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SAINT – A STANDARDIZED CGE-MODEL FOR ANALYSIS OF INDIRECT TAXATION

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SAINT
– a Standardized CGE-model for Analysis of Indirect Taxation

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Abstract: This paper describes a computable general equilibrium (CGE) model that builds on the IFPRI standard model but is more suitable for analysis of taxes on specific commodities. It has a richer structure of taxes and trade margins on commodities than the IFPRI model and a flexible nest structure of production and household demand functions. It may be used for open as well as for closed economies. Also, data for a Swedish implementation is described and this application of the model is compared to some previous Swedish CGE models in terms of the estimated effects of a doubling of the CO_2 tax rate.

Keywords: CGE-models, commodity taxes, permit trading.

JEL Code: D58, H23, D62

1 Introduction

After Walras proved the existence of a general equilibrium of a market economy in the late nineteenth century (Blaugh 1996), it took almost a hundred years before computable general equilibrium (CGE) models were used in applied research (Johansen 1960). From the 1970s onwards the development of computational power, solution algorithms and user interfaces made CGE models more widely used. More recently, the development of standardized models like the IFPRI standard model (Lofgren et al. 2002) has made CGE modelling less time consuming, since the researcher does not need to start from scratch when building a model for a specific country.

While the IFPRI model has been extensively used in development economics, it is not very well suited for environmental analysis and analysis of commodity taxation. This paper presents a standardized CGE-model for analysis of indirect taxation, called SAINT, which is a development of the IFPRI model with the purpose of making it more suitable for advanced analysis of taxes on commodities and similar policy instruments. It can also be useful in other applications where a sophisticated description of the structure of the use of intermediate inputs is needed.

SAINT can be used for closed economies as well as for small open economies. The production functions allow for substitutability between different intermediate inputs. The nest structure for both production functions and consumer demand functions is flexible, simplifying changes in the nest structure. It is possible to include both ad valorem and unit taxes on commodities and to define different tax rates for different users.

The main contribution of SAINT is the flexible modelling of trade margins, which are allowed to differ across users, making it possible to consider price differences across different users that are caused by factors other than differences in tax rates.[1] An appropriate modelling of prices is needed for an accurate calculation of the use in physical units like TWh and m^3, which is important in a study of unit taxation and emissions.

This paper also describes a Swedish implementation of the model based on data from 2001. The parameter settings of the model follow a "tradition" set by the OECD model for analysis of energy policy issues (Burniaux et al 1992), which has influenced recent Swedish CGE models, but we diverge in one important aspect, by using higher base-case elasticities of substitution

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[1] This development was first presented in a conference paper in Brussels 2006 (Bohlin 2006). A similar solution was later developed by Hill (SGOR 2008:108, appendix 1).

between different kinds of energy. It is shown that, because of this, a main difference to these other Swedish models is that a further increase of the Swedish CO_2-tax (doubling the tax rate) has a negative impact on total tax revenue.

The rest of this paper is structured as follows: Section 2 highlights some specific aspects of SAINT, while the complete mathematical formulation is presented in Section 3. Section 4 describes the Swedish implementation of the model and finally section 5 provides a summary.

2 Some specific features of the model

SAINT is a static CGE model[2] consisting of a large system of equations, e.g., for market clearing conditions and balanced budget conditions, and equations determining the impact of prices on behaviour. By solving this system of equations before and after a policy change we get the impact of this policy on the flows of payments in the economy and are able to calculate the welfare implications for the different households in the model as well as changes in prices and wages and different macro variables.[3]

2.1 The social accounting matrix

The model is constructed around a social accounting matrix, SAM, which is a comprehensive, economy wide data framework and typically represents the economy of a nation, but may also represent a regional economy. It is a square matrix in which each account is represented by a column and a row. Each cell shows the payment from the account of its column to the account of its row. Thus, the incomes of an account appear along its row and the expenditure along its column. A SAM should always be balanced

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[2] SAINT is prepared for recursive dynamics by inclusion of a couple of equations determining industry specific capital return and unit price of investments that could be used to calculate industry specific investments due to Tobin Q or similar formulations. Moreover, consumption of the households is determined from both income and wealth and not just from income as in the standard model. Including wealth in household demand functions has no impact at all in static simulations but in dynamic simulations accumulation of wealth will increase the intercept in the consumption function.

[3] The model could be downloaded from http://www.natskolan.se/research/saint.htm and freely used under the GNU , General public license. This means that you are free to use it for any purpose including commercial applications and also to alter or redistribute it freely subject to the following restrictions

(1) The origin of this software must not be misrepresented; you must not claim that you wrote the original software. If you use this software in a product, an acknowldgement in the product documentation would be appreciated. (2) Altered source versions must be plainly marked as such, and must not be misrepresented as being the original software. (3) This notice may not be removed or altered from any source distribution.

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so that column sums equal row sums i.e. total expenditure equal total revenue for all accounts.

Figure 2.1 shows the basic outline of the SAM for the SAINT modelling system.[4] In Figure 2.1 the tax accounts are specified in different rows, to show the structure of the tax system, but aggregated to one column in order to save space. Note, though, that the number of columns should always equal the number of rows in a SAM.

Some of the accounts in the SAM describe the different actors in the economy; these are the activity accounts, the household accounts and the government account. For the actors in the economy the rows give the incomes and the columns the expenditures. Balanced budget equations ensure that the row sums always equal the column sums. The behavioural equations in the model give the response of the different actors to changes in relative prices.

Some accounts describe the different markets in the economy; these are the commodity accounts and the factor account in which the rows give the demand and the columns the supply, and the market equilibrium equations in the model ensure that column sums always equal row sums. The accounts for trade margins redistribute trade margins to the demand for retail services in the relevant commodity account.

The "rest of the world" account describes the balance of payments and the tax accounts describe the tax system. In the "Savings Investments" column the commodity entries give the demand for commodities for investment purposes, while the entries for taxes and trade margins give the taxes and trade margins on these investments.

[4] Since commodity taxes and trade margins are user specific the SAM has a slightly different structure to the IFPRI standard model. In the IFPRI standard model commodity taxes and trade margins are paid out from the commodity accounts while in SAINT they are paid out of the accounts of the different actors. Therefore these accounts must be specified with different rows for different commodities, i.e. they are matrices instead of vectors. The use table, i.e. the rows in the commodity accounts, should be specified in basic prices, while in the IFPRI modelling system the use table should be specified in purchaser prices. A SAM constructed for the SAINT modelling system could easily be transformed into a SAM for the IFPRI modelling system by adding the matrices for commodity taxes and trade margins to the rows of the commodity account and moving the tax and trade margins entries in the columns of the actors to the columns in the commodity accounts. A SAM for the IFPRI modelling system lacks the information needed to transform it into a SAM for the SAINT modelling system.

Figure 2.1 The structure of the social accounting matrix

	Expenditures								
Receipts	**Activities**	**Commodities**	**Trade margins**	**Taxes**	**Factors**	**Households**	**Government**	**Saving and investments**	**Rest of the world**
Activities		Output in basic prices							
Commodities	Intermediate input at basic prices		Trade margins to retail services			Consumption at basic prices	Consumption at basic prices	Investments at basic prices	Export at basic prices
Trade margins	Trade margins on intermediate inputs					Trade margins on consumption	Trade margins on consumption	Trade margins on investments	Trade margins on export
Other taxes on households						Other taxes			
Taxes on exports		taxes on exports							
Taxes on imports		taxes on imports							
Taxes on factor income					Tax payment				
Unit taxes on commodities	Unit taxes on intermediate inputs					Unit taxes on consumption	Unit taxes on consumption	Unit taxes on investments	Unit taxes on export
Ad valorem taxes on commodities	Ad valorem taxes on intermediate inputs					Ad valorem taxes on consumption	Ad valorem taxes on consumption	Ad valorem taxes on investments	Ad valorem taxes on export
Activity taxes not related to factor cost	Other taxes on activities								
Factors	Value added								Factor income
Households					Factor income		Transfers		Transfers
Government				Tax collection					Transfers
Saving and investments						Saving	Saving		
Rest of the world		imports			Factor income	Transfers	Transfers		

The entries for households and government in the “Savings Investments” row give the domestic supply of savings to finance those investments. The entry for “rest of the world” in the “Savings Investments” row gives the surplus of the financial account in the balance of payments. If the entries in the “rest of the world” account are equal to zero, SAINT is automatically transformed into a closed economy model.

2.2 The price structure in SAINT

The most important difference between this model and the standard model is the treatment of commodity taxes and trade margins. This section explains the motivation for the chosen way of modelling. The price structure of SAINT follows the price structure in national accounts and is illustrated in Figure 2.2. The price consists of four components, the basic price, the trade margin, the unit tax and the value added tax. The trade margins are divided into a fixed part and a variable part that are related to the purchased quantity. The fixed trade margins do not have an impact on the marginal cost and do not show up in the demand equations. They only show up in the LES equation to reduce the income available to households for spending in marginal prices and in the activity price function to determine total cost of inputs. The behaviour of economic agents can thus be modelled as dependent on marginal costs, not on average costs.

Purchaser prices are determined from the basic price of the commodity, equal for all users, and the user-specific trade margins and tax rates. In the model equations purchaser prices are defined as:

$$PP_{c,p} = \left(PQ_c + tq_{c,p} + TM_{c,p}\right)\left(1 + tv_{c,p}\right)$$

where:
$PP_{c,p}$ = Purchaser price of commodity C when purchased by actor p
PQ_c = Basic price of commodity C
$tq_{c,p}$ = Unit tax rate of commodity C when purchased by actor p
$tv_{c,p}$ = Ad Valorem tax rate of commodity C when purchased by actor p
$TM_{c,p}$ = Variable trade margin on commodity C when purchased by actor p

Keeping track of trade margins in an appropriate way is important in a study of unit taxes since the size of the variable trade margins will determine the percentage increase in marginal cost from a specific unit tax rate.

Moreover, an appropriate modelling of trade margins will improve the possibility of calibrating the model on data for physical quantities and not only on data for monetary payments. This feature is important in environmental models where physical quantities are as important as monetary payments.

To understand the importance of an appropriate modelling of trade margins, consider the data on the use of electricity in the pulp and paper industry and the household sector displayed in Table 2.1. As can be seen, the average prices differ quite a lot between households and the pulp and paper industry.

Table 2.1 Electricity prices and use 2001

	Sector	
	Pulp and paper	households
Use of electricity in GWh	21 662	41 127
Amount of money spent (million SEK)	4 591	37 991
Taxes (million SEK)	106	14 991
Money spent less taxes (million SEK)	4 485	22 950
Average price less taxes (SEK per kWh)	0.21	0.56
Electricity purchased by 1 million SEK (GWh)	4.8	1.8

Source: Own calculation bases upon data from Statistics Sweden

In most CGE models, prices are assumed to be equal for all users and are normalised to 1, i.e. the quantity unit would be equal to the quantity that is purchased for one million SEK. From the fourth row of Table 3.1 we can see that such a procedure would make very large differences in the quantity units for different economic agents in terms of GWh.

