts, corporate income taxes and business profits taxes (Gewerbeertragsteuer). Although the model takes account of all these different taxes, the focus here is on capital income and business taxes.

To proceed with the description of the actual tax system of West Germany, let $EARNG_t$ be the firm's earnings gross-of-taxes, let $TKAP_t$ be the revenue of the business capital tax, let TBP_t be the revenue of the business profits tax, and let TC_t be the revenue of the corporate income tax, then the firm's net earnings are given by:

$$EARN_t = EARNG_t - TKAP_t - TBP_t - TC_t \quad (26)$$

with

$$EARNG_t = p_t Y(\bar{K}, L_t, M_t) - w_t L_t - p_{M_t} M_t - i_t D_t \quad (27)$$

where i_t is the rate of interest in period t . Note that p_t is the net-of-tax output price and p_{M_t} the vector of intermediate input prices gross of input taxes now.

Considering the fact that these taxes are to some extent deductible from each other when computing the firm's total tax burden, they can be defined as follows:

$$TKAP_t = t_K p_{K_t} K_t \quad (28)$$

$$TBP_t = t_B [EARNG_t + t_{DB} i_t D_t - \delta^T K_t^T - TKAP_t] \quad (29)$$

where t_K is the effective tax rate on business capital, t_B is the tax rate on business profits, δ^T is the rate of tax depreciation, and K^T represents the depreciable capital stock for tax purposes. Interest payments on debt are deductible from the base of corporate income taxes, but they can not be expensed from the business profit taxbase. Thus the parameter t_{DC} is zero and t_{DB} is equal to one in our base case. The corporate income tax can be defined as:

$$TC_t = t_{CR} [EARNG_t + t_{DC} i_t D_t - \delta^T K_t^T] \quad (30)$$

$$-TKAP_t - TBP_t - DIV B_t]$$

where t_{CR} is the statutory tax rate on retained profits. This specification is in accordance with the so-called full imputation system of capital income taxation that is currently practised under West German law. This system has a characteristic implication. Although dividends are taxed first at the corporate level, they are actually taxed at the household level, i.e. dividends are only subject to the personal income tax, as the firm's tax payments are fully rebated to the shareholders. Thus the gross dividend payments that are subject to full taxation at the household level, can be defined as:

$$DIV B_t = DIV_t + t_{CD} DIV_t \quad (31)$$

where t_{CD} is the corporate tax rate on net-dividend payments.

Before returning to the firm's optimization problem a more precise definition of the firm's investment expenditure, that captures the effects of taxation, can be given. Assuming, for the sake of simplicity, that the prices for the valuation of investment goods are equal to one, it follows:

$$I E_t = p_{K_t} I_t (1 - \eta) + p_t I_t c (1 - \tau) \quad (32)$$

with

$$\tau = t_{CR} (1 - t_B) + t_B \quad (33)$$

where τ is the overall tax rate on corporate profits and η is the effective rate of investment grants that can be interpreted analogous to the instrument of investment tax credits.

Now, the firm's optimization problem can be discussed in a more realistic framework. Starting with the arbitrage condition, it is assumed that in the presence of perfect capital markets the after-tax return from holding equities must be equal to the expected yield on any alternative asset. In particular, to induce equity owners to take the risk of holding the existing stock of equity, the after-tax rate of return must be equal to that of normal risk bearing assets, such as government or corporate bonds. Hence the arbitrage condition is given by:

$$\hat{r}_t = i_t (1 - t_R) + \mu = \frac{(1 - t_D) DIV B_t}{V_t} + \frac{(V_{t+1} - V_t) - V N_t}{V_t} \quad (34)$$

where $\hat{r}_t$ is the risk adjusted discount rate which equity owners apply to their expected returns and μ is the risk premium on equity, which may be different for each industry.

Thus the expected return on equity ($V_t \hat{r}_t$) is equal to the sum of after-tax dividends and capital gains on outstanding shares in each period. Note first, that the taxation of capital gains is not considered here, as it plays a negligible role in the actual West German tax system and second, that the flow of dividends includes the rebated tax payments, $t_{CD}DIV$ by corporations.

Ruling out the possibility that the value of the firm becomes infinite in finite time by imposing a transversality condition, the solution of the difference equation (34) yields the value of the firm:

$$V_t = \sum_{s=t}^{\infty} [(1 - t_D) DIV B_s - V N_s] \left[\prod_{v=t}^s (1 + \hat{r}_v)^{-1} \right] \quad (35)$$

Hence, the firm maximizes its value subject to the common constraint (see equation (17)). Thus, using the expressions in (17) and (35), we can state the firm's maximization problem by defining the Lagrangean function as:

$$L = \sum_{s=t}^{\infty} \{ [(1 - t_D) DIV B_s - V N_s] + q_s [I_s + (1 - \delta^R) K_s - K_{s+1}] \} \Theta_v \quad (36)$$

Using the equations (22) - (32) to rewrite the expression of the Lagrangean in terms of the state and the control variables and taking the derivative with respect to I_t yields an expression for the firm's optimal rate of investment:²³

$$\frac{I_t}{K_t} = h(\hat{Q}) = h \left[\left\{ \frac{(V_t - B_t)}{p K_t K_t} - 1 + b + t_I + \psi Z_t \right\} \frac{p K_t}{(1 - \tau) p_t} \right] \quad (37)$$

with $\psi = a(1 - t_D) - a + 1$

where B_t is the present value of tax savings due to depreciation deductions on existing capital, which are subtracted as they are not related to the current decision on new investment, while Z_t represents depreciation allowances on new capital goods, i.e. expected tax savings. The variable ψ reflects the specific interrelation of capital income taxation at the firm and at the individual level. Since the rate of investment, as stated above in equation (21), can be expressed as a function of Q , the optimal quantity of new investment in each period can be obtained in a straightforward manner by substituting the above expression of the 'tax-adjusted' Q in the linear investment function.

