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The ZEW Combined Microsimulation-CGE Model: Innovative Tool for Applied Policy Analysis

Markus Clauss and Stefanie Schubert

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Non-technical summary:

Ex ante evaluation of policy reform proposals in general relies either on microsimulation models or computable general equilibrium (CGE) models. This paper describes how the Centre of European Economic Research (ZEW) has merged two established models – the so-called STSM and PACE-L models – in order to obtain a linked microsimulation-computable general equilibrium model. This state of the art approach for applied policy analysis combines the advantages of the two model types.

Concerning microsimulation models, their main advantage is the foundation on individual household level data. This allows a detailed analysis of who gains and who loses from a reform proposal. The main disadvantage of microsimulation models is that they neglect general equilibrium effects. In particular, these models assume constant wages and interest rates. i.e. that the labour market equilibrium is the same before and after the analyzed policy change. CGE models, on the other hand, incorporate these effects.. Their disadvantage ist that they are based on aggregated household types rather than individual households. This brings a loss of information as regards heterogeneity of household which impedes in particular thorough distributional analysis.

Merging the microsimulation and the CGE-approach to policy evaluation is a means to combine the advantages of both model types. The approach delivers detailed results as regards distributional outcomes whilst taking into account the possible employment and wage impacts of policy reforms.

This paper provides an introduction to the fully integrated CGE-microsimulation model STSM/PACE-L. This model, developed and maintained at the ZEW, is the most advanced model of its kind in Germany. It integrates all individual households that are included the microsimulation model with flexible labour supply in the CGE model, whereby it achieves a much more precise representation of the household sector on the macroeconomic level than typical models with at best few representative households. The advantages of fully integrating simulation at the micro and macro level have shown in several cases of practical ex-ante evaluation studies.

Das Wichtigste in Kürze

Ex-ante Evaluationen von Politikreformen basieren in der Regel entweder auf Mikrosimulationsmodellen oder auf berechenbaren allgemeinen Gleichgewichtsmodellen (CGE-Modelle). Dieser Beitrag beschreibt die am Zentrum für Europäische Wirtschaftsforschung (ZEW) geleistete Verknüpfung beider Modelltypen zu einem integrierten Mikro-Makro-Simulationsmodell. Dieses Instrument, das auf den bereits existierenden ZEW-Modellen STSM und PACE-L aufsetzt, vereint die Vorteile beider Herangehensweisen.

Der größte Vorteil von Mikrosimulationsmodellen liegt in der Mikrofundierung: sie beruhen in der Regel auf umfangreichen Individualdaten. Dies ermöglicht detaillierte Projektionen, wie Arbeitsangebot und Einkommen nach einer Reform reagieren. So lassen sich Reformgewinner und Reformverlierer identifizieren. Ein Nachteil dieses Modelltyps liegt jedoch darin, dass mögliche gesamtwirtschaftliche Rückwirkungen der Reform auf Löhne und Beschäftigung nicht berücksichtigt werden. Im Gegensatz dazu integrieren CGE-Modelle diese Rückkopplungseffekte. Der Nachteil dieses Modelltyps ist jedoch, dass er in der Regel von aggregierten Haushaltstypen ausgeht. Durch diese Aggregation gehen erhebliche Informationen verloren. Dies erschwert beispielsweise genauere Verteilungsaussagen.

Ein kombiniertes, integriertes Mikro-Makro-Modell ist ein sinnvoller Entwicklungsschritt, der die Vorteile beider Modellklassen vereint. Ein solches Modell kann detaillierte Verteilungsaussagen unter Einschluss der durch eine analysierte Maßnahme ausgelösten Lohn- und Beschäftigungsfolgen generieren.

Dieser Beitrag bietet eine Einführung in das vollständig integrierte Mikro-Makro-Modell „STSM/PACE-L“. Dieses am ZEW entwickelte und gepflegte Modell gehört zu den am weitesten entwickelten Simulationsmodellen seiner Art in Deutschland. Es integriert alle Haushalte des Mikrosimulationsmodells in das CGE-Modell mit dynamischer Arbeitsangebotsentscheidung. Somit lassen sich die Verteilungswirkungen von Reformen viel genauer als in einem reinen Makromodell mit wenigen typisierten Haushalten untersuchen. Einige praktische Anwendungen für ex-ante Studien haben die Vorteile des ZEW-Modells mit seiner integrierten Vorgehensweise bereits unter Beweis gestellt.

The ZEW Combined Microsimulation-CGE Model: Innovative Tool for Applied Policy Analysis

Markus Clauss[1], Stefanie Schubert[2]

[1] Centre for European Economic Research, Mannheim

[2] WHU - Otto Beisheim School of Management, Vallendar

Abstract

This contribution describes the linkage of microsimulation models and computable general equilibrium (CGE) models using two already established models called "STSM" and "PACE-L" used by the Centre for European Economic Research. This state of the art research method for applied policy analysis combines the advantages of both model types: On the one hand, microsimulation models allow for detailed labor supply and distributional effects due to policy measures, as individual household data is used. On the other hand, by using a general equilibrium framework, labour market responses, such as wage and labour demand reactions are taken into account.

Keywords: microsimulation, applied CGE analysis, linked micro-macro models
JEL Code: C68, C81, D58, J22, J23

Corresponding author: Markus Clauss, ZEW, L7,1, D-68161 Mannheim, e-mail: clauss@zew.de.

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1 Introduction

Bourguignon/Spadaro (2006) provide an excellent discussion on the use of microsimulation models as a tool for analyzing policy reforms and their impact on the redistribution and poverty. Their paper also points out the limits and hints at future research directions in this field. One of the directions they mentioned was that of combining microsimulation and CGE models.