The difference in the pre-tax price in Table 3.1 may have different explanations. Some part of the difference is due to own production of electricity in the pulp and paper industry; some parts may be due to errors in data. But if a significant part of it reflects that large purchasers are able to buy electricity at lower unit prices, the technique of normalising prices has three problems. First, supply does not equal demand in physical terms, only in monetary terms. Second, it is difficult to calculate the total use of electricity in physical terms. Third, it is difficult to calculate a unit tax rate to be used in the model from a unit tax rate per GWh, since it must be recalculated from the amount of GWh in the quantity unit of each economic agent.

In national accounts, trade margins are defined as the part of the price that goes to a middleman in the retail trade industry, and thus as the difference between the amount paid by the user less taxes and the amount received by the producer. In SAINT in contrast, trade margins are the difference between the price really paid and a virtual price that is equal for all users.

In this thesis total trade margins are calibrated from trade margins in national accounts for most cases.[5] Fix trade margins are calibrated to zero if the total trade margins are lower than 30 percent of the basic price. If total trade margins are above 30 percent, the variable trade margins are set to 30 percent of the basic price and the rest of the trade margins are treated as a fixed trade margin.

2.3 A flexible nest structure in behavioural functions

The nest structure in the household demand functions is flexible. The user divides the commodities into subsets. For each subset an elasticity of substitution should be defined between the commodities within the subset. The different subsets of commodities are aggregated together using a linear expenditure system. This makes it possible to distinguish between substitutes and complements among the different commodities, and the user could easily change the structure of the household demand functions by changing the

[5] Trade margins on non-energy commodities are calibrated from trade margins in national accounts. Quantities of non-energy commodities are calibrated by normalising basic prices to one. For energy commodities, purchaser prices are calibrated by dividing total payments with use in physical units. Use in physical units is derived from total tax payments divided by unit tax rates. For fossil fuel a basic price is assumed making total trade margin on a specific fuel equal to the total trade margin on that fuel in the national accounts. In the case of electricity, trade margins are not reported in national accounts. Therefore the basic price is assumed to be on a level that avoids negative trade margins in too many sectors. The trade margins in national accounts depend upon the specification of the industries. It is only when the retailer is not classified under the same industry code as the producer that we will have any trade margins reported in national accounts. In the Swedish national accounts the electricity trading companies are classified under the same code as the producers and not in the retail trade sector meaning that trade margins according to the national account are equal to zero. Therefore trade margins have to be recalculated for the model.

subsets of commodities. For details about the household demand functions, see the list of equations.

For the use of intermediate goods in the production function, a similar system is adopted. For intermediate goods there is also a possibility of defining a subset of commodities without substitution possibilities. These commodities are always used in fix proportions to output. The user could easily adjust the nest structure of the production function by changing the subsets of commodities. For details about the production functions see the list of equations.

2.4 Balance of payments and macro closures

In the balance of payments, factor payments to other countries are dependent on domestic wage levels and profit rates, while factor income from abroad is exogenous. Transfers from abroad are fixed in foreign currency and are thus dependent on changes in the exchange rate, while transfers to other countries are fixed in domestic currency and thus independent of changes in the exchange rate.

The macro closures define the macroeconomic constraints in the model by defining what macro variables should be exogenous and what mechanisms should determine the endogenous macro variables. For the balance of payments four different closures are available; closed economy, fixed exchange rate, flexible exchange rate with foreign savings fixed and flexible exchange rate with foreign savings flexible.

For the savings – investments balance there are six closures available. In one closure marginal propensity to save is fixed and total saving determines the amount of investments. In another closure both investments and marginal propensity to save are fixed and foreign saving is determined from domestic saving less investments.[6] In the other four closures investments are fixed and different mechanisms adjust domestic savings to achieve the savings investments balance. For the government budget five closures are available. In one closure government saving is determined from the tax payments less government expenditure; the other four closures achieve a fixed amount of government saving by adjustments of different tax rates.

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[6] This closure requires the closure for balance of payment with both exchange rate and foreign savings flexible and vice versa. If we choose to have both the exchange rate and the foreign savings endogenous both marginal propensity to save and investments need to be exogenous.

As in the standard model there are three closures for the factors of production. One closure has unemployment and a fixed wage rate. Under full employment the factors are either freely mobile between activities or not. When factors are not free to move between activities, the wage rate will differ between activities. When factors are free to move, the user may choose either to have an equal wage rate in the whole economy or specify specific wage differentials between activities.

2.5 Emission trading

Following the small open economy assumption, the domestic economy cannot influence the price of the permits that are exogenously given. To simplify the model, the permits are modelled as an increase of the unit tax on fossil fuel. Since emission trading does not give any income to the government, a transfer is made from the government to the capital owners in the industries included in the emission trading system, from here on labelled as ETS industries. The size of the transfer to each industry is equal to the price times the amount of permits each industry receives.

The difference between total emissions in the ETS industries and domestic supply of permits gives the net export in permits. This net export gives a payment to the government from the rest of the world. Thus, the government revenue from the extra tax is exactly equal to its cost for the transfer to the capital owners and to the rest of the world. The governmental budget is not affected by emission trading.

The model assumes that the initial distribution of permits is made in a way that does not influence behaviour. This is certainly not the case in the ETS system of the EU, since exiting plants do not keep their permits and entrants may receive permits. The way permits are distributed in EU ETS does influence decisions about entry and exit.

3 A complete mathematical formulation of the model

3.1 SETS

Sets defining different kinds of accounts in the SAM

AC	global set for model accounts - aggregated microsam accounts
ACNT(AC)	all elements in AC except TOTAL
A(PNI)	activities
AETS(A)	all activities included in emission trading
ANETS(A)	all activities not included in emission trading
C(AC)	commodities
F(AC)	factors
FCAP(F)	capital
FLAB(F)	labour
FLAND(F)	natural capital
H(INSD)	households
INS(P)	institutions
INSD(PNI)	domestic institutions
INSNG(INS)	non-government institutions
P(AC)	all purchasers
PNE(PNI)	all purchasers except exports and investments
PNI(P)	all purchasers except investments

Sets used to define the nest structures

CGA	set to define commodity groups in intermediate use
CGH	set to define commodity groups in household consumption

Sets used to define different kinds of commodities

CD(C)	commodities with domestic sales of output
CDN(C)	commodities without domestic sales of output
CE(C)	exported commodities
CEN(C)	non-export commodities
CGOV(C)	commodities consumed by government
CLEO(C)	commodities with Leontief technology
CM(C)	imported commodities
CMN(C)	non-imported commodities
CSUBI(C)	commodities with ces technology in production
CTR(C)	commodities used for trade margins
CX(C)	commodities with output
FOSSIL(C)	fossil fuels
FOSSILPERM(FOSSIL)	fossil fuels included in permit trading
FOSSILNPERM(FOSSIL)	fossil fuels not included in permit trading

3.2 VARIABLES

Variables where the first letter is P are prices, Q quantities and Y income.

CPI	consumer price index (based on purchaser prices)
DMPC	change in marginal propensity to consume for selected inst
DTINS	change in domestic institution tax share
EG	total current government expenditure
EH_h	household consumption expenditure in household *h*
EXR	exchange rate
FSAV	The financial account in domestic currency, note that positive investments abroad are equal to negative financial account. If the variable FSAV is positive, foreigners invest more in the domestic country than domestic citizens invests abroad.
$FTM_{c,pni}$	fix part of trade margins on commodity *c* purchased of *pni*
$FTMINV_{c,a}$	fix part of trade margins on investments in *c* in activity *a*
GADJ	government demand scaling factor
GOVSHR	govt consumption share of absorption
$GRPROF_{a,fcap}$	gross return from capital *fcap* in activity *a*
GSAV	government savings
$IADJ_{a,fcap}$	investment scaling factor in activity a for capital *fcap*
IADJM	general investment scaling factor
INVSHR	investment share of absorption

MPC_{insd}	marginal propensity to consume for dom non-gov institution *insd*
MPCADJ	savings rate scaling factor
NETPERMIT	net import of emission permits
PA_{a}	output price of activity *a*
$PCAP_{a}$	price of aggregate capital in activity *a*
$PCGA_{a,cga}$	price of intermediate aggregate *cga* in activity *a*
$PCGH_{h,cgh}$	price of aggregated commodity *cgh* in household *h*
PDS_{c}	supply price for com'y *c* produced & sold domestically
PE_{c}	price of exports of commodity *c* in national currency
$PI_{a,fcap}$	price per unit of investments of *fcap* in activity *a*
$PLAB_{a}$	price of labour aggregate in activity *a*
$PLEO_{a}$	price of aggregate Leontief intermediates in activity *a*
PM_{c}	price of imports of commodity *c* in national currency
PQ_{c}	price of composite good *c* (basic price i.e. without taxes and trade margins)
PSC_{a}	price of production less Leontief inputs in activity *a*
$PSUB_{a}$	aggregate substitutable inputs less operating surplus in activity *a*
$PSUBI_{a}$	price of aggregate substitutable intermediates in activity *a*
PWE_{c}	world price of exports of commodity *c* in foreign currency
PWM_{c}	world price of imports of commodity *c* in foreign currency
PX_{c}	average output price of commodity *c*
QA_{a}	level of domestic activity in activity *a*
$QAGGINV_{a,fcap}$	quantity of aggregate investments *fcap* in activity *a*
$QCAP_{a}$	quantity of capital aggregate in activity *a*
$QCGA_{a,cga}$	quantity of aggregated commodity *cga* in activity *a*
$QCGH_{h,cgh}$	quantity of aggregated commodity *cgh* in household *h*
QD_{c}	quantity of domestic sales of commodity *c*
QE_{c}	quantity of exports of commodity *c*
$QF_{f,a}$	quantity demanded of factor *f* from activity *a*
QFS_{f}	quantity of factor supply of factor *f*
QG_{c}	quantity of government consumption of commodity *c*
$QH_{h,c,cgh}$	quantity consumed of com *c* by household *h* in group *cgh*
$QINT_{c,a}$	quantity of intermediate use of commodity *c* in activity *a*
$QINTA_{csubi,a,cga}$	quantity of intermediate use of *csubi* in activity *a* in commodity group *cga*
$QINV_{c,a,fcap}$	quantity of investment demand for commodity *c* in activity *a* to be used in formation of capital good *fcap*
$QLAB_{a}$	quantity of labour aggregate in activity *a*
$QLEO_{a}$	quantity of aggregate Leontief intermediate inputs in activity *a*
QM_{c}	quantity of imports of commodity *c*
QQ_{c}	quantity of composite goods supply of commodity *c*