23. For a detailed description of this derivation see SUMMERS (1981b).

Thus, given the firm's production function and the solution for the optimal level of investment, the optimal paths of employment, the intermediate goods input, and investment can be computed for each industry. As firms, like the representative household, are regarded as having perfect foresight, their decisions are not based on current information alone. In particular, investment decisions are based on expectations about the future development of the firm's market value. Given the above specification of the firm's investment behavior, these decisions are obviously based on expectations of the prospective streams of dividends and tax savings due to depreciation deductions.

2.3. The Government Sector

The model incorporates government activities in three characteristic ways. By collecting taxes the government obtains income that is either used to make redistributive transfer payments to the household in a lump-sum fashion, or is spent on producer goods and labor or capital services. Avoiding the problem of specifying a production function for the public sector, the government is modeled like a single consumer. Hence, government expenditures are described as an element of final demand. Using a Cobb-Douglas function, constant expenditure shares of producer goods, labor, and capital in overall public consumption are assumed. Government expenditures do not affect the household's utility function. Thus, we implicitly assume the private utility function to be separable in private and public goods. With regard to the dynamic setting of the model we assume a steady-state growth path of overall public expenditures and transfer payments.

Considering the major elements of the West German tax system total government revenue, TTR_t , is simply given by summing up the various taxes in each period

$$TTR_t = TL_t + TPRD_t + TVAT_t + TY_t + TKAP_t + TBP_t + TC_t \quad (38)$$

where TL_t is an ad valorem tax on the use of labor services by each industry, $TPRD_t$ is the tax on output of producer goods of each industry, $TVAT_t$ is the value added tax on consumption goods, TY_t is the total tax on personal income. The taxes levied on the firm's capital stock and income are defined as above. Although we cannot discuss the details of the various tax schedules here thoroughly, some brief remarks may serve to point out some intricate features of the treatment of taxes.

At the household level we distinguish personal taxes on labor income, on received dividends, and on interest earnings. Thus we can capture the different tax burdens on the various income sources. In particular, capital income and interest income are assumed to be taxed at a different rate, due to the fact, that there are tax exemptions for private savings. This also takes into account the existence of tax evasion. As there exists a full imputation system in West Germany, it may be acceptable to use a single marginal income tax rate with respect to the firm's dividend payments and labor income, but this modeling would

be inappropriate for a discussion of tax policy changes that affect the stream of interest payments.

Value-added taxes are modeled as sales taxes, i.e. as an ad valorem tax on purchases of consumer goods. Although the computation of effective tax rates for each category of consumer goods is in principle possible, this treatment is not without a hitch. As the actual design of the VAT in West Germany incorporates exemptions and zero-rating, only two thirds of the tax burden is directly imposed on private consumption.²⁴ A similar problem is raised by the treatment of production taxes. First of all, it is necessary to note that production tax is a collective term of various taxes which have quite different tax bases. As we model the business profits tax and the business tax on capital explicitly at the firm's level, they both have to be subtracted from the revenues obtained by taxes on output of producer goods. Furthermore, the remaining production taxes can be modeled as if they were levied on private consumption. Thus, we implicitly assume that because of competitive producer behavior these taxes are completely shifted forward and are effectively paid by consumers.

A particular virtue of the underlying q-theoretic approach of investment behavior is that it permits one to model the effects of taxation at the firm level in an appropriate manner. That is certainly true with respect to the different treatment of economic depreciation and tax depreciation. The model incorporates a detailed treatment of corporate income taxes, business profits taxes, and investments grants, and it is capable of considering additional features such as immediate depreciation allowances or the deductibility of interest income.

If we assume that the government is running a deficit the government budget constraint for each period can be derived in a straightforward manner. Let GOV_t be the purchases of producer goods, labor, and capital by government, then using the same notation as before leads to

$$TT R_t + BG_t - BG_{t-1} = GOV_t + r BG_{t-1} + T R_t \quad (39)$$

The accumulation of public debt is formally constrained by the assumption that government deficit is growing at a constant and exogenously given rate which is related to the optimal growth rate of the private sector.

24. The importance of this empirical finding for tax policy analysis was pointed out by GOTTFRIED, STÖB and WIEGARD (1990) and the article by GOTTFRIED and WIEGARD in this volume.

2.4. The Foreign Sector

In recent CGE literature, there is growing concern about the fact that considering taxation in an open economy framework is often crucial for the evaluation of tax policy changes²⁵. Although the importance of the apparent international mobility of capital has been stressed in this context the model presented here focuses solely on commodity trade and ignores international capital flows. Thus, the external sector is treated in a simple, but common manner.²⁶

In order to close the general equilibrium system and to obtain a solution of the model, a trade balance constraint is added

$$\sum_{i=1}^7 q_i X_i = \sum_{i=1}^7 q_i M_i \quad (40)$$

where q_i is the domestic price of imports and exports, X_i and M_i represent the export demand and import supply for each of the seven producer goods, respectively. The export demand and import supply functions are given with constant price elasticities

$$X_i = X_i^0 \left(\frac{q_i}{e} \right)^{\varepsilon} - \infty < \varepsilon \leq -1 \quad i = 1 \dots 7 \quad (41)$$

$$M_i = M_i^0 \left(\frac{q_i}{e} \right)^{\eta} \quad 0 < \eta < \infty \quad i = 1 \dots 7 \quad (42)$$

where ε and η denote the elasticities of export demand and import supply and X_1^0 and M_1^0 represent the base year exports and imports, respectively, while e is interpreted as the exchange rate between domestic and foreign prices. This rate can be eliminated by a simple substitution. With export demand and import supply functions that depend only on domestic prices, the trade balance constraint can be rewritten as:

25. For an introduction to recent discussions on international aspects of tax policy see e.g. BOVENBERG (1988), GOULDER, EICHENGREEN (1988), FRENKEL and RAZIN (1989) and SUMMERS (1988).