In our contribution, we briefly describe the general methods of microsimulation and general equilibrium modeling. We provide a detailed presentation of the microsimulation model STSM and the computable general equilibrium model PACE-L as well as the linkage of both models. The combination and full integration of microsimulation and computable general equilibrium (CGE) models has lead into a new era of computational modeling (*Davies, 2004*). At the cutting edge of economic research, the Centre of European Economic Research (ZEW, Mannheim) uses a combined CGE-microsimulation model for Germany to analyze policy implications arising from different reform proposals.

Microsimulation models and computable CGE models are usually separately employed for the evaluation of policy reform proposals. The main advantage of microsimulation models lies in the micro foundation created by using individual household data. This allows the calculation of partial equilibrium labour supply effects and, from which we draw a detailed analysis of gainers and losers after a reform proposal. The main disadvantage of using a microsimulation model is that general equilibrium effects and feedback effects are neglected. This means that results are calculated under the assumption that, e.g. wages and interest rates do not change. In contrast, CGE models take these effects into account but are usually based on aggregated household types. The loss of information within the household sector makes a detailed analysis of the reform effects impossible. Therefore, the combination of microsimulation and CGE-models to combine the advantages of both types and to reduce the disadvantages of each model type is a further logical development.

All in all, the recent developments in microsimulation models for Germany are dominated by three research institutes[1]: First the German Institute for Economic Research (DIW), the Institute for the Study of Labour (IZA) and the Centre for European Economic Research

[1] Besides these research institutes, microsimulation models are also applied and maintained at universities or at the Institute of Employment Research, a department of the Federal Employment Service.

(ZEW).2 While DIW uses a microsimulation model, the IZA has established a combined CGE-microsimulation model, albeit with only one representative household in the CGE-model. The ZEW, as stand alone, uses a fully integrated CGE-microsimulation model with around 4,000 households.

The paper is organized as follows: In Section 2 the microsimulation model is illustrated, which algebraically describes the household labour supply model to consider behavioural response. We also describe the data used and the most important German tax transfer regulations. Section 3 refers to the general equilibrium modeling. A general overview is followed by the presentation of the general equilibrium model PACE-L. The linkage of the microsimulation model STSM to the general equilibrium model PACE-L is given in Section 4. Section 5 concludes and presents an outlook for further research.

2. Microsimulation

It was *Guy Orcutt (1957)* who brought microsimulation models into social sciences as a new type of modeling that is based on distributions, and therefore can be regarded as micro based. Although this was a revolutionary contribution, the employment of microsimulation models in economic analysis actually developed three decades later. The explanation can be found in the access to individual based data (e.g the German Socio Economic Panel/GSOEP started in 1984) and in growing computing power (*Harding/Gupta, 2007*).[3]

Microsimulation models, in particular tax–benefit microsimulation models, use a detailed representation of a tax system to simulate policy reforms. Structurally, microsimulation models are based on micro data with detailed information on socio-demographic variables (e.g. number of children in household, age, sex or education), incomes, taxes, benefits and working time of households and individuals. If the micro data are a representative sample of the population, the simulated effects also serve as forecast for the possible impact of the proposed reforms (see *Harding, 1996*).

[2] See for example*: Haan/Wrohlich (2007*), *Haan et al. (forthcoming)*, *Haan (2006), Wrohlich/Steiner (2008), Wrohlich (2006), Bonin/Kempe/Schneider (2003), Brenneisen/Peichl (2007 a,b), Peichl/Schaefer (2006), Arntz et al. (2008), Clauss/Schnabel (2008), Arntz/Boeters/Guertzgen (2006)*

[3] See *Lenhard (2004)* for an illustration of creating a full computerized decision making system i.e. for the weather forecast.

There are two main branches of microsimulation models: On the one side, there are static models that do not consider behavioural response of the households/individuals after the policy changes have come into effect. These arithmetic models simulate only the so called "morning-after effects" or "first-round effects". On the other side there are models which also allow for behavioural reactions by integrating a household labour supply model. The estimated labour supply effects also establish a partial equilibrium as the labour supply side of the household sector is regarded. These so called "second round effects" can also be transferred and assessed in a following distribution and poverty analysis.

A very promising development is EUROMOD (*Sutherland, 2001, 2007*) which is a popular European microsimulation model covering 15 EU member states and which is continuously expanding. For Germany, in particular, *Wagenhals (2004)* gives an overview on the existing microsimulation models applied to the German economy, although it is not clear if all of them still exist. *Peichl (2005)* gives an overview on the existing branches of simulations models. In addition, he also outlines the developments in Germany.

2.1 The ZEW-Tax and Benefit Microsimulation Model (STSM)

The ZEW tax and benefit microsimulation model (STSM) is a static microsimulation model for empirical analysis of the impacts of taxes, social security contributions and transfers on the income and labour supply of private households in Germany. The data basis is the GSOEP[4] which is a yearly based panel study of 12.000 representative households of the German economy. The microsimulation model described here uses the variables of the wave 2005 which are complemented with retrospective information of 2006 to have a more precise data position in the status.