QSC_a	quantity of production less Leontief inputs in activity *a*
$QSUB_a$	quantity of aggregate substitutable parts of production less capital in activity *a*
$QSUBI_a$	quantity of aggregate substitutable intermediates in activity *a*
QT_c	quantity of trade and transport demand for commodity *c*
QX_c	quantity of aggregate marketed output of commodity *c*
TABS	total absorption
TFIN	rate of direct tax on financial return
TFINADJ	scaling factor for tax on returns from financial assets
$TFLAB_{flab}$	rate of direct tax on labour (soc sec and income tax)
$TINS_{insd}$	rate of direct tax on domestic institutions *insd*
TINSADJ	direct tax scaling factor
TLABADJ	labour tax scaling factor
$TM_{c,pni}$	trade margins on commodity *c* when purchased by *pni* (always domestic currency, even for exports)
$TMI_{c,a}$	trade margins on commodity *c* when purchased by activity *a* for investments
WALRAS	savings-investment imbalance (should be zero)
WALRASSQR	Walras squared
$WEALTH_h$	the wealth of household *h*
WF_f	economy-wide wage (rent) for factor *f*
$WFDIST_{f,a}$	factor wage distortion variable for factor *f* in activity *a*
$YFIN_a$	total financial income of domestic financial asset *a*
$YFLAB_{flab}$	total labour income from domestic and foreign activities
YG	government income
YH_h	household income in household $_h$
$YIFIN_{insd}$	financial income of institution $_{insd}$

3.3 PARAMETERS

Parameters other than tax rates

α_a^{cap}	shift parameter for CES production function capital in activity *a*
α_a^{cga}	shift parameter for ces production function cga in activity *a*
α_h^{cgh}	shift parameter in nested ces utility function for household *h*
α_a^{lab}	shift parameter for CES production function labour in activity *a*
α_c^{q}	shift parameter for Armington function for commodity *c*
α_a^{sc}	shift parameter for CES prod. function qsc nest in activity *a*
α_a^{sub}	shift parameter for CES prod. function sub nest in activity *a*
α_a^{subi}	shift parameter for CES production function subi in activity *a*
α_c^{t}	shift parameter for CET function for commodity *c*
$\beta_{cgh,h}$	marg. share of hhd cons on com. group *cga* for household *h*
$cint_h$	the marginal increase in consumption from an increase in wealth in household *h*
$cwts_{c,h}$	consumer price index weights for commodity *c* in household *h*
δ_c^{arm}	share parameter for CET function for commodity *c*
$\delta_{fcap,a}^{cap}$	share parameter for CES activity production function capital for capital good *fcap* in activity *a*
δ_c^{cet}	share parameter for Armington function for commodity *c*
$\delta_{csubi,a,cga}^{cga}$	share parameter for ces activity production function cga for commodity *csubi* in commodity group *cga* in activity *a*
$\delta_{h,c,cgh}^{cgh}$	share parameter in nested ces utility for commodity *c* in commodity group *cgh* in household *h*
$\delta_{flab,a}^{lab}$	share parameter for CES activity production function labour for labour category *flab* in activity *a*
δ_c^{q}	share parameter for import demand equation for commodity *c*

δ_a^{sc}	share parameter for CES production function qsc nest in activity *a*
δ_a^{sub}	share parameter for CES production function sub nest in activity *a*
$\delta_{a,cga}^{subi}$	share parameter for CES act. production function intermediates for commodity group *cga* in activity *a*
δ_c^{t}	share parameter for export supply equation for commodity *c*
factinret	return on foreign assets
FAP	foreign asset position this year
finin	financial income from abroad in foreign currency
$finout_a$	share of foreign income in total financial income from activity *a*
FLP	foreign liabilities this year
FNAP	foreign net asset position this year
$ftmq_{c,pni}$	fix part of trade margins in quantities on commodity *c*
$ftmqinv_{c,a}$	fix part of trade margins in quantities on investments of commodity *c* in activity *a*
$\gamma_{cgh,h}$	subsist. consumption of commodity group *cgh* for household *h*
$ica_{c,a}$	Leontief intermediate input *c* per unit of aggregate Leontief intermediate in activity *a*
$inta_a$	aggregate Leontief intermediate input share in activity *a*
isc_a	aggregate substitutable intermediate input share in activity *a*
$iwts_{c,a,fcap}$	quantity commodity *c* in one unit of investment in capital good *fcap* in activity *a*
$labin_{flab}$	income from abroad of labour category *flab* in foreign currency
$labout_{flab}$	share of foreign income of labour category *flab* in total income of labour category *flab* from domestic activities
$mpc01_{insd}$	0-1 parameter for potential flexing of savings rates
$mpcbar_{insd}$	marg. prop. to consume for dom non-gov inst *insd* (exog part)
$\overline{qg}_c$	exogenous (unscaled) government demand for commodity *c*
$\overline{qinv}_{c,a,fcap}$	Investment demand in base year for commodity *c* in the formation of capital good *fcap* in activity *a*
$qdst_c$	inventory investment in commodity *c*
$qpermit_a$	domestic supply of CO_2 permits to activity *a*
return	required rate of return on investments
ρ_c^{arm}	Armington function exponent for commodity *c*

ρ_a^{cap}	CES production function exponent capital in activity *a*
ρ_c^{cet}	CET function exponent for commodity *c*
ρ_a^{cga}	CES production function exponent cga in activity *a*
$\rho_{h,cgh}^{cgh}$	CES expenditure system exponent for commodity group *cgh* in household *h*
ρ_a^{lab}	CES production function exponent labour in activity *a*
ρ_c^{q}	Import demand function exponent for commodity *c*
ρ_a^{sc}	CES production function exponent qsc nest in activity *a*
ρ_a^{sub}	CES production function exponent qsub nest in activity *a*
ρ_a^{subi}	CES production function exponent subst. intermediates in activity *a*
ρ_c^{t}	Export demand function exponent for commodity *c*
$shifl_{insd,flab}$	share of dom. institution i in income of labour *flab*
$shifin_{insd,a}$	share of dom. institution i in income from the capital return of activity *a*
$shifinin_{insd}$	share of dom. institution i in financial income from abroad
$shtr_c$	share of commodity *c* in transactions
$supernum_h$	LES supernumerary income
$\theta_{a,c}$	yield of commodity *c* per unit of activity *a*
$tins01_{insd}$	0-1 parameter for potential flexing of dir tax rates
$trnsfr_{p,p}$	transfers from purchaser *p* to purchaser *p* (All transfers from rest of the world are in foreign currency; all transfers to rest of he world are in domestic currency)
$trq_{c,pni}$	quantity of trade margins when commodity *c* is purchased by purchaser *pni*
$trqi_{c,a}$	quantity of trade margins in investments when commodity *c* is invested in activity *a*

Tax rates

ta_a	rate of tax on producer gross output value in activity *a*
te_c	rate of tax on exports of commodity *c*
$tflbar_{flab}$	rate of direct tax on labour category *flab* in base (soc sec tax)
tfinbar	rate of direct tax on financial return in base
$tinsbar_{insd}$	rate of direct tax on dom inst *insd* in base
tar_c	rate of import tariff on commodity *c*
$tq_{c,pni}$	unit tax on commodity *c* when purchased by purchaser *pni*
$tqi_{c,a}$	unit tax on commodity *c* when used as investment in activity *a*
$tv_{c,pni}$	value tax on commodity *c* when purchased by purchaser *pni*
$tvi_{c,a}$	value tax on commodity *c* when used as investment in activity *a*

3.4 EQUATIONS

Price Block

The price block consists of two equations that determine import and export prices in domestic currency, one equation that defines CPI and several equations that ensure that price multiplied by quantity of an aggregate is equal to prices multiplied by quantities of its components.

Import price

$$PM_C = pwm_C \cdot (1 + tar_C) \cdot EXR \qquad c \in CM$$

The price in domestic currency for an imported good is equal to the world market price of that good, multiplied with 1 plus the ad valorem import tariff and the exchange rate defined as domestic currency over foreign currency.

Export price

$$PE_c = pwe_c \cdot (1 - te_c) \cdot EXR - TM_{c,'row'} \qquad c \in CE$$

The price in domestic currency for an imported good is equal to the world market price of that good, multiplied with 1 minus the ad valorem export tax and the exchange rate defined as domestic currency over foreign currency.

Absorption

$$PQ_c \cdot QQ_c = PDS_c \cdot QD_C + PM_c \cdot QM_c \qquad c \in CD$$

The money paid for domestic absorption is equal to the domestic price multiplied with total quantity but must also be equal to the money paid for imports plus the money paid for goods that are produced and sold domestically.

Value of domestic production

$$PX_c \cdot QX_c = PDS_c \cdot QD_C + PE_c \cdot QE_c \qquad c \in CX$$

Total sales of domestic firms are equal to their sales in the domestic market plus their sales in the international market.

Activity price from demand side

$$PA_a = \sum_{c \in C} PX_c \cdot \theta_{a,c} \qquad a \in A$$

The price of total output in an activity is equal to the sum of the price of each produced commodity times the output share of that commodity in one unit of production.

Input price of aggregate Leontief intermediates

$$PLEO_a = \sum_{cleo \in C} \left(PQ_{cleo} + tq_{\text{cleo,a}} + TM_{\text{cleo,a}} \right) \cdot (1 + tv_{\text{cleo,a}}) \cdot ica_{cleo,a} \qquad a \in A$$

The price of the aggregate of those intermediate goods that are used in fixed proportion to output is equal to the sum of the share of that commodity in one unit of output times the basic price of each commodity together with taxes and trade margins.

Activity price from supply side

$$PA_a \cdot (1 - ta_a) \cdot QA_a = \sum_{c \in C} FTM_{c,a} \cdot (1 + tv_{c,a}) + PSC_a \cdot QSC_a + PLEO_a \cdot QLEO_a \qquad a \in A$$

Total income in an activity is equal to the price of its output times the quantity of output less activity taxes and it is also equal to the total cost in the activity. Total cost is equal to fix trade margins and the cost of the two main aggregates in the production function.

Price of substitutable costs plus operating surplus

$$PSC_a \cdot QSC_a = PCAP_a \cdot QCAP_a + PSUB_a \cdot QSUB_a \qquad a \in A$$

Price of substitutable costs less Capital

$$PSUB_a \cdot QSUB_a = PLAB_a \cdot QLAB_a + PSUBI_a \cdot QSUBI_a \quad a \in A$$

The sum of labour cost and cost for substitutable intermediates.