26. This simple model of trade behavior and more sophisticated models of the foreign sector are discussed by GOULDER, SHOVEN and WHALLEY (1983).

$$q_i^\varepsilon X_i^0 \left[\frac{\sum_{j=1}^7 q_j^{(\varepsilon+1)} X_j^0}{7} \right] \frac{\varepsilon}{(\eta - \varepsilon)} = q_i^\eta M_i^0 \left[\frac{\sum_{j=1}^7 q_j^{(\eta+1)} X_j^0}{7} \right] \frac{\eta}{(\varepsilon - \eta)} \quad (43)$$

III. BENCHMARK DATA SET, PARAMETER SPECIFICATION AND SOLUTION METHOD

In order to solve the model numerically, it has to be applied to actual data of the West German economy. Constructing an appropriate benchmark data set for a disaggregated CGE model is always a rather time-consuming and intricate task. All the more, this is true with respect to West Germany. In contrast to Anglo-Saxon countries, where a fast growing body of CGE literature has provided a considerable amount of information on the behavior of the various agents and on the structure of consumption and production, there has hardly been done any research work in this direction in West Germany. In particular, constructing a data set for a dynamic CGE model has to start from scratch. In this paper we will only give some rough outlines of the data set. The numerical calculations are based on a benchmark data set from 1982, being the first year in which full data collection could be achieved due to the publication time lag of official statistics.

3.1. Data on the household sector

Data on consumer income and expenditure are provided by the income and consumption statistics (EVS) of the Federal Statistics Office (FSO) for certain years. A special survey is conducted every five years that is based on a random sample. We use the EVS data for 1983 (see *Statistisches Bundesamt* 1987a). In order to guarantee the consistency of the benchmark data set we had to scale back these figures to 1982, our 'base case' year. The EVS data are disaggregated by sixteen consumer groups and nine consumer goods. The survey provides data on labor income, transfer income, and to some extent on capital income. Furthermore, it provides information on the income tax payments and all of the consumer expenditure data for the household sector component of our model. Using these data, we construct an expenditure matrix that relates the expenditures of each household group to each of the nine consumer goods. Finally, aggregation over all consumer groups yields the figures for the representative household.

Although there is a rich data set available with regard to the household sector, a quite troublesome problem is caused by the fact that the FSO statistics use different price concepts. The input-output statistics are mainly based on producer prices, whereas the EVS survey rests upon acquisition prices, which are defined as the sum of producer price,

unit costs of wholesale and transportation services, and the pro rata value added tax. Therefore, to assure the consistency of the data set the income and expenditure figures have to be expressed in terms of producer prices.

Fortunately the FSO input-output statistics (see *Statistisches Bundesamt* 1987a) contain a matrix that describes how the expenditures on consumer goods are converted into expenditures on producer goods. From this conversion matrix we also obtain information on the effective rates of the value added tax. As noted before, these tax rates only reflect that part of the VAT that is levied directly on private consumption. To comprise the entire VAT, further computation is required. A major source of data on income tax rates is a special FSO report (see *Statistisches Bundesamt* 1988) which is compiled from individual income tax returns.

3.2. Data on the production sector

The major source for data on intermediate production and value added is the FSO input-output statistics. They provide us with data on labor income by industry and on the total return of corporated and uncorporated enterprises by industry. Furthermore, they contain figures of capital stocks in each industry valued at replacement costs. Taxes on labor use by industry are obtained from an additional FSO national accounts statistics (see *Statistisches Bundesamt* 1987a).

Although there are some problems with regard to the calculations of the above figures, it is much harder to obtain reliable information on the data that are required to describe the firms' investment behavior. Some detailed information on dividend payout ratios by industry and debt-capital ratios by industry can be gathered from the FSO corporations balance-sheet, profit and loss account statistics (see *Statistisches Bundesamt* 1986). The economic depreciation rates and the tax depreciation rates by each industry are calculated based on information from various sources. Effective rates of investment grants for each industry are compiled from the official report on federal subsidies (see *Subventionsbericht* 1983) and published statistics of the German Institute of Economic Research (see DIW 1984).

The adjustment cost parameters of the q-theoretic investment function are calculated based on research work done by FUNKE, RYLL and WILLENBOCKEL (1989). No reliable estimates of the equity risk premium for each industry are available. We use 'best guesses' based on information published in QUARTZ (1976). Although the FSO input-output statistics report production taxes as part of each industry's gross value added, there is no official information available with respect to the distribution of the various tax payments by each industry. However, by employing data from several sources we calculate the production tax by each industry net of subsidies, business profits tax, and business capital tax. Effective tax rates on business capital for each industry are derived from FSO data on capital stocks and the estimated business capital tax payments by each industry. In the base year we use a value of 0.56 for the statutory corporate income tax rate. Thus implying

a value of 0.5625 for the corporate income tax rate on distributed profits, that refers to net dividend payments. For the effective tax rate on business profits we use a value of 0.1442.

3.3. Data on the government sector and foreign trade

Since we model the government as a single consumer and its expenditures as an element of final demand, we have to modify the FSO input-output table which includes a separate column for the governmental services. We take this column of intermediate inputs as our basic government expenditure column, i.e. as one component of final demand. In addition, government purchases gross-of-tax labour services. Figures for the net-of-tax payments for labor services and for the governmental labor tax payments are obtained from FSO statistics. We also employ data from FSO statistics on government capital stock, on government purchases of capital endowments, and on the level of public debt.