2.1.1 Household Labour Supply Model

The STSM integrates both a simulation model for the German tax and transfer system and an econometrically estimated labour supply model. We use a structural model of household labour supply to transfer the outcomes of the STSM in behavioural responses of the households. We assume that the individual faces different hour categories producing different utilities according to the preferences of the individual. The individual decides to

[4] See *Haisken De-New/Frick (2005)*

choose the hour category with the highest utility. Married or cohabiting couples are regarded as one decision maker, jointly maximizing their utility.[5]

We use a linear translog utility function as proposed by *Van Soest (1995)*. For each individual we assume a weekly time endowment (TE) of 80 hours. We identify leisure as $lm_i = TE - h_i$ and $lf_i = TE - h_i$ where lm indicates the weekly leisure of a male and lf the weekly leisure of a female of the respective household i.

$$U_{ij}(x_{ij}) = x_{ij}' A x_{ij} + \beta' x_{ij} + \varepsilon_{ij} \qquad (1)$$

The utility of category j U_{ij} is as linear function in x_{ij}, containing monthly disposable income and leisure of the household in natural logarithm $(\log y_i, \log lm_i, \log lf_i)$.. The unobserved part is defined by ε_{ij} which is assumed to be iid. The symmetric 3x3 matrix A contains the coefficients of the interactions and quadratic terms of the included variables and the vector β contains the coefficients of the linear terms.

There are also further covariates that enter the utility function which controls different preferences for leisure ("observed heterogeneity") of households (i.e. age, education, number of children, regional dummy for Eastern Germany, nationality, dummy for part-time or full-time employment).

The probability of a decision maker now choosing category *j* instead of category *l* is given by:

$$\Pr_j = \Pr(U_j > U_l) = \Pr((x_j' A x_j + \beta' x_j) - (x_l' A x_l + \beta' x_l) > \varepsilon_l - \varepsilon_j), \forall l \neq j \qquad (4)$$

The equation is solved by making distributional assumption about the unobserved part of the utility function. In particular, it is assumed that the density for each unobserved part of the utility function is following a Gumbel or type I extreme value distribution.

$$f(\varepsilon_{ij}) = \exp(-\varepsilon_{ij}) \cdot \exp(-\exp(-\varepsilon_{ij})) \qquad (5)$$

[5] An extension of the unitary household model would be to focus on intra-household sharing of incomes which has been done with a collective household model in *Beninger/Laisney/Beblo (2007).*

As shown by *McFadden (1974, 2001)* the difference of the unobserved parts has a logistic distribution. The probability of choosing category j can thus be written as in Equation (6)

$$\Pr_j\left(U_j > U_l\right) = \Pr(X = j) = \frac{\exp\left(x_j' A x_j + \beta' x_j\right)}{\sum_m \exp\left(x_m' A x_m + \beta' x_m\right)}, \forall l \neq j \tag{6}$$

The parameters of the conditional logit model are estimated by maximum likelihood, assuming the IIA-assumption holds (See Equation 7).

$$L = \prod_{i=1}^{n} \prod_{j=1}^{m} \Pr\left(H = j\right)^{d_{ij}} \tag{7}$$

Where $\Pr\left(H = j\right)$ describes the choice probability of category j, and d_{ij} is defined as indicator which takes the value $d_{ij} = 1$ if household i has chosen category j and 0 if not.

2.1.2 Data Basis and Selection of Households

For the empirical implementation of the STSM, a data set is needed that contains the necessary person- and household characteristics, is representative of the German population, contains a sufficient number of cases and is up-to-date. The GSOEP basically fulfils these requirements. However, there are some restrictions like the missing information about household assets, which are required to detect transfer entitlements, and the limited information on tax rebates. All in all, the GSOEP with all its advantages and disadvantages embodies the best compromise for the tax-transfer-simulation out of all the micro-datasets available today for Germany.
Income and transfers cannot be simulated for every household in the GSOEP. A selection of households is done because of various reasons. On the one hand, the simulation of hypothetical incomes for alternative employments requires information about the entitlement to unemployment benefit in the case of unemployment. This entitlement can be deduced from the employment participation during the three previous years, the information about which is contained in the GSOEP. Since the income information has ben col-

lected retrospectively in the succeeding year, only those households who have participated in the survey in four consecutive years enter the simulation.
Missing values for workers' compensation, duration of employment, and earnings from rent and lease are being imputed if they can be deduced sufficiently from other information. In case where this is not possible, the households are eliminated from the simulation. Finally, those households are excluded for which the required information about the head of the householder's or the partner's marital situation is missing. For a simulation of the incomes depending on the amount of employment, only the householder's or the partner's amount of employment is varied. Certain information such as the potential entitlement to unemployment benefit are thus only needed for the head of the household and their partners - and households are accordingly only excluded if the information was missing for these persons. From the group of the remaining households, those persons who live in one household together with the householder, but are neither relatives nor cohabitant, are excluded. A further selection of households results from the designated application of the STSM to simulate the employment behaviour of employees. In the economic theory, the labour-supply decision is usually modelled as a trade-off between utility from consumption or leisure. This trade-off between temporary consumption and leisure cannot be assumed to be the same for all types of persons facing the labour-supply decision. This concerns, for example, retired persons, trainees, persons in military/civil service, as well as students. The self-employed persons' labour-supply decision should significantly different from the one made by employees. The analysis thus focuses on certain groups of employees and unemployed, for whom a similar consumption- and leisure-utility calculation can be assumed. We do not include the following groups of persons:

- persons younger than 20 or older than 65 years of age
- recipients of pension, retirement transition or early-retirement payments
- trainees (school, university, vocational training etc.)
- persons in maternity leave or military/civil service
- mainly self-employed persons.

Legal income tax regulations, which are only relevant for these types of persons, were not implemented. Thus, for these persons, simulations cannot be done. We differentiate householders and partners with variable and with invariable labour supply. Three types of households that are treated differently result in the following:

1. households with flexible householder and flexible partner (flexible households)
2. households with flexible householder or flexible partner (mixed households)
3. households with inflexible householder and inflexible partner (inflexible households).