Consumer price Index

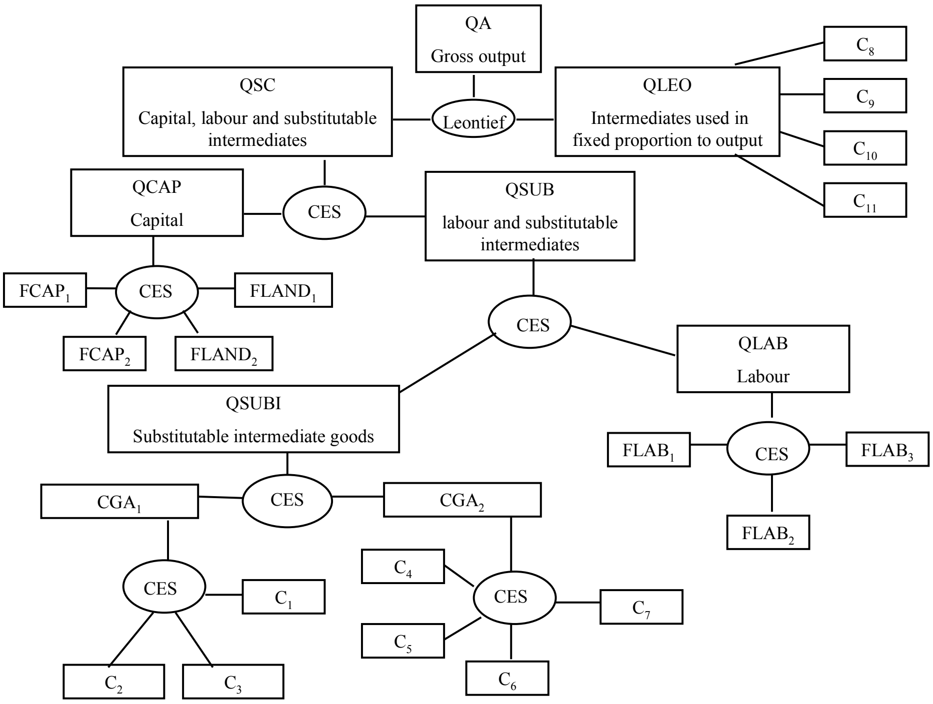
$$CPI = \sum_{c \in C} \sum_{h \in H} \left(1 + tv_{c,h}\right) \cdot \left(PQ_c + tq_{c,h} + TM_{c,h}\right) \cdot cwts_{c,h}$$

Production Block

The nest structure of the production function is shown in Figure 3.1. At top nest the substitutable inputs, QSC, are aggregated together with the intermediate goods that are used in fixed proportion to output, QLEO. Below the aggregate of different capital goods, QCAP is aggregated together with the aggregate of labour and substitutable intermediate goods, QSUB, which is aggregated from all substitutable intermediate goods, QSUBI, and all categories of labour, QLAB. QCAP is aggregated from the different kinds of capital goods. There are two sets of capital goods, FCAP for real capital and FLAND for natural capital. QLAB is aggregated from the different categories of labour, FLAB. QSUBI is aggregated from the different groups of substitutable intermediate goods, CGA, which in turn are aggregated from the single commodities, C.

At the top of the nest there is Leontief technology and the rest of the nest is CES. The elasticity of substitution has to be symmetric i.e. the same between every pair of CGA, as well as between every pair of commodities included in the same CGA group. In the same way the elasticity of substitution has to be the same between every two kinds of capital or labour. If no commodities are defined as substitutable, the QSUBI nest will not be included in the model and all intermediates will be included in QLEO.

Figure 3.1 Nest structure of production functions



Total output in an activity may consist of more than one kind of commodity; the parameter defines the share of a specific commodity in total output of an activity. The same commodity may be produced in different industries and the make matrix equation aggregates the total output of a commodity from the output in specific industries. For simplicity, the production function is divided into several equations aggregating together the different aggregates. The production block consists of these equations and their first order conditions together with the make matrix equation.

Demand for aggregate Leontief intermediates

$$QLEO_a = inta_a \cdot QA_a \qquad a \in A$$

The total quantity of intermediate inputs that are used in fixed proportions to output is always equal to that fixed proportion.

Demand for substitutable intermediates plus the capital stock

$$QSC_a = isc_a \cdot QA_a \qquad a \in A$$

The quantity of all inputs with substitution possibilities has to be a constant share of output since they cannot be substitutes for anything else.

QSC part of production function

$$QSC_a = \alpha_a^{sc} \cdot \left(\delta_a^{sc} \cdot QCAP_a^{-\rho_a^{sc}} + \left(1 - \delta_a^{sc}\right) \cdot QSUB_a^{-\rho_a^{sc}} \right)^{\frac{-1}{\rho_a^{sc}}} \qquad a \in A$$

The quantity of total substitutable inputs is a CES function of capital and other substitutable inputs.

QSUB part of production function

$$a \in A$$

$$QSUB_a = \alpha_a^{sub} \cdot \left(\delta_a^{sub} \cdot QLAB_a^{-\rho_a^{sub}} + \left(1 - \delta_a^{sub}\right) \cdot QSUBI_a^{-\rho_a^{sub}} \right)^{\frac{-1}{\rho_a^{sub}}}$$

QSUB part of production function for activities not using substitutable intermediates

$$QSUB_a = QLAB_a \qquad a \in A$$

The quantity of substitutable inputs other than capital is a CES function of total labour and total substitutable intermediate inputs if substitutable intermediate inputs are used in the activity. For other activities it is simply equal to aggregated labour.

Aggregation of different capital good

$$a \in A$$

$$QCAP_a = \alpha_a^{cap} \cdot \left(\sum_{fcap \in FCAP} \delta_{fcap,a}^{cap} \cdot QF_{fcap,a}^{\;\;-\rho_a^{cap}} + \sum_{fcap \in FCAP} \delta_{land,a}^{land} \cdot QF_{fland,a}^{\;\;-\rho_a^{cap}} \right)^{\frac{-1}{\rho_a^{cap}}}$$

The total quantity of capital is equal to a CES function of all different capital goods.

Aggregation of different groups of intermediate goods

$$QSUBI_a = \alpha_a^{subi}\left(\sum_{cga \in CGA} \delta_{a,cga}^{subi} \cdot QCGA_{a,cga}^{\;-\rho_a^{subi}}\right)^{\frac{-1}{\rho_a^{subi}}} \qquad a \in A$$

The total quantity of substitutable intermediate goods is a CES function of the different commodity groups defined by the user.

Aggregation of different labour categories

$$QLAB_a = \alpha_a^{lab}\left(\sum_{flab \in FLAB} \delta_{flab,a}^{lab} \cdot QF_{flab,a}^{\;-\rho_a^{slab}}\right)^{\frac{-1}{\rho_a^{lab}}} \qquad a \in A$$

The total quantity of labour is a CES function of the different labour categories defined by the user.

Aggregation of different substitutable intermediates

$$a \in A$$

$$cga \in CGA$$

$$QCGA_{a,cga} = \alpha_a^{cga}\left(\sum_{csubi \in CSUBI} \delta_{csubi,a,cga}^{cga} \cdot QINTA_{csubi,a,cga}^{\;-\rho_{a,cga}^{cga}}\right)^{\frac{-1}{\rho_{a,cga}^{cga}}}$$

The total quantity in each commodity group is a CES function of the specific substitutable intermediate goods.

First order condition QSC part of PF

$$\frac{QCAP_a}{QSUB_a} = \left(\frac{`PSUB_a}{PCAP_a} \cdot \frac{\delta_a^{sc}}{1-\delta_a^{sc}}\right)^{\frac{1}{1+\rho_a^{sc}}} \qquad a \in A$$

First order condition QSUB part of PF

$$\frac{QLAB_a}{QSUBI_a} = \left(\frac{`PSUBI_a}{PLAB_a} \cdot \frac{\delta_a^{sub}}{1-\delta_a^{sub}}\right)^{\frac{1}{1+\rho_a^{sub}}} \qquad a \in A$$

First order condition capital

$$a \in A$$
$$f \in CAP$$

$$WF_{fcap} \cdot \overline{WFDIST}_{fcap,a} = PCAP_a \cdot QCAP_a \cdot$$
$$\left(\sum_{fcap' \in FCAP'} \delta^{cap}_{cap',a} \cdot QF_{cap',a}{}^{-\rho^{cap}_a} + \sum_{fland' \in FLAND'} \delta^{land}_{fland',a} \cdot QF_{fland',a}{}^{-\rho^{cap}_a} \right)^{-1} \cdot \delta^{cap}_{fcap,a} \cdot QF_{fcap,a}{}^{-\rho^{cap}_a - 1}$$

This is the demand equation for a specific capital good

First order condition land

$$a \in A$$
$$f \in FLAND$$

$$WF_{fland} \cdot \overline{WFDIST}_{fland,a} = PCAP_a \cdot QCAP_a \cdot$$
$$\left(\sum_{fcap' \in FCAP'} \delta^{cap}_{cap',a} \cdot QF_{cap',a}{}^{-\rho^{cap}_a} + \sum_{fland' \in FLAND'} \delta^{land}_{fland',a} \cdot QF_{fland',a}{}^{-\rho^{cap}_a} \right)^{-1} \cdot \delta^{land}_{fland,a} \cdot QF_{fland,a}{}^{-\rho^{cap}_a - 1}$$

This is the demand equation for a specific natural capital

First order condition labour

$$a \in A$$
$$f \in FLAB$$

$$WF_{flab} \cdot \overline{WFDIST}_{flab,a} =$$
$$PLAB_a \cdot QLAB_a \cdot \left(\sum_{flab' \in FLAB'} \delta^{lab}_{flab',a} \cdot QF_{flab',a}{}^{-\rho^{lab}_a} \right)^{-1} \delta^{lab}_{flab,a} \cdot QF_{flab,a}{}^{-\rho^{lab}_a - 1}$$

This is the demand equation for a specific category of labour

First order condition intermediate aggregates

$$a \in A$$
$$f \in FLAB$$

$$PCGA_a = PSUBI_a \cdot QSUBI_a \cdot \left(\sum_{cga' \in CGA'} \delta^{subi}_{a,cga'} \cdot QCGA_{a,cga'}{}^{-\rho^{subi}_a} \right)^{-1} \delta^{subi}_{a,cga} \cdot QCGA_{a,cga}{}^{-\rho^{subi}_a - 1}$$

First order condition substitutable intermediates

$$a \in A$$
$$c \in CSUBI$$
$$cga \in CGA$$

$$(1 + tv_{csubi,a})(PQ_{csubi} + tq_{csubi,a} + TM_{csubi,a}) = PCGA_{a,cga} \cdot QCGA_{a,cga} \cdot \left(\sum_{csubi' \in CSUBI'} \delta^{cga}_{csubi',a,cga} \cdot QINTA_{csubi',a,cga}{}^{-\rho^{cga}_a} \right)^{-1} \delta^{cga}_{csubi,a,cga} \cdot QINTA_{csubi,a,cga}{}^{-\rho^{cga}_a - 1}$$

This is the demand equation for a specific substitutable intermediate good. For every commodity group this equation would only be defined for the commodities in that group.

Demand for substitutable intermediate goods

$$QINT_{csubi,a} = \sum_{cga \in CGA} QINTA_{csubi,a,cga} \qquad a \in A, \; c \in CSUBI$$

In practise this is not a sum since for every commodity QINTA is only defined for one CGA. This equation is needed only because we need the variable to be defined with and without the cga index.

Disaggregated demand for Leontief intermediates

$$QINT_{cleo,a} = ica_{cleo,a} \cdot QLEO_a \qquad a \in A, \; c \in CLEO$$

This is the demand equation for a specific Leontief intermediate good The parameter ica defines the share of every specific commodity in one unit of aggregate Leontief intermediates.

Aggregation of output from different industries (the make matrix)

$$QX_c = \sum_{a \in A} \theta_{a,c} \cdot QA_a \qquad c \in C$$

Total output of a specific commodity is the sum of the produced quantity of that commodity in all activities. The model assumes no substitution between outputs i.e., secondary products must be produced in specific proportions to the main product. If this assumption is regarded unrealistic the user may prefer to redistribute secondary products using BWSEC.GMS

Investment block

Demand for commodities for investment purposes is determined in the investment block. Moreover gross return and unit price of investments are calculated.