Data on foreign trade is also taken from the FSO input-output statistics. In order to get zero trade balance, we allocate the 1982 trade surplus of 41.744 million DM proportionately among the imports.

3.4. Parameter Specification

Two further steps have to be taken to solve the model numerically. First, the basic data must be adjusted so that the well known equilibrium conditions of a Walrasian economic system are satisfied. That implies certain consistency adjustments of the underlying input-output statistics²⁷. Second, we must determine certain parameter values for the key equations in the model, such that the benchmark data set of 1982 will exactly be reproduced and will correspond with an equilibrium solution of the economic system. We will only make some brief remarks on the second, so called calibration procedure²⁸.

In contrast to the parameterization of static or recursive CGE models, the calibration of a dynamic, intertemporal model raises a twofold problem. Not only must the basic replication condition be met by the exact reproduction of the benchmark data set, but also must a dynamic stability condition be fulfilled in such a way, that the parameter specification guarantees a steady-state growth path of the economic system. The calibration procedure starts by borrowing certain extraneous parameter estimates from the econometric literature, and proceeds with specifying remaining parameters by taking into

27. The basic consistency adjustment procedures, that are needed to construct a benchmark data set, are described in BALLARD, FULLERTON, SHOVEN and WHALLEY (1985).

28. A standard reference is MANSUR and WHALLEY (1984).

consideration specific parameter restrictions that are implicitly given by the model's equilibrium conditions.

Thus, on the production side we choose reliable estimates of the elasticities of substitution, σ_i , for each industry²⁹ and by using the restrictions imposed by the producer's optimization problem we derive the appropriate scale parameters, θ_i , and share parameters, γ_i for each industry. On the household side, we specify exogenously the rate of time preference, ρ , the value of the intertemporal substitution elasticity, δ , and parameter ν that refers to the consumer's risk premium. The share parameters of the government's Cobb-Douglas utility function are immediately derived from the vector of final purchases by the government. Finally, the specification of parameters for the foreign trade functions requires the selection of a value for the own-price elasticity of export demand, and then allows to choose a combination of the parameters ε and η for the elasticities of foreign export demand and import supply. The value of -1.11 for the own-price elasticity of export demand is taken from STERN, FRANCIS and SCHUMACHER (1976)³⁰, in addition we assume a combination of $\varepsilon = -10$ and $\eta = 0.12$. For the chosen values of all the other parameters see appendix A, table A.6.

Considering the steady-state aspect of the calibration procedure we must first of all choose values for the steady-state growth rate, g , and the rate of inflation, π , which are both exogenous parameters in the model. Then, corresponding to the fundamental equation of neoclassical economic growth we define the steady-state rate of gross investment, (I/K) , in each industry as the sum of the depreciation rate, δ^R , and the rate of growth, g . Simple rewriting of this definition yields the figures for first(base) period investment in each industry. Furthermore, using the q -investment function, as derived in chapter 2.2., we obtain the steady-state values of the tax-adjusted q -variables for each sector. Since all the information necessary to determine q is given by the benchmark data set, the next step is to derive the several components of q , being in particular the market value of the firm and the tax savings due to depreciation allowances on existing capital and new investment in each industry. Before turning to the household sector, we must finally determine the financial structure and the capital income streams in each industry. Since debt-capital ratios and payout ratios for each industry are specified exogenously, we can derive the first(base) period values for all of the financial magnitudes by using the fundamental arbitrage condition, the cash-flow identity equation, and an initial guess for the nominal interest rate. All these values will be in correspondence with the initial steady-state.

On the household side, as described in chapter 2.1, steady-state growth and consumption are determined by the given values of the consumption parameter (ρ , δ , $\hat{r}$) and total wealth. Given initial labor income, transfers, and the initial steady state value of total non-human wealth we can solve the consumer's maximization problem for the first(base)

29. The elasticities of substitution for the seven industrial sector of the model are 'best guesses', which are based on informations we took from PUSSE(1980) and FROHN et.al.(1973).

30. See also NAGGL (1981).

period level of consumption (see equation 14). Finally, the first(base) period level of household savings follows immediately by subtracting consumption from initial household income. Assuming perfect capital markets, household lending and total firm borrowing are equalized by the interest rate. As capital supply and capital demand are derived separately, equilibrium is not guaranteed. If necessary, a capital market equilibrium is obtained by iteration of the dynamic part of the calibration procedure, while using updated guesses of the interest rate. Thus, the model's parameterization is closed.

3.5. Solution method

To solve dynamic CGE models two major methodical aspects must be considered. First, as we assume perfect foresight, consumers and producers are both regarded as exhibiting forward-looking behavior and as holding expectations of future economic variables with subjective certainty. Thus, in a discrete model framework it follows implicitly, that in any period the decision-making process of agents is based on correct information on the current period values of certain magnitudes, and on expectations about the future values of certain other variables. The latter ones are so-called lead variables. Second, the underlying intertemporal framework implies, that in any period, the economic transactions depend on current prices and quantities as well as on the past and future values of these magnitudes. This intertemporal interdependency requires individual decision-making and coordination of activities within the entire economy, to be logically consistent in two ways. Equilibrium must be ensured in any period as well as over the entire time horizon under consideration. Thus, expected and realized values of economic variables must generally conform, and all markets must clear in any period.

Considering these aspects and the consequent computational problems, alternative solution procedures for dynamic CGE models have been developed. At present, three major methods can be distinguished: first, a multiple shooting method adopted from the differential equation literature by LIPTON, POTERBA, SACHS and SUMMERS (1982); second, a three stage method developed by AUERBACH and KOTLIKOFF (1987), that uses an iterative Gauss-Seidel algorithm on all stages; and third, an extended path or two-part iteration method examined by FAIR and TAYLOR (1983) and applied to CGE tax policy modeling by GOULDER and SUMMERS (1989), see also FISHER, HOLLY and HUGHES-HALLETT (1986). We follow closely the latter solution procedure.