For single-households, the second type of household does not apply. Households in which neither the householder nor the partner display a variable labour supply (group three) are excluded from the labour supply simulation. Single-households are excluded from the simulation if the householder had no variable labour supply. Group one, in which both the householder and the partner have a flexible labour supply in couple-households, can thus be included in the simulation of labour-supply reactions. The second group, in which either the householder or the partner show a flexible labour supply, represents a special case. For these mixed couple-households, a simulation of the labour-supply reactions is done, but they are technically treated as single-households. The detection of the net household income depending on the employment behaviour is done for the partner with flexible labour supply for different amounts of employment while, for the partner with inflexible labour supply, actually working time is considered.

For the simulation of income depending on the employment behaviour, only the first and second group (the flexible and mixed households) are relevant. For an analysis of the actual incomes without behavioural responses, the third group can also be included.

2.1.3 Regulations of the Tax and Benefit System

The ZEW micro simulation model calculates the disposable household income, as well as the taxes and benefits. The calculation of these outcomes is based on a very detailed representation of the German tax and transfer system, summarized very briefly below.

The net disposable household income detected in the STSM is derived from the components stated in Table 1. The first part of the table contains the household's income; the second part lists the wage-replacement benefits and transfers; and the third part applies the deductions.

Table 1: Components of the Household Net Income

	Income components
1	Income from employment + Income from assets + Income from rent and lease + Income from self-employment, agriculture, forestry,
2	+ child benefit + raising benefit + housing benefit + unemployment benefit I and II + social assistance
3	- social security contributions - taxes
	disposable household net income

Incomes

The data contain the information on actual wages or salary received which, enables us to calculate the income from employment. For the simulation of different market states we estimate the hourly wage rate of each individual, which is then multiplied by the associated working time.[6] The pieces of information about the incomes from assets contained in the data are limited in several ways: Firstly, we only have information on the returns through interests and dividends, secondly, the returns on interest and dividends are not differentiated by types of investment but are rather displayed as a total amount. Thus, it is assumed that the entire revenues can be considered as earnings from assets. The information about incomes from rent and lease is rather incomplete. We either can observe income from rent or lease of moveable assets or from the surrender of rights. In the data only income from rent and lease of real property are explicitly listed. The data also show missing values to a relevant extent for the information about interest and acquittance payments, as well as for operating expenses which are associated with income from rent

[6] For people who are not working we estimate a wage regression with selection correction as proposed by *Heckman (1976)*

and lease. To avoid elimination of these cases on the one hand - and trying not to skew the data on the other hand - we replaced the missing information. Income from agriculture and forestry, from business and from self-employment are not collected separately in the GSOEP. Special regulations for these types of income in the income tax law can thus not be considered. As mentioned earlier, self-employed are excluded from the labour supply simulation. Income from self-employment is therefore only measured through the channel of supplementary income. Since it is not possible to disentangle whether supplementary income is from self-employment or employment, it is assumed to be 100% from self-employment.

Benefits

We have information on the number, the relation to the householder and the age of persons in the household. As such we can identify and model the child benefit by multiplying the number of children with the respective rate of 154 Euro (from the fourth child onwards the rate amounts 179 Euro). We restrict the availability of child benefit to children under the age of 26 and we apply the deduction rule (if the child's income exceeds 7,680 Euro per annum). On the other side there exist child tax allowances of 5,808 Euro for each child. We implement a yield test to decide whether the household benefits more from the child benefit or from child allowances. The information on the number of the children is also used to model the child-raising benefit. As there are two alternatives offered by the legislation, we assume that the standard rate is chosen. This rate amounts to 300 Euro per month. It is assumed that one person could always dedicate himself/herself to raising the child in the sense of the legislation if he or she was not employed for more than 19 hours per week or receiving unemployment benefit, assistance or child-raising benefit for a similar activity. In cases this precondition is met by persons with a child younger than 2 years, and if certain income thresholds are not exceeded, generally, an entitlement to child-raising benefit is fulfilled.

The amount of actual rent is collected in the GSOEP. Generally, it is known whether and how many heating- and hot-water costs are included within the rent, so that a rent adjusted by these components can be calculated. If the information is missing – regardless of whether or not heating- and hot-water costs are in the rent - it is assumed that they are not contained. Thus, the actually paid rent according to the Housing Benefit Law may possibly be overestimated in some cases. The potential impact of this overestimation on the simulated housing benefit is, however, already limited by the ceiling amounts of rent

eligible for benefit applying for the housing-benefit calculation. In the case that the information about the actually paid rent is missing entirely, the ceiling amounts eligible for benefit are imputed. The actual amount of housing benefit results from bulky tables, which consist of three dimensions. These are the household-size, the amount of rent or encumbrance to consider, and the monthly family income. These tables are not exactly transferred into the simulation but approximated by a function for each household-size.
In the GSOEP we can also refer to the employment and unemployment spells. This information, and the questionnaire about receiving unemployment benefit, serve to identify the entitlement in Unemployment Benefit I (UB I). This benefit is income- related and the duration in UB I strongly depends on the prior employment record. It offers a replacement rate of 60% for persons without dependent children and 67% percent for others. In return, the Unemployment Benefit II (UB II) is basically a minimum income program for all households in which at least one person is considered to be a labour force participant, but with means-testing. As such we simulate the UB II entirely in our model without referring to actual transfer payments. The basic amount is 345 Euro. For each partner or adult child in the household 80% of the basic amount are considered. For example, for a couple without children the minimum income level (net of rent payments) is 621 Euro per month. There are supplementary payments for extraordinary situations (e.g. for single parents, for disabled persons, for special dietary requirements of sick persons etc.). For children, a lower monthly rate is paid. In general, the rent for "adequate housing" is also added. The Social Assistance comprises equivalent rates and is analogously simulated. The differences to UB II are first, that within the household no labor force participant exist and second, the allowances for the means testing.