Gross return to a specific real capital

$$GRPROF_{a,fcap} = WF_{fcap} \cdot \overline{WFDIST}_{fcap,a} \cdot QF_{fcap,a} \qquad a \in A$$

This equation calculates gross return of a specific capital good in a specific activity.

Gross return to a specific natural capital

$$GRRENT_{a,fland} = WF_{fland} \cdot \overline{WFDIST}_{fland,a} \cdot QF_{fland,a} \qquad a \in A$$

This equation calculates gross return of a specific capital good in a specific activity.

Investment demand

$$QINV_{c,a,fcap} = IADJM \cdot IADJ_{a,fcap} \cdot \overline{qinv}_{c,a,fcap} \qquad a \in A,\ c \in C,\ fcap \in FCAP$$

In simulations with variable investments IADJM adjusts so that investments equal saving. In simulations with fixed investments IADJM is fixed and investment is the same as in the base scenario.

Unit price of aggregate investment

$$PI_{a,fcap} = \sum_{c \in C} \left(1 + tvi_{c,a}\right)\left(PQ_c + tqi_{c,a} + TMI_{c,a}\right) \cdot iwts_{c,a,fcap} \qquad a \in A,\ fcap \in FCAP$$

The price of a real capital good is equal to the sum of the prices of the goods it is made of times the share of these goods in one unit of the capital good.

Aggregate investment demand

$$QAGGINV_{a,fcap} = \sum_{c \in C} \frac{\left(1 + tvi_{c,a}\right)\left(PQ_c + tqi_{c,a} + TMI_{c,a}\right) \cdot QINV_{c,a,fcap}}{PI_{a,fcap}} \qquad a \in A,\ fcap \in FCAP$$

The quantity of investment is equal to the money spent on investments divided by the price per unit of that capital good.

Trade block

The trade block consists of the Armington and CET functions and their first order conditions.

CET function

$$QX_c = \alpha_c^t \cdot \left(\delta_c^{cet} \cdot QE_c^{\rho_c^{cet}} + \left(1-\delta_c^{cet}\right) \cdot QD_c^{\rho_c^{cet}}\right)^{\frac{1}{\rho_c^{cet}}} \qquad c \in \left(CE \cap CD\right)$$

The CET equation addresses the allocation of marketed domestic output to two alternative markets, the domestic market and exports. It reflects the assumption of imperfect transformability between the two destinations.

Export - domestic supply ratio

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \cdot \frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{1+\rho_c^t}} \qquad c \in \left(CE \cap CD\right)$$

Producers are assumed to allocate their selling efforts between the domestic and foreign market according to the relative prices on the different markets. Note that this is not the f.o.c of the CET equation if $\rho_c^t \neq \rho_c^{cet}$ giving a possibility of relaxing the assumption of optimal behaviour in international trade.

Output Transformation for domestically sold outputs without exports and for exports without domestic sales

$$QX_C = QD_C + QE_C \qquad c \in \left(CD \cap CEN\right) \cup \left(CE \cap CDN\right)$$

Armington equation

$$QQ_c = \alpha_c^q \cdot \left(\delta_c^{arm} \cdot QM_c^{-\rho_c^{arm}} + \left(1-\delta_c^{arm}\right) \cdot QD_c^{-\rho_c^{arm}}\right)^{-\frac{1}{\rho_c^{arm}}} \qquad c \in \left(CM \cap CD\right)$$

The Armington equation assumes imperfect substitutability between domestic production and imports.

Import - domestic supply ratio

$$\frac{QM_c}{QD_c} = \left(\frac{PDS_c}{PM_c} \cdot \frac{\delta_c^q}{1-\delta_c^q} \right)^{\frac{1}{1+\rho_c^q}} \qquad c \in (CM \cap CD)$$

The choice between domestic production and imports will depend on their relative price. Note that this is not the f.o.c of the Armington equation if $\rho_c^q \neq \rho_c^{arm}$ giving a possibility of relaxing the assumption of optimal behaviour in international trade.

Armington equation for non-imported outputs and non-produced imports

$$QQ_C = QD_C + QM_C \qquad c \in (CD \cap CMN) \cup (CM \cap CDN)$$

Trade Margins Block

The trade margins block determines the cost of retail trade services and allocates the payment for them to the market of retail trade services.

Demand for trade margins (retail service)

$$c \in CTR$$

$$QT_{ctr} = shtr_{ctr} \cdot \begin{pmatrix} \sum_{a \in A} \sum_{c \in C} trq_{c,a} \cdot QINT_{c,a} + \sum_{h \in H} \sum_{c \in C} trq_{c,h} \cdot \sum_{cgh \in CGH} QH_{h,c,cgh} \\ + \sum_{a \in A} \sum_{c \in C} trqi_{c,a} \cdot \sum_{fcap \in FCAP} QINV_{c,a,fcap} + \sum_{c \in C} trq_{c,gov} \cdot QG_c \\ + \sum_{c \in C} trq_{c,row} \cdot QE_c + \sum_{pni \in PNI} \sum_{c \in C} ftmq_{c,pni} + \sum_{a \in AI} \sum_{c \in C} ftmqinv_{c,a} \end{pmatrix}$$

The sum of all trade margins for all purchasers and commodities defines total demand for retail services.

Determination of trade margins

$$TM_{c,pni} = \sum_{ctr \in CTR} trq_{c,pni} \cdot shtr_{ctr} \cdot PQ_{ctr} \qquad c \in C, \; pni \in PNI$$

Determination of trade margins on investments

$$TMI_{c,a} = \sum_{ctr \in CTR} trqi_{c,a} \cdot shtr_{ctr} \cdot PQ_{ctr} \qquad c \in C, \; a \in A$$

The size of the trade margin will depend on the amount of retail service that is required, when this actor purchases this commodity, and the unit price of retail services.

Fix trade margins

$$FTM_{c,pni} = \sum_{ctr \in CTR} ftmq_{c,pni} \cdot shtr_{ctr} \cdot PQ_{ctr} \qquad c \in C, \; pni \in PNI$$

Fix TM on investments

$$FTMINV_{c,a} = \sum_{ctr \in CTR} ftmqinv_{c,a} \cdot shtr_{ctr} \cdot PQ_{ctr} \qquad c \in C, \; a \in A$$

Fix trade margins are independent of the quantity purchased, and are used to get a more realistic price of a marginal unit of the good.

Institution block

The institution block determines the income and expenditure of households and government.

Labour income

$$flab \in FLAB$$

$$YFLAB_{flab} = \sum_{a \in A} WF_{flab} \cdot WFDIST_{flab,a} \cdot QF_{flab,a} + labin_{flab} \cdot EXR$$

Total labour income is equal to the wage rate times the amount of labour in each activity plus labour income from abroad.

Income of financial assets

$$fin \in FIN$$

$$YFIN_{a} = \sum_{fcap = FCAP} GRPROF_{a,fcap} + \sum_{fland = FLAND} GRRENT_{a,fland} + Qpermit_{a} \cdot Ppermit$$

Income of the shares in an activity is equal to the operating surplus, which will be equal to the return to real capital and the value of emission permits allocated to this activity. All profits are assumed to be paid out to the households.

Institutional labour income

$$flab \in FLAB$$
$$i \in INSD$$

$$YIFL_{i,flab} = shifl_{i,flab} \cdot \left(1 - tflab_{flab}\right) \cdot \left(YFLAB_{flab} - labout_{flab} \cdot \sum_{a \in A} WF_{flab} \cdot wfdist_{flab,a} \cdot QF_{flab,a} \right)$$

Labour income to a specific institution (most often household) is equal to this institution's share of labour income less labour taxes and labour income to other countries.

Institutional financial income

$$i \in INSD$$

$$YIFIN_i = \sum_{a \in A} \left[shifin_{i,a} \cdot \left(1 - tfin\right) \cdot \left(1 - finout_a\right) \cdot YFIN_a \right]$$
$$+ shifinin_i \cdot \left(1 - tfin\right) \cdot finin \cdot EXR$$

Financial income of a specific institution is equal to this institution's share of the return from domestic financial assets less capital taxes and financial income to other countries, plus this institution's share of the return from foreign assets less taxes.

Income of domestic households

$$h \in H$$

$$YH_h = \sum_{flab \in FLAB} YIFL_{h,flab} + YIFIN_h + trnsfr_{h,gov} \cdot CPI + trnsfr_{h,row} \cdot EXR$$

Total income of a domestic household is equal to the sum of labour income, financial income, transfers from the government and transfers from the rest of the world.

Wealth of the household

$$h \in H$$

$$WEALTH_h = shifinin_h \cdot FAP$$
$$+ \sum_{a \in A} shifin_{h,a} \cdot \left(1 - finout_a\right) \cdot \left(\sum_{fcap \in FCAP} \frac{GRPROF_{a,fcap}}{deprate_{a,fcap} + RETURN} + \sum_{fland \in FLAND} \frac{GRRENT_{a,fland}}{RETURN} \right)$$

Total wealth of a household is equal to the value of its share of domestic financial assets plus the value of its share of foreign assets.

Household consumption expenditure

$$h \in H$$

$$EH_h = MPC_h \cdot \left(\left(1 - TINS_h\right) \cdot YH_h - trnsfr_{row',h}\right) + cint_h \cdot WEALTH_h$$

Total consumption in a household is equal to MPC times its income less taxes and transfers to other countries plus an intercept that is dependent on the wealth of the household.

Total consumption is allocated to the different commodity groups, CGH, by a linear expenditure system. The household has a fixed quantity of each CGH determined from $\gamma_{cgh,h}$, the subsidiary or habit consumption. The money left is spent on the different commodity groups according to fix budget shares determined from $\beta_{cgh,h}$. Within each CGH the consumption is allocated to the specific commodities from a CES utility function.

The EH Les equations

$$h \in H$$
$$cgh \in CGH$$

$$QCGH_{h,cgh} \cdot PCGH_{h,cgh} = PCGH_{h,cgh} \cdot \gamma_{cgh,h}$$
$$+ \beta_{cgh,h} \cdot \left(EH_h - \sum_{c' \in C'} FTM_{c',h}\left(1 + tv_{c',h}\right) - \sum_{cgh' \in CGH'} PCGH_{h,cgh'} \cdot \gamma_{cgh',h} \right)$$

This is the LES equation defining fixed shares of spending of the different commodity groups for that part of household expenditure that is not used up for subsidiary consumption.

The CES equations in household demand

$$h \in H$$
$$cgh \in CGH$$

$$QCGH_{h,cgh} = \alpha_{h,cgh}^{cgh} \cdot \left(\sum_{c \in C} \delta_{h,c,cgh}^{cgh} \cdot QH_{h,c,cgh}^{\;-\rho_{h,cgh}^{cgh}} \right)^{\frac{-1}{\rho_{h,cgh}^{cgh}}}$$

The total quantity of a commodity group is a CES equation of the specific commodities in that group.