The basic idea of the two-part iteration method is to employ different, but, appropriate iteration procedures for computing equilibrium prices that ensure the existence of both intratemporal, and intertemporal equilibrium solutions. The first iteration part computes for each time period the intratemporal equilibrium, based on information on current variables, and on given expectations of future economic variables or, in other words, with expectations temporarily fixed. Since the solution procedure starts normally in the first period, we solve sequentially forwards by using augmented capital stocks variables, once the initial intratemporal equilibrium is computed. Thus, solving the model for each period

based on an initial path of lead variables yields a sequence of intratemporal equilibrium solutions, and therefore, parallel to the path of expectation terms, a path of derived values for the lead variables. The second iteration part updates these expectation terms as long as the path of lead variables does not conform to the path of derived values. For the first iteration part, a Newton-type algorithm is employed, whereas the updating of the lead variables is achieved by a Gauss-Seidel procedure. Since we distinguish current variables from lead variables, we must identify those variables that carry expectations of future economic conditions. On the household side, we assume the existence of expectations of future labor income. Therefore, human wealth, HW , is treated as a lead variable. On the production side, expectations about the future are focused on the costs and returns of investment projects. Therefore, all the variables contained in the investment function (V, B, Z) are treated as lead variables. To reduce computational efforts variable B can be calculated on the basis of values for variable Z .

3.6 Equilibrium conditions

Finally, we have to specify the equilibrium conditions for both, the intratemporal and the intertemporal part of the model. Considering exogenous labor supply and labor demand by each of the seven industries and government, the output demand and supply for each sector, the demand and supply for financial funds, and the balance of government expenditures and revenues, the intratemporal equilibrium conditions for each period are

$$\begin{aligned}
 L^S &= \sum_{j=1}^7 L_j^D \\
 \sum_{j=1}^7 Q_j^S &= \sum_{j=1}^7 Q_j^D \\
 S &= \sum_{j=1}^7 (B N_j + V N_j) + \Delta B G
 \end{aligned} \tag{44}$$

where S represents savings and ΔBG denotes changes in government deficit.

Intertemporal equilibrium requires that the forward expectation terms, i.e. the values of the specified lead variables, are equal to the current values of these variables for each period. Thus the time path of the expectation terms, denoted here by the character E , must correspond to the path of realized values for each of the lead variables. A distinctive feature of all the solution methods employed to solve intertemporal models is that they require the specification of terminal conditions. Therefore we must compute the long-run, steady-state values of the lead variables. Since we take these steady-state values, denoted here by an asterisk, as terminal conditions, the intertemporal equilibrium conditions are

$$EYH_t = YH_t \quad t = 2, 3, \dots, T \quad EYH_{T+1} = YH^*$$

$$\begin{array}{lll}
 EV_t = V_t & t = 2, 3, \dots T & EV_{T+1} = V^* \\
 EZ_t = Z_t & t = 2, 3, \dots T & EZ_{T+1} = Z^*
 \end{array} \quad (45)$$

IV. RESULTS OF TAX POLICY SIMULATIONS

The evaluation of tax policy changes based on CGE models is typically carried out by comparing the quantities and values of the 'base case' equilibrium with the magnitudes that are obtained by computing the so-called counterfactual equilibrium. In the case of dynamic models an appropriate way to measure the effects of policy changes is to compare the time path of certain key variables by using two different growth scenarios of the economy. The first, base scenario is characterized by a steady-state path of the economy that conforms to the benchmark data set. The second, counterfactual scenario describes the growth path of the economy that will be reached after a policy change. As the numerical solution of the model implies to calculate the convergence to a new steady-state, we receive information not only with regard to the new steady-state position of the economy but also on the transition path of the economy. We generally examine an time intervall of 65 years.

The simulations performed all start with the assumption that the steady-state growth rate of the economy in the base case is 2.5 percent. Detailed information on the base case data set being used for the West German economy is summarized in table A.1 that describes the aggregated and adjusted input-output matrix, table A.2 contains information on the various components of final demand, table A.3 reports the values of key variables for each of the seven production sectors, table A.4 contains information on the various taxes and tax related parameters for each industry, and table A.5 gives some information on the household and the government sector, respectively by presenting consolidated budgets for each of them (see Appendix A).

All the simulations presented here employ the concept of equal-tax-yield policy changes³¹. Thereby, it is guaranteed that the value of government expenditure is the same as before the tax change. In particular, we assume that any reduction in tax revenues resulting from a policy change is replaced by lump-sum taxes paid by the representative household. We adopt this simple replacement scheme here for two reasons, first it is an easy but reasonable way to compute an equal yield equilibrium and second we will focus here on the incentive and intertemporal efficiency effects of changes of existing taxes, rather than on the discussion of the introduction of new and replacement of old taxes.