Deductions

As social security contributions we consider pension, health and employment contributions up to the upper social security contribution limit. The GSOEP does not contain detailed information about which health insurance company the person has chosen. We circumvent this information deficit by applying average rates for Germany. However, we incorporate the specific social security contribution regulations which accrue to the atypical employments like mini-job (up to 400 Euro gross monthly income) and midi-jobs (from 400 to 800 Euro gross monthly incomes). The taxes are further deducted by applying the contemporary tax-scheme. As the German tax system defines a progressive tax system, offering income splitting for married couples, we assume that married couples always choose joint income taxation.

3. General Equilibrium

General equilibrium models allow analyses of exogenous shocks, taking into account the whole economy rather than parts of it. These models account for all factor markets as well as markets for goods. Economic agents, such as households, firms or the government are represented through income balance equations, demand and supply functions. The agents' decisions result from the respective optimisation problem: households choose the utility-maximising labour-leisure combination, while firms decide about the cost-minimising factor input combination. On each market, supply and demand are balanced by an adjustment of relative prices using the so-called "market clearance conditions". However, it is possible to allow for markets, which do not clear. This applies especially to the labour market, where unemployment plays an important role[7].

Within a model that includes *n* markets, Walras Law states that only *n-1* markets are independent from each other (see *Mas-Colell et al., 1995*). This implies that if all markets except one are in equilibrium, then the last market must also be in equilibrium. Although the model represents *n* markets, only *n-1* prices can be determined. Fixing a numeraire, the Walrasian equilibrium can be characterized by *n-1* equations *n-1* variables which determine relative prices rather than absolute price

3.1 Applying General Equilibrium Models

Computable (CGE) or applied general equilibrium (AGE) models combine the theoretical general equilibrium framework and statistical data to improve practical relevance. The use of these models allows for an operationalization of complex research questions, which cannot be solved analytically. Furthermore, economic results can be quantified, thus pointing out which effects dominate and which are of minor importance. Therefore, CGE models represent an important tool for analyzing and comparing potential reform scenarios ex-ante.

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[7] See *Böhringer/Boeters/Feil (2005)* for a CGE-analysis including union wage-bargaining and the effects on employment and unemployment.

Applied general equilibrium models were pioneered by *Johansen (1960)* who established the CGE modeling tradition, which started in the 1970s (see, e.g., *Ballard et al., 1985a*, *Shoven/Whalley, 1984*). Currently, general equilibrium models that are solved numerically are widely used by research centers, the World Bank or the European Commission (see, e.g., *Böhringer/Löschel, 2005*).

These models use data, which typically come from the national accounts. The macroeconomic data are used to build a social accounting matrix (SAM, see, e.g., *Pyatt/Round, 1985*), which comprises all economic flows of an economy for a certain period. It includes all economic agents of the general equilibrium model. According to the economic theory, an agent's sum of expenditure equals that of his/her revenues. Applying statistical data, this condition is generally not met in reality due to various reasons. Therefore, different approaches were made to address this problem and to provide a consistent social accounting matrix, e.g. the Cross Entropy Method (*Robinson/Cattaneo/El Said., 2001*).

Given the consistent data base, all required parameter of the model can be calibrated (see *Mansur, 1984*, for an overview of calibration). Here, one assumes that the status quo economy is in equilibrium, which is reflected by the data. Solving the model equations for the parameters to be calibrated and plugging in prices and amounts of the benchmark year yields the unknown parameters. The calibration procedure can be interpreted as a point estimation of parameters (see *Böhringer/Wiegard, 2003*). Admittedly, it would be preferable to estimate these parameters using econometric methods. But this would require a lot of observations for each parameter, which are often not available.

3.2 The PACE-L Model: The Model Framework

PACE-L is a static general equilibrium model built to analyse policy reform proposals. The model represents a small open economy. We apply the Armington assumption to seven representative firms producing twelve homogenous commodities and services, using capital, labour and intermediate inputs. The model distinguishes between low and high-skilled labour. Workers are mobile, but they can only change sectors during a period of unemployment. Matching of unemployed workers with vacant jobs occurs at random. Capital is assumed to be mobile among sectors.

One of the model’s distinctive features is the incorporation of decentralized wage- bargaining in both the labour markets for low-skilled and high-skilled individuals. In each labour market, an employers' organization and a labour union are engaged in wage negotiations, which are modelled as a "right-to-manage" Nash-bargaining. We assume that the bargaining parties have rational expectations about the labour demand outcome. Furthermore, the model includes a discrete choice labour supply module that allows for the distinction between labour supply at the intensive margin and labour at the extensive margin.

The detailed formulation of the model reads as follows: for the production sectors, we assume that each individual firm is small in relation to its respective sector. All firms in one sector interact through monopolistic competition, which means that they produce variants of the sectoral output good Y_s thus attracting different consumers. This is how a firm can exploit market power in the respective market segment. From this follows that output prices $p_{y,s}$ consist of costs of primary inputs and intermediary inputs plus a fixed mark-up m_s.The budget constraint of the respective firm can be written as:

$$(1-m_s)p_{y,s}Y_s = \sum_{ss} p_{a,ss}A_{ss,s} + r(1+t_k)K_s + \sum_i w_{i,s}(1+t_{l,i})L_{i,s}, \qquad (8)$$

where

$A_{ss,s}$ ≔ intermediary input from Armington good
K_s ≔ capital input,
$L_{i,s}$ ≔ labour input of skill type

Profits in sector s are given by

$\pi_s = m_s p_{y,s} Y_s$.