Household's commodity demand

$$h \in H$$
$$cgh \in CGH$$
$$c \in C$$

$$\left(1+tv_{c,h}\right)\left(PQ_c + tq_{c,h} + TM_{c,h}\right) = QCGH_{h,cgh} \cdot PCGH_{h,cgh}$$
$$\cdot \left(\sum_{c' \in C'} \delta_{h,c',cgh}^{cgh} \cdot QH_{h,c',cgh}^{\;\;-\rho_{h,cgh}^{cgh}} \right)^{-1} \cdot \sum_{c \in C} \delta_{h,c,cgh}^{cgh} \cdot QH_{h,c,cgh}^{\;\;-\rho_{h,cgh}^{cgh}-1}$$

The first order condition of the CES equation determines the demand for a specific commodity.

Net Import of emission permits

$$Netpermit = Ppermit \cdot$$
$$\left(\sum_{aets=AETS} \sum_{fossilperm=FOSSILPERM} QINT_{fossilperm,aets} \cdot carbshare_{fossilperm} - \sum_{aets=AETS} Qpermit \right)$$

Net import of permits is equal to the permit price times the difference between permits used by domestic firms and permit supply to domestic firms.

Government consumption demand

$$QG_c = GADJ \cdot qbarg_c \qquad c \in CGOV$$

GADJ is a fixed adjustment factor for the size of government consumption. It becomes flexible in static simulations when siclos 4 or 5 is used, where it is instead government consumption as a share of domestic absorption that is constant.

Government revenue

$$YG = \sum_{h \in H} TINS_h \cdot YH_h + tfin \cdot \left(\sum_{a \in A} (1 - finout_a) \cdot YFIN + finin \cdot EXR \right)$$
$$+ \sum_{flab \in FLAB} tflab_{flab} \cdot \left(YFLAB_{flab} - labout_{flab} \cdot \sum_{a \in A} WF_{flab} \cdot WFDIST_{flab,a} \cdot QF_{flab,a} \right)$$
$$+ \sum_{c \in CM} tar_c \cdot pwm_c \cdot QM_c \cdot EXR + \sum_{c \in CE} te_c \cdot pwe_c \cdot QE_c \cdot EXR$$
$$+ \sum_{flab \in FLAB} YIFL_{gov,flab} + YIFIN_{gov} + trnsfr_{gov,row} \cdot EXR$$
$$+ \sum_{a \in A} \sum_{c \in C} \left[tq_{c,a} \cdot QINT_{c,a} + tv_{c,a} \cdot (PQ_c + tq_{c,a} + TM_{c,a}) \cdot QINT_{c,a} \right]$$
$$+ \sum_{a \in A} ta_a \cdot PA_a \cdot QA_a + \sum_{h \in H} \sum_{c \in C} \sum_{cgh \in CGH} \left[tq_{c,h} \cdot QH_{h,c,cgh} + tv_{c,h} \cdot (PQ_c + tq_{c,h} + TM_{c,h}) \cdot QH_{h,c,cgh} \right]$$
$$+ \sum_{a \in A} \sum_{c \in C} \left[tqi_{c,a} \cdot \sum_{fcap \in FCAP} QINV_{c,a,fcap} + tvi_{c,a} \cdot (PQ_c + tqi_{c,a} + TMI_{c,a}) \cdot \sum_{fcap \in FCAP} QINV_{c,a,fcap} \right]$$
$$+ \sum_{c \in C} \left[tq_{c,gov} \cdot QG_c + tv_{c,gov} \cdot (PQ_c + tq_{c,gov} + TM_{c,gov}) \cdot QG_c \right]$$
$$+ \sum_{pni \in PNI} \sum_{c \in C} (tv_{c,pni} FTM_{c,pni}) + \sum_{a \in A} \sum_{c \in C} (tvi_{c,a} FTMINV_{c,a})$$

Government revenue is the sum of all kinds of taxes plus factor income and transfers from abroad.

Government expenditure

$$EG = \sum_{c=C} (PQ_c + tq_{c,gov} \cdot TM_{c,gov}) \cdot (1 + tv_{c,gov}) \cdot QG_c$$
$$+ \sum_{h=H} trnsfr_{h,gov} \cdot \overline{CPI} + trnsfr_{row,gov} + netpermit$$
$$+ \sum_{c=C} FTM_{c,gov} \cdot (1 + tv_{c,gov}) + \sum_{aets=AETS} Qpermit_{aets} \cdot Ppermit$$

Government expenditure is equal to government consumption plus transfers to households and transfers to other countries.

System constraints block

The system constraints block consists of the market equilibrium conditions, balance of payments, and the savings investments balance.

Factor market

$$\sum_{a\in A} QF_{f,a} = QFS_f \qquad f \in F$$

Total factor supply is equal to factor supply in all activities.

Market for retail trade services

$$c \in CTR$$

$$QQ_{ctr} = \sum_{a\in A} QINT_{ctr,a} + \sum_{h\in H} \sum_{cgh\in CGH} QH_{h,ctr,cgh} + QG_{ctr}$$
$$+ \sum_{a\in A} \sum_{fcap\in FCAP} QINV_{ctr,a,fcap} + qdst_{ctr} + QT_{ctr}$$

Commodity market for commodities other than retail services

$$c \in CNTR$$

$$QQ_c = \sum_{a\in A} QINT_{c,a} + \sum_{h\in H} \sum_{cgh\in CGH} QH_{h,c,cgh} + QG_c + \sum_{a\in A} \sum_{fcap\in FCAP} QINV_{c,a,fcap} + qdst_c$$

Supply equals demand in all commodity markets. There are two different market equilibrium equations for commodity markets since QT is only defined for retail services.

Balance of payments

$$\sum_{c\in C} pwm_c \cdot QM_c \cdot EXR + \sum_{flab\in FLAB} labout_{flab} \cdot \sum_{a\in A} WF_{flab} \cdot WDIST_{flab,a} \cdot QF_{flab,a}$$
$$+ \sum_{a\in A} finout_a \cdot YFIN_a + \sum_{i\in I} trnsfr_{row,i} + NETPERMIT$$
$$= \sum_{c\in C} pwe_c \cdot QE_c \cdot EXR + \sum_{flab\in FLAB} labin_{flab} \cdot EXR + finin \cdot EXR$$
$$+ \sum_{i\in I} trnsfr_{i,row} \cdot EXR + FSAV$$

If we have a surplus in the current account, it has to be equal to foreign saving (financial account). Note that factor payments to rest of the world are dependent on domestic wage levels and profit rates. Transfers from abroad are fixed in foreign currency, while transfers to other countries are fixed in domestic currency.

Government balance

$$YG = EG + GSAV$$

Government saving is equal to income less expenditure.

Direct institutional tax rates

$$h \in H$$

$$TINS_h = tinsbar_h \cdot \left(1 + TINSADJ \cdot tins01_h\right) + DTINS \cdot tins01_h$$

The direct income tax can be adjusted in specific closures. In govclos 2 DTINS is adjusted while in govclos 3 TINSADJ is adjusted.

Labour tax rates

$$TFLAB_{flab} = tflbar_{flab} \cdot \left(1 + TLABADJ\right) \qquad f \in FLAB$$

In govclos 4 the labour tax rate is adjusted through the adjustment factor TLABADJ for the government saving to remain constant.

Capital tax rates

$$TFIN = tfinbar \cdot \left(1 + TFINADJ\right)$$

In govclos 5 the capital tax rate is adjusted through the adjustment factor TFINADJ for the government saving to remain constant.

Saving investment balance

$$\sum_{h \in H} \left[\left(1 - MPC_h\right) \cdot \left((1 - TINS_h) \cdot YH_h - trnsfr_{row',h} \right) - cint_h \cdot WEALTH_h \right]$$
$$+ GSAV + FSAV =$$
$$\sum_{c \in C} \sum_{a \in A} \left(PQ_c + tqi_{c,a} + TMI_{c,a} \right) \cdot \left(1 + tvi_{c,a}\right) \cdot \sum_{fcap \in FCAP} QINV_{c,afcap}$$
$$+ \sum_{c \in C} PQ_c \cdot qdst_c + \sum_{a \in A} \sum_{c \in C} \left[\left(1 + tvi_{c,a}\right) \cdot FTMINV_{c,a} \right] + walras$$

Total saving is always equal to total investments if the Walras law holds. If it does not hold the variable Walras will not be equal to zero and an error message will be received.

Closure block

The closure block includes the equations needed to implement he different macro closures.

Household's marginal propensity to consume

$$h \in H$$

$$MPC_h = mpcbar_h \cdot \left(1 + MPCADJ \cdot mpc01_h\right) + DMPC \cdot mpc01_h$$

In specific closures the marginal propensity to consume is adjusted.

Total absorption

$$TABS = \sum_{h \in H} \sum_{c \in C} \left(1 + tv_{c,h}\right) \cdot \left(PQ_c + tq_{c,h} + TM_{c,h}\right) \cdot \sum_{cgh \in CGH} QH_{h,c,cgh}$$
$$+ \sum_{c \in C} \left(1 + tv_{c,gov}\right) \cdot \left(PQ_c + tq_{c,gov} + TM_{c,gov}\right) \cdot QG_c$$
$$+ \sum_{c \in C} \sum_{a \in A} \sum_{fcap \in FCAP} \left(1 + tvi_{c,a}\right) \cdot \left(PQ_c + tqi_{c,a} + TMI_{c,ga}\right) \cdot QINV_{c,a,fcap} + \sum_{c \in C} PQ_c \cdot qdst_c$$

Ratio of investments to absorption

$$INVSHR \cdot TABS = \sum_{c \in C} \sum_{a \in A} \sum_{fcap \in FCAP} \left(1 + tvi_{c,a}\right) \cdot \left(PQ_c + tqi_{c,a} + TMI_{c,a}\right) \cdot QINV_{c,a,fcap}$$
$$+ \sum_{c \in C} \sum_{a \in A} FTMINV_{c,a} \cdot \left(1 + tvi_{c,a}\right) + \sum_{c \in C} PQ_c \cdot qdst_c$$

Ratio of government consumption to absorption

$$GOVSHR \cdot TABS = \sum_{c \in C} \left(PQ_c + tq_{c,gov} + TM_{c,gov}\right) \cdot (1 + tv_{c,gov}) \cdot QG_c + \sum_{c \in C} (1 + tv_{c,gov}) \cdot FTM_{c,gov}$$

The last three equations are needed in closures where investments and government consumption are not fixed in quantities but as shares of domestic absorption.

4 A Swedish implementation

We construct a model over the Swedish economy by using the standardized model together with a dataset from 2001. For details of the construction of the dataset, see appendix 1. The applied Swedish model consists of 27 activities producing 27 commodities. All commodities are produced in a separate activity to avoid the restriction that secondary outputs must be produced in fixed proportions. To analyse the interaction between the tax rates on different fuels, six different commodities and thus six different activities are specified within the refinery industry. When reporting the results, these six activities are added up to one industry to decrease the size of the tables.