31. See SHOVEN and WHALLEY (1977).

4.1. Efficiency effects of business tax reforms

There has been a long and still lasting debate on the reform of the local business profits tax and the local tax on business capital in West Germany³². In the fiscal year 1982, our base period, these taxes amounted to 6.8 percent of total federal tax revenue and since then this share slightly increased. After personal income and value added taxes they are still the third largest source of government revenue. Their is widespread belief that the reform or even the elimination of the business tax is a pressing political issue. Several tax exemptions and tax allowances that are part of the official tax schedule give reason for the assumption of considerable distortionary effects of these taxes. Replacing the business tax with a value added tax of the net income type or with an increase of the existing value added tax of the consumption type is often recommended. Because of the great importance of business taxes for local government agencies this debate is focused to a great deal on the problem of appropriate structures of fiscal federalism. Instead, we will concentrate here on the intertemporal efficiency aspect of business tax reforms. To get some quantitative information on the potential efficiency gains that could be obtained by reducing business taxes, we assume that both taxes, on business profits and on business capital, are abolished. The results of this radical experiment are displayed in table 1, where the percentage changes of certain of key variables from the base case steady-state are reported. There is a similar pattern of results for all sectors. Eliminating the business taxes leads to higher after-tax profits and raises dividend payments. The increase in current earnings and in the discounted stream of expected future distributions by firms results in a sharp rise of the value for all firms. Since these increases are reflected in larger values for the industries tax-adjusted q , investment and the capital stock will finally rise. Table 1 reports the percentage changes of the new steady-state values from the base case values which are reached after 65 periods. Again, similar results could be obtained for the other sectors. Investment rises steadily over all periods in sector 7 and reaches its new steady-state value of 3.4 percent by the fiftieth period. There is a much sharper rise in the value of firms for this sector in the first three periods, reflecting the fact, that increases in the stream of future earnings are immediately considered on stock and asset markets.

In our first simulation we assume interest payments on firms' debt to be fully deductible from the corporate income taxbase, but to be non deductible from the taxbase of business profits. Therefore, in accordance with the tax law at the beginning of 1982, we set the parameter values of t_{DC} equal to one and t_{DB} equal to zero. Since then, two major modifications of the business profits tax schedule in 1983 and 1984 lead to a partial deductibility of 0.50 percent. Considering this tax change by setting the value of t_{DB} equal to 0.5 we run a second simulation.

The results of this less radical reform of the business tax are reported in table 2. As expected, the magnitude of the effects on the firms' investment behavior is less than in

32. For an introduction to the German debate on this issue see STRAUSS (1984) and SCHMIDT (1988).

our first simulation. Although only a small increase in after-tax profits and dividend payments is caused by the introduction of partial deductibility of interest payments on debt, there is a strong positive effect on investment observable. Compared to our first more hypothetical simulation of a complete elimination of the business tax, the simulation

Table 1

Sector	1	2	3	4	5	6	7
After-tax profit	11.3	11.6	7.0	9.6	11.1	10.4	12.1
Dividend payment	22.6	20.7	24.4	20.4	19.9	26.1	27.7
Value of firm	17.9	18.8	16.0	17.6	18.0	21.3	18.4
Tax-adjusted Q	2.4	2.0	0.1	1.0	2.0	1.9	0.6
Investment	3.3	3.	0.0	2.3	2.8	3.2	3.4

Table 2

Sector	1	2	3	4	5	6	7
After-tax profit	2.4	2.1	1.5	1.6	1.9	2.5	1.9
Dividend payment	3.3	2.7	2.4	2.2	2.4	3.8	2.8
Value of firm	2.0	1.9	1.1	1.4	1.7	2.5	1.5
Tax-adjusted Q	0.8	0.8	0.08	0.2	0.5	0.5	0.2
Investment	1.74	1.54	0.85	1.0	1.4	1.9	1.3

of the actual tax reform in 1983/84 generates a positive investment effect throughout all industries that amounts to nearly 50 percent of the first simulation. Thus, the conclusion can be drawn, that much of the intertemporal distortions of the business taxes can be

eliminated by rather minor changes in the official tax schedule that are practicable with respect to the existing system of fiscal federalism.

*4.2. Cutting corporate and personal income taxes:
in the 1990 West German tax reform*

In the last two decades many industrial countries have seen substantial cuts in statutory income tax rates. In most cases these cuts were supported by arguments of reducing allocational inefficiencies. In particular, the reform of the West German tax system between 1986 and 1990 has been justified with reference to positive effects on capital formation.

As there is a full imputation system with respect to corporate income taxes under law in West Germany, cutting marginal taxes for the highest income bracket is always connected with a parallel reduction of the statutory tax rate on corporate income. We will concentrate on the final step of this reform, a reduction of the statutory corporate tax rate from 0.56 to 0.50 enacted at the beginning of the year 1990 and a cut of the income tax rate from 0.34 to 0.27. The value of 0.34 for the income tax rate is calculated using data on income tax payments and overall taxable income, that is contained in the benchmark data set for 1982. As mentioned before, we assume that interest income of the household is taxed at a somewhat lower rate of 0.30. Technically we employ a linear approximation of the official income tax schedule. In the same way we calculate the income tax rate that is effective since the last step of the income tax reform in 1990. Again, we assume that tax rate on interest income (0.24) is lower than the tax rate on labor income and dividends. To get information on both tax cuts, we run two simulations. First, we assume that only the statutory corporate rate is reduced, in a second simulation we investigate the combined effect of both tax cuts.

The results for a separate reduction of the tax rate on corporate income are reported in table 3. Again, there is a similar pattern of results for all the industries, but also a remarkable and unexpected effect of this tax cut on investment. Although there are slightly higher values for dividend payments and the value of firms, after tax profits are reduced in some sectors and investment decreases in all sectors. These findings support the idea of a taxation paradox resulting from lower corporate income taxes³³. Such a disincentive effect of corporate tax cuts with regard to investment behavior is mainly caused by reductions of depreciation allowances on existing capital and new investment and by lower tax savings due to the deductibility of interest on the firm's debt, that both result from cutting the corporate income tax. Therefore, one can expect a positive correlation between the values of the debt capital ratio and the rates of tax depreciation on the one hand and the negative investment effect on the other hand. Comparing these figures for

33. For the discussion of tax paradoxes within the area of corporate income taxation see SINN (1987).

Table 3

Sector	1	2	3	4	5	6	7
After-tax profit	-0.2	-0.6	2.3	2.0	1.4	0.6	3.5
Dividend payment	6.3	5.1	14.0	9.0	7.9	9.0	13.0
Value of firm	5.9	5.2	8.0	9.0	7.0	7.5	8.2
Tax-adjusted q	-0.5	-0.7	-0.1	-0.2	-0.4	-0.1	-0.2
Investment	-4.1	-5.1	-1.8	-1.5	-3.4	-3.5	-1.3