To derive optimal demand for intermediate and value added inputs, we apply a nested constant-elasticity-of-substitution (CES) production structure. The inputs consist of low-skilled labour and a composite of high-skilled labour and capital (HK-aggregate). This reflects the empirical evidence that low-skilled labour is a relatively good substitute for the HK-aggregate - whereas the substitution elasticity between capital and high-skilled labour is relatively low. The cost functions of the value added aggregate $c_{va,s}$ and the HK-aggregate $c_{hk,s}$ for each sector s can be written as:

$$c_{va,s} = \left[\beta_s^L \left(\frac{w_{L,s} \cdot (1+t_{l,s,L})}{\overline{w}_{L,s} \cdot (1+\bar{t}_{l,s,L})} \right)^{1-\sigma_s^L} + (1-\beta_s^L) c_{hk,s}^{1-\sigma_s^L} \right]^{\frac{1}{1-\sigma_s^L}}$$

$$c_{hk,s} = \left[\beta_s^H \left(\frac{w_{H,s} \cdot (1+t_{l,s,H})}{\overline{w}_{H,s} \cdot (1+\bar{t}_{l,s,H})} \right)^{1-\sigma_s^H} + (1-\beta_s^H) \left(\frac{r(1+t_{k,s})}{\overline{r}(1+\bar{t}_{k,s})} \right)^{1-\sigma_s^H} \right]^{\frac{1}{1-\sigma_s^H}}, \tag{9}$$

where

β_s^L := benchmark value share of L in VA aggregate,
β_s^H := benchmark value share of H in HK aggregate,
$w_{i,s}$:= wage of skill group i (gross of wage tax),
r := rental rate of capital,
σ_s^L := elasticity of substitution in VA nest,
σ_s^H := elasticity of substitution in HK nest,
$t_{l,i}$:= social security contributions of labour of type i,
$t_{k,s}$:= capital input tax,

and the "bar" superscript denotes benchmark values. Cost minimization at each nest yields the following demand functions for the primary factors at the sectoral level:

$$K_s = Y_s \left(\frac{c_{va,s}}{c_{hk,s}} \right)^{\sigma_s^L} \left(c_{hk,s} \frac{\overline{r}(1+\bar{t}_k)}{r(1+t_k)} \right)^{\sigma_s^H},$$

$$L_{H,s} = Y_s \left(\frac{c_{va,s}}{c_{hk,s}} \right)^{\sigma_s^L} \left(c_{hk,s} \frac{\overline{w}_{H,s}(1+\bar{t}_{l,H})}{w_{H,s}(1+t_{l,H})} \right)^{\sigma_s^H}, \tag{10}$$

$$L_{L,s} = Y_s \left(c_{va,s} \frac{\overline{w}_{L,s}(1+\bar{t}_{l,L})}{w_{L,s}(1+t_{l,L})} \right)^{\sigma_s^L}.$$

We assume that in each sector, an employer's association and a trade union bargain over wages following the right-to-manage approach: parties bargain over wages, and subsequently, firms decide on labour demand, taking the bargained wages as given. The bargaining outcome results from the maximisation of a Nash function. This Nash function includes both parties' objective functions and respective fallback options. The objective function of the employer is given by its profit π_s, while the fallback option implies zero profits. The Nash function Ω_s can be written as:

$$\ln \Omega_s = \ln \pi_s + \rho_{H,s} \ln \Gamma_{H,s} + \rho_{L,s} \ln \Gamma_{L,s}. \tag{11}$$

where $\rho_{r,s}$ denotes bargaining power of both skill types L, H relative to the firm's bargaining power. For each skill type, the union's objective function $\Gamma_{r,s}$ is employment $L_{r,s}$ times the value of a job $V_{r,s}$ minus the value of unemployment $V_{U,r}$:

$$\Gamma_{r,s} = L_{r,s}\left(V_{r,s} - V_{U,r}\right). \tag{12}$$

According to the literature on search unemployment (e.g. *Pissarides 1990*), the values of the labour market states are recursively determined as weighted averages of the incomes in the case of employment and unemployment. The weights are computed from the transition probabilities between the labour market states, which are employment and unemployment. This means, the value of a job $V_{r,s,t}$ in period t is given by:

$$V_{r,s,t} = \frac{1}{1+r}[I_{r,s}(1+npc_{r,s}) + (1-\mu_{r,s})V_{r,s,t+1} + \mu_{r,s}V_{U,r,t+1}]. \tag{13}$$

$\mu_{r,s}$ represents the sector-specific separation rate from employment to unemployment, $npc_{r,s}$ is a non-pecuniary pay component, and $I_{r,s}$ is the average disposable income of an employed worker. Using the steady-state assumption, we can replace the value of employment of the previous period by its value of the current period. We can use the difference between the value of employment and unemployment to simplify the Nash function by:

$$V_{r,s} - V_{U,r} = [\frac{I_{r,s}(1+npc_{r,s}) - rV_{U,r}}{r+\mu_{r,s}}], \qquad (14)$$

to yield an objective that only depends on the average disposable income $I_{r,s}$ of an employed worker. In contrast, the value of unemployment $V_{U,r}$ is assumed to be exogenously given. The wage resulting from the bargaining negotiations is, in turn, used to calculate the average income in case of employment.