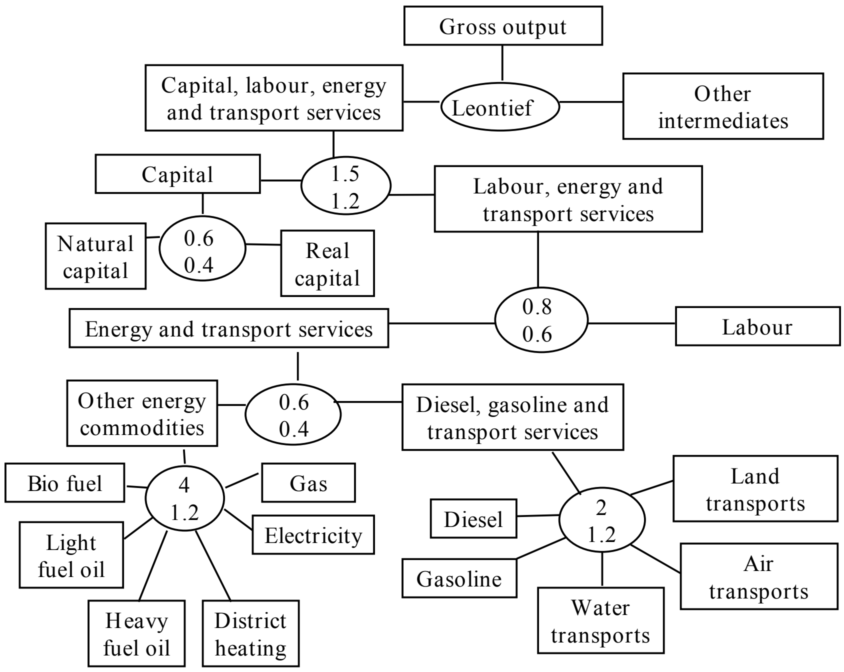
4.1 Production functions

The production functions in the model are nested CES functions (Figure 4.1). At the top-level output is a combination of capital, labour, energy, transport services and other intermediate goods. Capital is divided into real capital and natural capital. Natural capital consists of land that is used in production of biofuel, agriculture and forestry, rivers that are used in the production of electricity and mines that are used in mining. All other industries only use real capital. Other intermediates consist of all intermediate goods except energy and transport services, and are assumed to be used in fixed proportions to output, i.e., under Leontief technology. Transports and energy commodities are divided into two commodity groups. One first group consists of diesel, gasoline and transport services and the second of other energy commodities.

Choosing a set of reasonable elasticities for a CGE model cannot be based solely on econometric estimates, as these are derived from historical data and specific contexts. Since reinvestments take time, the long-run adjustment to a change in relative prices is difficult to catch in econometric analysis. The time period in the data set must include a significant time period after a permanent shift in relative prices if the capital stock is to be replaced according to the new relative prices. There is also a big divergence in econometric estimates between different studies, for example Burniaux et al (1992) report elasticities of substitutions, ranging from below 1 up to 2 digit numbers, between different kinds of energy from different studies. A recent meta-analysis of inter-fuel substitution elasticities (Stern 2009) for coal, oil, natural gas and electricity suggest values around unity for the short-run elasticity. However, Stern notes that these are biased downwards to an unknown degree. In contrast, evidence from cross-section estimates suggests values significantly greater that unity for the long-run elasticity (except for coal-electricity). However, as Stern further remarks, these cross-section estimates might be biased in an unknown direction too.

In Figure 4.1 the numbers refer to the elasticities of substitution and are assumed to be the same in all industries at the referred level. The following assumptions regarding substitution possibilities in the model have been made: Labour and energy are assumed to be easy to substitute with capital in the long run. In the long run it should be even easier to substitute between different kinds of heating systems. However, it is assumed to be more difficult to substitute between labour and energy. For the elasticity of substitution between different transports, a compromise is made between the easiness of substituting in-house transport (consumption of diesel) and purchased transport services and the difficulty of substituting sea transport for land transport.

Figure 4.1 Nest structure of the production functions



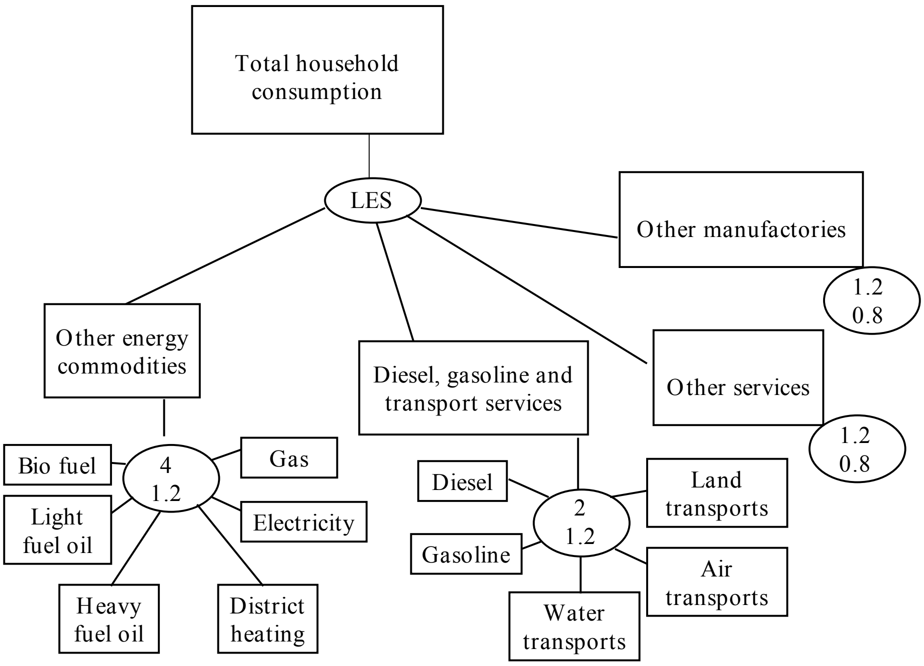
The numbers in ellipses refers to the elasticity of substitution between the aggregates. The top number is the long run elasticity and the bottom number is the short run elasticity.

These elasticities are higher than the elasticities used in other Swedish CGE models. For example, Hill (2001) uses 0.6 for the elasticity of substitution between different kinds of energy while we use 4 in our base case. Hills elasticity of 0.6 must be considered as a very low number for the long-run elasticity, taking into account the econometric estimates of unity for the short run elasticity. Our 4 may, on the other hand, be considered high but may be seen as an optimistic view on the possibility of substituting different kinds of energy after reinvestments in new technology.

4.2 Household consumption

There is one representative household in the model. Consumer behaviour is described in Figure 4.2.

Figure 4.2 Nest structure of household demand



The numbers in ellipses refers to the elasticity of substitution between the commodities. The top number is the long run elasticity and the bottom number is the short run elasticity.

Household demand is modelled as a LES-CES nested system with a LES system at the top aggregating four commodity groups: diesel gasoline and transport services, other energy commodities, other manufactories and other services. Within these four aggregates there are CES equations.

Since the elasticity of substitution between the four commodity groups is probably fairly low, the Frisch parameter has been set to achieve a relatively high proportion of subsidiary consumption.[7] The elasticity of substitution between different commodities within diesel gasoline and transport services as well as between different commodities within other energy commodities follows the reasoning in the production functions whereas the elasticity of substitution between commodities within the other two aggregates are assumed to be lower since they are more heterogeneous.

4.3 A comparison with other Swedish CGE models

Table 4.1 compares some properties of this model, in the following denoted as Bohlin, with three other CGE models that have been used to analyse energy taxes in Sweden. The HK model is a development from the Harrison & Kriström (1999) model. The Hill model is a development from the Hill (2001) model. For both these models we refer to the versions used in Hill & Kriström (2002). EMEC2 refers to the second version of the EMEC model presented in Östblom & Berg (2006) and used at the Swedish National Institute of Economic Research. The most important differences between the models are probably the elasticities of substitution between different kinds of energy. The HK model stands out as the most disaggregated model.

[7] In a LES system one part of the consumption of every commodity is fixed in quantity, the so-called habit or subsidiary consumption, while the rest of the consumption expenditures are allocated in fixed proportions on the different commodities. (Deaton, A & Muellbauer, J, 1980) The Frisch parameter determines the share of subsidiary consumption in total consumption.

Table 4.1 Swedish CGE models for analysis of energy taxation

	HK*	Hill*	EMEC2**	Bohlin
Activities	88	17	26	27
Commodities	88	20	33	27
Labour categories	11	2	2	1
Households	30	1	6	1
Energy substitution	Limited	Medium	Medium	High
Labour supply	Depends on real wage	Depends on real wage	Constant	Constant
Emissions	CO_2	CO_2, NOx, SO_2	CO_2, CO, CH_4, NOx, N_2O, SO_2, Particulate matter	CO_2
Energy tax rates	1995	1995	2007	2001
Dynamics	No	No	No	No

**Source Hill & Kriström 2002, Hill 2001 **Source Östblom & Berg 2006, Östblom & Hammar 2007*

Table 4.2 compares the results from a 100 percentage increase in the CO_2 tax in three of the models above. Since the Hill and HK models were calibrated on tax rates from 1995 and Bohlin from 2001, the results from the models are not directly comparable. Therefore two different results from Bohlin are reported. The fourth column shows the results from a 100 percentage increase of the tax rates of 2001. In the third column we first simulate the impact from a reduction of all energy taxes to the level of 1995, and thereafter increase the CO_2 tax by 100 percent. The third column is thus most comparable with the other two models.

Table 4.2 100-percent increase in CO_2 tax in different models.

	HK*	Hill*	Bohlin	
Tax rates from year	1995	1995	1995	2001
Welfare (EV as percentage of national income)	-0.3	-0.9	-0.9	-1,5
Emission (% Change)	-1.7	-11	-20	-21
Tax change on labour %	-2.6	-2.8	3.4	5.8

**Source Hill & Kriström 2002*

When comparing the three models, we see that the emission reduction, as well as the reduction of welfare, is larger when the substitution possibilities between different kinds of energy are increased. Comparing the Bohlin model with tax rates from 1995 with the Bohlin model with tax rates from 2001, we see that the cost is higher when doubling the higher tax rate in 2001 than doubling the lower tax rates of 1995. The percentage changes in emissions are the same but, since the level of emissions is lower for 2001, the absolute change is lower. Moreover, the absolute change in the tax rates is higher when we double higher tax rates. Since the cheapest means of reducing emissions were already taken in 2001, increasing them even further will be more costly and give lower reduction of emission.

The third row of table 4.2 shows the change in the tax rate of labour needed to give the same government budget surplus. In the Hill and HK models energy taxes still contribute to total tax income, and increased tax rates on energy provide a possibility of reducing the tax rate of labour. In the Bohlin model the higher elasticity of substitution between different kinds of energy reduces the use of fossil fuel so much that the tax rate of labour must be increased to keep the budget balance.

5 Summary

This paper has described a computable general equilibrium (CGE) model developed for analysis of taxes on specific commodities such as environmental taxes. It has a rich structure of taxes and trade margins on commodities, and a flexible nest structure in production and household demand functions. It can be used for open as well as for closed economies.