Table 4

Sector	1	2	3	4	5	6	7
After-tax profit	4.3	3.0	2.9	4.3	3.7	3.5	5.7
Dividend payment	4.2	4.5	12.0	8.0	6.1	14.0	12.0
Value of firm	11.3	11.2	11.0	11.8	11.4	14.2	12.2
Tax-adjusted q	1.4	1.0	0.1	0.7	1.0	1.2	0.3
Investment	1.8	1.5	0.1	1.3	1.5	1.1	1.6

each sector shows, that there is support for this assumption. Only the results for sector 3 are not in accordance with this explanation. This line of argument is also supported by simulation results not reported here. Simulation runs with lower rates of tax depreciation showed that the disincentive effect of a corporate tax cut decreases slightly.

The results for the combined reduction of the corporate and personal income tax are reported in table 4. There is an obvious change in the direction of the induced effect on investment. Cutting personal income taxes implies not only a reduction of the tax burden on wage income but lowers also the tax burden on dividend earnings and interest income. Therefore, recalling the arbitrage condition defined by equation (34), a reduction of the personal income tax leads to an increase of the net-of-tax rate of return. Under reasonable assumptions about intertemporal preferences, this results in more savings and stimulates investment. Thus, the negative effects of the reduction of the corporate income tax rate on investment are more than compensated by the lower tax burden on capital income. Again, this result is supported by the simulation of a separate cut of the personal income tax which leads to strong positive incentive effects with respect to investment.

V. CONCLUSIONS AND AVENUES FOR FUTURE RESEARCH

The dynamic tax policy model presented above proves to be an appropriate tool for the analysis of tax policy changes that imply intertemporal efficiency effects. It is capable of providing some tentative insights into the quantitative magnitude of hypothetical and actual tax reforms. Our preliminary simulation results lead to four main conclusions: First, the elimination of the business profits tax and the tax on business capital would cause a strong positive effect on investment. Second, permitting partial deductibility of the interest payments on debt has been a first step in the right direction and lead to a reduction of intertemporal inefficiencies caused by the business taxes. Third, corporate tax cuts can result a taxation paradox and generate a strong disincentive effect with respect to investment, that is mainly caused by a reduction in tax savings and depreciation. Fourth, the 1990 tax reform in West Germany generated a small positive effect on capital formation, mainly due to the fact that cutting the tax rates on the personal level implies a reduction of the tax wedge between the market rate of interest and the net-of-tax rate of return. The positive effect caused by this reduction is so strong that it even compensates the disincentive effect of the corporate tax cut.

Several extensions and modifications of the model presented here are possible. First, it would be reasonable to use a different and more disaggregated structure of the economy. In particular, by turning the attention to the reform of corporate income taxation it would be reasonable to disaggregate the manufacturing sector. Second, while dealing with taxes on noncorporate and corporate firms it might be worthwhile to treat both types of firms differently. The housing sector as a typical noncorporate sector would deserve a more detailed treatment. Thirdly, employing a more sophisticated treatment of the foreign

sector seems to be a worthwhile extension of the model, allowing the analysis of corporate income taxation in a framework that takes account of international capital mobility.

APPENDIX

Table A.1: Adjusted Input - output matrix

SECTOR	1	2	3	4	5	6	7	TOTAL
1	46900.55	62942.20	23925.88	8514.41	70316.16	563.13	31512.39	244674.72
2	10274.84	98975.92	33769.89	12864.56	7175.84	40388.93	39777.29	243227.26
3	8413.11	8177.18	251776.95	5280.17	4029.20	21951.31	29853.74	329481.66
4	761.26	4932.40	7193.95	43229.35	3861.64	7740.73	38070.56	105789.88
5	6773.82	750.89	282.54	49.61	43811.03	39.90	25266.94	76974.73
6	2608.17	510.45	1186.24	349.47	277.66	2844.28	19822.55	27598.83
7	8159.45	29892.53	61935.76	16491.59	17596.49	22901.77	265793.67	422771.27
	244674.72	243227.26	329481.66	105789.88	76974.73	27598.83	422771.27	1450518.35
Labor	48004.00	61353.00	206029.00	50712.00	27605.00	73950.00	298940.00	766593.00
Capital	71721.72	33785.00	53991.46	19277.43	16849.37	10384.64	174365.98	380375.59
	203616.92	301319.58	640091.66	156768.58	191522.39	180764.69	923403.13	2597486.94

CLASSIFICATION OF PRODUCTION SECTORS

1. Agriculture, forestry, mining
2. Chemicals, oil refining
3. Steel, machinery, motor vehicles, electrical engineering
4. Wood, paper, textiles
5. Food
6. Construction
7. Services

Table A.2: Components of final demand

TOTAL INTER-MEDIATE USE	C + I	GOV	EX	IMP	TFD	TOTAL
244674.724	48773.481	5801.514	10187.000	105819.800	-41057.805	203616.919
243227.264	58837.704	12557.407	80682.000	93984.800	58092.311	301319.575
329481.657	173460.683	16898.819	246342.000	126091.500	310610.002	640091.657
105789.883	71147.045	3521.454	30694.000	54383.800	50978.699	156768.582
76974.728	124751.182	2278.480	19037.000	31519.000	114547.662	191522.390
27598.832	146923.677	4699.282	2465.000	922.100	153165.859	180764.691
422771.267	420060.778	57257.084	59253.000	35939.000	500631.862	923403.128
1450518.354	1043954.549	103014.040	448660.000	448660.000	1146968.590	2597486.943