Given the wages for low and high-skilled workers, which result from the bargaining negotiations, firms decide about their labour demand according to their labour demand equations displayed above. The difference between labour supply and demand endogenously determines unemployment. In equilibrium, job-seekers must be indifferent between any two of the sectors.

The household sector is comprises three representative households, two worker households and one capitalist household. One representative worker household captures individual households with flexible labour supply. These individual households derive utility from leisure and consumption. To derive optimal labour supply, we use the same discrete choice model (*Van Soest, 1995*) as the microsimulation model. Labour supply finally determines the disposable household income which is used for consumption. In contrast, the second representative worker household includes all households, whose labour supply is assumed to be fixed. The third household is endowed with capital and property rights of the firms. Only the household mentioned last takes a consumption-savings decision. The representation of this decision follows the approach of *Ballard et al. (1985b)*, where the household purchases an investment good representing a fixed-coefficient composite of all goods (*Böhringer et al., 2005*).

We assume identical consumption spending patterns for all three aggregate households. Aggregate consumption C, which is equal to the sum of the consumption of the three household types, is distributed among the different consumption goods C_z, according to a CES function:

$$\frac{C_z}{\overline{C}_z} = \frac{C}{\overline{C}}\left(\frac{P_C}{\overline{P}_C}\frac{\overline{p}_{z,c}}{p_{z,c}}\right)^{\sigma_c}, \qquad (15)$$

$$\frac{P_C}{\overline{P}_C} = \left[\sum_z \theta_z^C \left(\frac{p_{c,z}(1+t_{c,z})}{\overline{p}_{c,z}(1+\overline{t}_{c,z})} \right)^{1-\sigma_c} \right]^{\frac{1}{1-\sigma_c}}, \tag{16}$$

where

P_C := consumer price index,

θ_z^C := benchmark value share of consumption good z,

$p_{c,z}$:= producer price of consumption good z,

$t_{c,z}$:= consumption tax,

σ_c := elasticity of substitution in consumption,

A reform scenario is always modelled as budget neutral reform by fixing the government budget T in real terms according to the benchmark level. Government revenues consist of taxes on capital K_s, labour, consumption C_z of commodity z, output Y_s and profits π_s :

$$T = \sum_s t_{k,s}\, rK_s + T_{MS} + \sum_z t_{c,z}\, p_{c,z} C_z + \sum_s t_{y,s}\, p_{y,s} Y_s + \sum_s t_\pi \pi_s, \tag{17}$$

where $t_{k,s}$ is the capital tax rate, $t_{c,z}$ the consumption tax rate, $t_{y,s}$ the output tax rate, and t_π the profit tax rate. r, $w_{i,s}$, $p_{c,z}$ and $p_{y,s}$ denote the respective prices. The profit tax includes all other taxes paid by firms. T_{MS} is the balance of labour income taxes plus social security contributions minus transfer payments of individual households.

3.2 The PACE-L Model: The Application to the German Economy

We apply the theoretical general equilibrium model to the German economy. Various sources of data are used to build a consistent data base representing the equilibrium status quo, which is taken as the standard for our comparative analyses. Macroeconomic data for the CGE-model is taken from national accounts. We use the 2002 input-output table (IOT) provided by the Federal Statistical Office of Germany, which contains a consistent data set of economic transactions for 71 sectors. From the IOT, we derive the value of capital services, total labour income and profits. The German Federal Bank's publication on annual accounts of West-German enterprises supplies another important figure for calculating profits, namely the profit per Euro of sales ratio net of taxes. The value of capital services is calculated as the difference between total capital earnings and profits. Mark-up rates result as the ratio of profits over sales. Furthermore, we apply data of the employment statistics register to divide total labour income into earnings of low-skilled and high-skilled individuals. An employee without a vocational or academic degree is treated as unskilled. We derive the tax rates applied at the aggregate level from the tax revenue statistics of the Federal Ministry of Finance (BMF, 2002).

Furthermore, some econometric estimates are taken from publications, such as substitution elasticities for the production sectors (*Falk/Koebel, 1997*). Complementary information on factor price elasticities are taken from *Buslei/Steiner (1999)*. Armington elasticities required for the production of the Armington goods from imports and domestically produced goods are taken from *Welsch (2001).*

The data source of the household type covering individual households with flexible labour supply is the German Socio-Economic Panel (GSOEP). In contrast to other CGE models, which use aggregated household data from national accounts or use microdata to build highly aggregated household types, we directly use individual data without aggregation (see *Arntz et al., 2008*, for different aggregation levels of households). Moreover, the required data is derived using the fully sophisticated microsimulation model rather than simplified tax and transfer rules. The details of linking the two models are presented in the following section.

4. Linking the Models

The microsimulation model of Section 2 and the CGE model of Section 3 are linked to combine the advantages of both models. Firstly, the microsimulation model based on individual household data is used to calculate all those parameters which are required to run the CGE model. This comprises parameters given in Table 2:

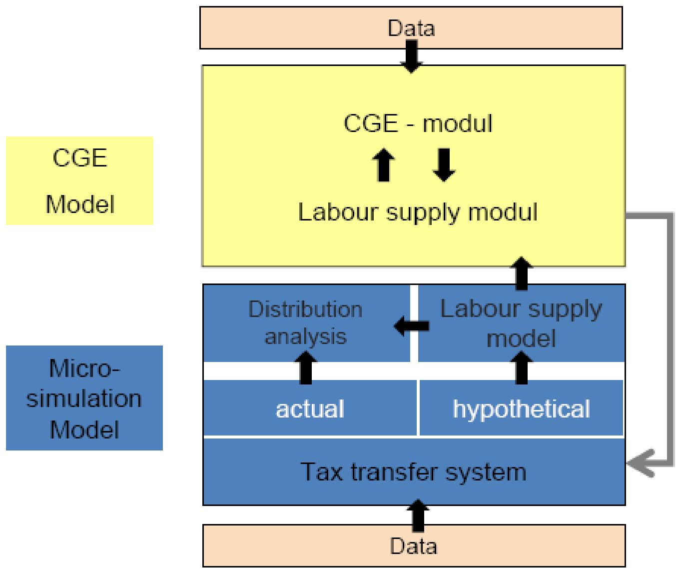
Table 2: Transfer Microsimulation – CGE Model: Parameters

Parameter	Depending on
Estimated Parameters	
Parameters utility function	Household
Gross wage	Household, person
Calculated and Statistical Parameters	
Household weight	Household
Dummy skill type	Household, person, skill type, scenario
Taxes	Household, working hours, scenario
Transfers	Household, working hours, scenario
Marginal tax rate	Household, person, working hours, scenario
Gross income	Household, working hours, scenario
Disposable income	Household, working hours, scenario

Table 2 reveals that the microsimulation model does not only provide for calculated parameters but also econometric estimates. Furthermore, some parameters vary, e.g. concerning labour supply options, and have to be derived for all dimensions. Disposable income, for example, depends on labour supply options or labour supply option combinations for couples.

The data are transferred to the CGE model that additionally uses macroeconomic data of national accounts and other sources. Within the CGE model, the labour supply module and the CGE module are kept separate and iterated until a global solution results. First of all, the labour supply module produces the labour supply reactions of our policy measures. Given the partial equilibrium nature of this analysis, wages and unemployment rates are held constant. The intermediate results of the first round equal those of the pure microsimulation model. The resulting labour supply is aggregated by skill type and transferred to the CGE module. Running the CGE module, we derive wage reactions and changes in the unemployment rate resulting from the change in labour supply. The changes in wages and income taxes required to balance the public budget are fed back to the labour supply module for the next iteration, where the next round's labour supply effects are computed. This continues until the two modules converge. Transferring data from the labour supply module to the CGE module requires the aggregation of individual labour supply per skill type, which is measured in efficiency units. We assume that the individual wages move in proportion to the average macro-economic wage of the respective skill group. When transferring data from the CGE module to the labour supply module, it is therefore firstly necessary to adjust individual wages and, secondly, to account for the change in the income tax rate, which is used to balance the government's budget in the CGE module.

Figure 1: The Combined Microsimulation-CGE-Model



The CGE model yields the overall solution. Given equilibrium wages, tax rates and labour supply, this information can be transferred back to the microsimulation model. Using the microsimulation model has the advantage that the results can be analyzed on a highly detailed level, since the model includes an advanced tool to investigate distributional and allocative effects.

As Figure 1 reveals, the labour supply model appears twice. At the current state of the art, technical problems resulting from the data transfer between the microsimulation and the CGE model exceed the additional effort, which is caused by formulating the labour supply model twice. However, a further development of such a combined model would be, to re-establish the position of the labour supply model, and iterate between the microsimulation model and the CGE model.

5. Conclusion

In our contribution, we illustrate the development of the most up-to-date microsimulation CGE model in Germany, which defines the new state of the art in modelling policy analysis. The development or our combined microsimulation-CGE model at the Centre for European Economic Research (ZEW, Mannheim) has been initiated by the work of *Arntz et al. (2008)*. The authors extended the already existing CGE-model by integrating more than 3,000 individual households, which were linked to the microsimulation model. In their work, they compared the standard CGE model comprising 26 household types with the highly disaggregated version of this model. They show that the usage of a disaggregated model with individual households allows for a better distinction of the extensive and intensive labour supply effects compared to an aggregated model with a certain number of representative, or only one representative household. This becomes very important in evaluating the likely participation effects of a policy reform. Moreover, the authors find that the inclusion of general equilibrium effects can be fundamental in the valuation of the impact of policy reform proposals. In particular, allocative and distributive effects vary between the aggregated and disaggregated model versions, while the differences in macro-economic variables are of minor importance.

An application of this model to a policy reform was presented by *Franz et al. (2007)*. The authors quantify economic effects of the so-called “Hartz IV” welfare reform. The key element of this reform, which was already implemented in 2005, is to merge the two co-existing transfer systems. The authors aim to quantify the economic effects that can be traced back to this welfare reform. Since only few people are marginally affected, relatively small general equilibrium effects are calculated. The distribution analysis shows that a positive labour supply reaction of former transfer recipients does only translates into slight employment gains.

The combined microsimulation-CGE model has also served the Council of Economic Experts (*Sachverständigenrat, 2007*) when evaluating the employment and labour supply effects of the introduction of a basic income proposal. This reform proposal includes dramatic changes for most households, while also influencing the wage setting and unemployment to a high degree. In both of these analysis, the distribution analysis gives valuable insights into the effects at the individual household level that cannot be analyzed using an aggregated CGE model. At the same time, feedback effects covered by the general equilibrium approach influence wages, incomes and the overall effects, which should necessarily be taken into account.

Although *Guy Orcutt (1967)* suggested to link models that operate at different levels of aggregation, attempts to do so have remained limited. The combination of Computable General Equilibrium models (CGE) and microsimulation models heralds a new era of computational modeling. Future research is set to face many black boxes and pitfalls. Nevertheless, the combination of microsimulation models and general equilibrium analyses proves very promising, as it opens up new perspectives in economic analysis.

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