Table A.3

Sector	1	2	3	4	5	6	7
Use of labor	33184.00	42122.00	146417.00	37096.00	19723.00	52864.00	215366.00
Tax on labor	14820.00	19231.00	59612.00	13616.00	7882.00	21086.00	83574.00
Use of capital	678840.00	260460.00	489950.00	160500.00	127030.00	84340.00	1411810.00
Rate of economic depreciation	0.0420	0.0517	0.0530	0.0488	0.0487	0.0551	0.0429
Investment	45482.28	19982.49	38240.59	11848.11	9362.11	6755.63	95861.89
Adjustment costs	3424.10	1722.61	3353.72	982.77	775.30	608.03	7313.83
Rate of adjustment costs	0.0752	0.0862	0.0877	0.0829	0.0828	0.0900	0.0762
Before-tax profits	59324.40	28970.23	42998.18	16231.75	14436.30	8774.99	135276.15
Dividends	13643.48	9698.02	4349.01	2591.71	3868.62	637.30	20313.03
Dividend payout ratio	0.6655	0.7996	0.4414	0.5236	0.6888	0.3014	0.5995
Interest on debt	15821.41	6537.37	14347.00	4028.44	3188.37	2217.68	46403.66
Debt capital ratio	0.3900	0.4200	0.4900	0.4200	0.4200	0.4400	0.5500
New bonds	13980.27	5776.62	12677.44	3559.65	2817.34	1959.61	41003.67
New shares	5130.62	1370.67	6100.53	1727.06	1249.12	1208.75	21966.58
Retentions	34078.93	15252.90	30231.64	9823.63	7642.26	5895.36	71382.86
Risk premium	0.0400	0.0500	0.0390	0.0400	0.0510	0.0380	0.0500

Table A.4

Sector	1	2	3	4	5	6	7
Business profit tax	6105.913	2804.184	3925.714	1621.184	1491.431	811.088	17646.773
Total business tax	6520.005	3142.782	4577.348	1765.634	1628.624	916.513	19538.598
Corporate income tax	3792.626	227.865	2577.321	1680.705	1004.846	1096.851	21287.614
Total tax savings	-4688.443	-1397.592	-3522.921	-804.597	-634.987	-488.491	-10001.744
Total tax on firms	10312.632	3370.647	7154.668	3446.339	2633.469	2013.364	40826.212
Rate of tax depreciation	0.1379	0.2057	0.1873	0.1662	0.1796	0.1964	0.0832

Table A.5: Consolidated budgets

REPRESENTATIVE HOUSEHOLD

CONSUMPTION	767940.945	LABOR INCOME	688376.000
TAX ON CONSUMPTION	121677.960	CAPITAL INCOME	185879.318
PERSONAL INCOME TAX	142794.543	TRANSFERS	249659.876
SAVINGS	91501.746		
TOTAL	1123915.195		1123915.195

GOVERNMENT

TOTAL GOVERNMENT CONSUMPTION	308794.040	CONSUMPTION TAXES	121677.960
: GOODS	103014.040	TAXES ON LABOR USE	64176.000
: LABOR	141604.000	BY GOVERNMENT	
: TAXES ON LABOR USE	64176.000	PERSONAL INCOME TAXES	142794.543
TRANSFERS	249659.876	TAXES ON FIRM LEVEL	48218.556
INTEREST PAYMENTS	38234.143	TAX ON LABOR USE	219821.000
TOTAL	596688.059		596688.059

Table A.6: Main parameter values

Parameter values for the value added function

SECTOR	1	2	3	4	5	6	7
ALPHA	0.0622	0.2831	0.5716	0.4011	0.2983	0.8189	0.2021
SIGMA	0.7500	0.8100	0.8200	0.9000	0.7000	0.8500	0.9950
GAMMA	1.7292	3.1852	2.4745	2.2539	4.3257	2.1506	1.9664
PHI	0.3127	0.8359	1.2113	0.9933	0.8107	1.4845	0.71024

Parameter values for the q-investment function

$$I = a + bq_t$$

$$a = 0.040874$$

$$b = 1.68257$$

Parameter values for the consumption function

$$\text{DELTA} = 1.0000$$

$$\text{RHO} = 0.0318$$

$$\text{Nu} = 0.0500$$

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SUMMARY

In order to study the effects of some West German tax reforms, a dynamic numerical general equilibrium model is presented. Analytically the structure of the model is characterized by assuming forward looking behavior. The household sector is described by the assumption of a representative consumer, whereas on the production side, based on official input-output statistics, seven producer good sectors are considered. Private investment is explained by using a simple q-theoretic approach. The model considers the government to be a single consumer and contains considerable detail on the West German tax system. Empirically the model is based on a 1982 data set.

ZUSAMMENFASSUNG

Vorgestellt wird ein dynamisches numerisches Gleichgewichtsmodell, das die Grundlage liefert für die steuerpolitische Analyse einiger Maßnahmen im Bereich der Einkommens- und Unternehmensbesteuerung der Bundesrepublik Deutschland. In analytischer Hinsicht repräsentiert das Modell ein allgemeines intertemporales Konkurrenzgleichgewicht, das gekennzeichnet ist durch die Annahme vollkommener Voraussicht. Während die Haushaltsseite durch einen repräsentativen Konsumenten beschrieben wird, werden auf der Unternehmensseite ausgehend von der amtlichen Input-Output-Statistik sieben Produktionssektoren unterschieden. Die privaten Investitionen werden anhand einer einfachen q-Theorie beschrieben. Die Modellierung des Staates umfaßt neben dem Staatskonsum in detaillierter Weise das bundesdeutsche Steuersystem. Die quantitative Spezifikation des Modells ist auf das Jahr 1982 bezogen.