In the Swedish implementation of the model, with higher elasticities of substitutions than other Swedish CGE models, we get a higher impact on emissions than other Swedish models. Another implication of the higher elasticities is that a further increase of the Swedish CO_2-tax (doubling the tax rate) in our model has a negative impact on total tax revenue, while total tax revenue increases in the other models.

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Data sources

For the construction of the SAM the following data sources were used:

From national accounts:

1. Supply table in basic prices.
2. Use table divided into four sub matrices;
   - A. Basic price
   - B. Taxes on products
   - C. VAT
   - D. Trade margins
3. Investments per industry and commodity in purchaser prices.

From balance of payments:

1. Labour income and capital returns from and to other countries
2. Transfers from and to other countries

From Yearbook of Tax Statistics

1. All other taxes but taxes on products and VAT
2. Transfers from government to households

From www.rsv.se
Tax rates for energy taxes

From www.scb.se
Use of energy in quantity units

Appendix 1

A Swedish SAM of 2001 for SAINT CGE modelling system

This appendix describes the construction of a Social Accounting Matrix, SAM, to be used in the CGE model SAINT for the Swedish economy of 2001.

Aggregation and disaggregation of industries and commodities

The supply and use tables consisted of 55 industries in the original. These were aggregated to 49 industries by the following aggregations. NACE 16 was merged with NACE 15, NACE 19 with NACE 18, NACE 37 with NACE 36, NACE 66 and 67 with NACE 65, and finally NACE 95 was merged with NACE 93. The original supply and use tables consisted of 56 commodities. These were aggregated to 55 commodities in a first step by merging CPA 95 with CPA 93.

To create a dataset that is a little bit more detailed in terms of the energy use, the commodity codes CPA 20, 23 and 40 were disaggregated. A detailed use table was delivered from Statistics Sweden for CPA 23 and CPA 40 while the use of CPA 20 and the supply table were approximated.

CPA 20 was disaggregated into biofuel and other products of wood. All use of wood products in the production of electricity gas and district heating were supposed to be Bio fuel. The price of Bio fuel was first calculated by dividing the use at purchaser price with the physical quantity in this industry, and then that price was used to calculate the use at purchaser prices of Bio fuel in the other industries from data on use in physical quantities.

To disaggregate the supply of CPA 23 the same import share for all the fuels was assumed. To disaggregate CPA 40 it was assumed that only electricity was imported and that the other commodities were only produced domestically. To disaggregate CPA 20 it was assumed that all bio fuel was produced domestically. After these disaggregations the SAM consisted of 63 commodities.

Calculation of physical quantities and trade margins on energy

The use of bio fuel in toe (tonnes of oil equivalents) was found at www.scb.se. The physical quantities of electricity and fossil fuels were calculated by dividing the tax payments with the tax rate. For calculations of tax rates see Table A.1. For some industries and fuels tax payments according to the data were zero, probably due to rounding off of a number smaller than 0.5. For these industries physical quantities were calculated by division of the use in purchaser prices with the sum of the tax rate and the assumed pre tax price. For those industries that did not pay tax on electricity, data on the physical use of electricity from www.scb.se were used. There is no unit tax on district heating. Thus, it was not important to calculate physical quantities and the conventional method of normalising prices to 1 was used.

Trade margins

Trade margins on energy commodities were calculated by subtracting unit taxes, VAT and the use in physical quantities times an assumed basic price from the use at purchaser prices. For fossil fuels the assumed price was chosen in a compromise between getting a small difference in total trade margins on fossil fuels from original data and avoiding negative trade margins in too many sectors.

In the original data there are no trade margins on electricity, probably due to the fact that retail sellers of electricity are classified in the same industry code as the producers. For electricity the assumed price was chosen in order to avoid negative trade margins in too many sectors. For industry 40 the supply of electricity was reduced and the supply of trade margins (retail services) was increased to get balance in the supply and use of trade margins.

Trade margins on non-energy commodities were calculated directly from the matrix of trade margins in national accounts. For commodities with trade margins of 30 percent of the basic price or more, the marginal trade margin was set to 30 percent of the basic price and the remaining part was treated as a fix trade margin not included in the marginal price.

Table A.1 Tax rates on energy used in the calibration

Fuel	purchaser	Taxrate *	Motivation
Gasoline litre	All	4.50	
Diesel litre	All except 05,13 and 61	3.39	
	NACE 05 fishing	0.02	All diesel used in boats is taxfree
	NACE 13 mining of metal ores	0.75	diesel used in special vehicles in mining is taxfree
	NACE 61 Water transports	0.01	All diesel used in boats is taxfree
Light fuel oil litre	NACE 01-37	0.38	agriculture and manufacturing pay no energy tax and just 25 % of CO_2 tax
	NACE 40 Electricity, gas, steam and hot water supply	0.73	No taxes on prod. of electricity, half energy tax on prod. of heat**
	NACE 41 - 95	2.21	
	households	2.21	
Heavy fuel oil litre	NACE 01-37	0.42	agriculture and manufacturing pay no energy tax and just 25 % of CO_2 tax
	NACE 40 Electricity, gas, steam and hot water supply	0.76	
	NACE 41 - 95	2.28	
	households	2.28	
electricity kWh	NACE 01-37	0	No tax on manufacturing and agriculture
	NACE 40-55, 61-95	0.18	
	NACE 60 land transports	0.03	No tax on railways
	H	0.18	
gas litre	NACE 01-37	0.29	agriculture and manufacturing pay no energy tax and just 25 % of CO_2 tax
	NACE 40 Electricity, gas, steam and hot water supply	0.63	No taxes on prod. of electricity, half energy tax on prod. of heat
	NACE 41 - 95	1.37	
	Households	1.37	

** from www.rsv.se **An assumption of 50% electricity and 50 % heat is used in the calculation of the tax rate. In the combined production of heat and electricity probably all plants say that they use fossil fuels to produce electricity and bio fuel to produce heat. On the other hand many plants just produce heat. The 50 % is just a guess*

Other adjustments and calculations

Undistributed taxes on commodities were added to "other net taxes on production" in the industry that produced the commodity. In order to balance the SAM again after these manipulations the supply of the main commodity in all industries was adjusted so that both commodity and activity accounts balanced. For most commodities these adjustments were negligible compared to the total supply. For a few commodities they were significant though. Theoretically, this adjustment should be equivalent to assuming that all consumers bear the same proportion of the undistributed unit taxes, since a tax on the production of a commodity should have the same effects as a tax on its use.

Direct purchases abroad by residents were added to imports. Once again the supply of the main commodity in all industries was adjusted so that both commodity and activity accounts balanced. This time all the adjustments in the supply table were negligible compared to the total supply.

Financial intermediation services indirectly measured (FISIM) were assumed to be paid by households and redistributed to household consumption. Households income from labour was calculated as total payments for labour from domestic industries plus labour income from abroad (from balance of payments) less taxes on labour (from Yearbook of Tax Statistics) less labour income paid to foreign citizens (from balance of payments).

The capital income of households was calculated as total payments for capital from domestic industries (operating surplus in national accounts) plus capital income from abroad (from balance of payments) less capital income to foreign citizens (from balance of payments) less capital taxes (from Yearbook of Tax Statistics) less capital income of the governmental sector. Capital income of government was assumed to be 30 billion SEK. Household and government savings were calculated as income less expenditure. Thereafter the financial account (foreign saving) was calculated as total savings less total investment. Since all other accounts in SAM balance, the balance of payment has to balance as well.

Calculation of the investment matrices

Investment disaggregated into industries was only available in purchaser prices. To divide that matrix into the four components (the basic price, the trade margin, the unit tax and the value added tax), the cross entropy method was used. It is reasonable to assume that firms pay the same tax rate for commodities regardless if they use them as intermediate goods or for investment purposes. So the sub matrices were estimated in order to minimize the entropy distance between the tax rates for intermediate and investment goods. In the same way the entropy distance in the trade margins' share of the price was minimized between the use of a specific commodity as intermediate good and the use of the same commodity for investment purposes.

Adjustments of capital return and exports

In long-run equilibrium the return to capital should be equal in all industries. Table A.2 contains the gross and net return to capital according to national accounts. Gross return is calculated by dividing operating surplus with the size of the capital stock. Net return is calculated by dividing operating surplus less depreciations with the size of the capital stock.

From Table A.2 it can be seen that capital return varies a lot between different industries. Basically there can be two reasons for this; either the economy is not in long-run equilibrium or there are errors in data. An example of a likely disequilibrium is industry A32 "Manufacture of radio, television and communication equipment and apparatus", in which output fell drastically in 2001 and it is likely that the labour force was not adjusted immediately according to the fall in output. An example on an error in data is probably A75 "Public administration and defence; compulsory social security", in which depreciations were 23 times as large as total capital stock, probably due to accounting principles in the governmental sector.

Since negative returns are not allowed in the model the industries with negative operating surpluses had to be adjusted. As the model calculates the use of capital from the return to capital, it may also be reasonable to adjust operating surplus in industries with abnormal return, and where it is likely that data over capital stock is a more accurate measure of the capital stock than the operating surplus.

Table A.2 Gross and net return on capital in National accounts

NACE	Explanation	gross	net
01	Agriculture, hunting and related service activities	0.13	0.04
02	Forestry, logging and related service activities	0.54	0.49
05	Fishing, fish hatcheries and fish farms; service activities incidental to fishing	0.41	0.25
10-12	Mining of coal, lignite, uranium and thorium; extr. of peat, crude petroleum and gas	0.05	-0.44
13	Mining of metal ores	0.12	-0.15
14	other mining and quarrying	0.13	0.08
15-16	Manufacture of food, beverages and tobacco products	0.41	0.19
17	Manufacture of textiles	0.46	0.27
18	Manufacture of wearing apparel, luggage, handbags, and footwear;	1.16	0.78
20	Manufacture of wood and of products of wood, cork, straw and plaiting materials	0.37	0.20
21	Manufacture of pulp, paper and paper products	0.35	0.22
22	Publishing, printing and reproduction of recorded media	0.86	0.34
23	Manufacture of coke, refined petroleum products and nuclear fuels	0.72	0.48
24	Manufacture of chemicals and chemical products	0.45	0.34
25	Manufacture of rubber and plastic products	0.34	0.13
26	Manufacture of other non-metallic mineral products	0.53	0.35
27	Manufacture of basic metals	0.28	0.10
28	Manufacture of fabricated metal products, except machinery and equipment	0.48	0.25
29	Manufacture of machinery and equipment n.e.c.	0.67	0.43
30	Manufacture of office machinery and computers	2.21	1.27
31	Manufacture of electrical machinery and apparatus n.e.c.	0.63	0.39
32	Manufacture of radio, television and communication equipment and apparatus	-2.91	-3.52
33	Manufacture of medical, precision and optical instruments, watches and clocks	0.51	0.35
34	Manufacture of motor vehicles, trailers and semi-trailers	0.36	0.18
35	Manufacture of other transport equipment	0.46	0.30
36	Manufacture of furniture, Recycling; manufacturing n.e.c.	0.19	0.01
40	Electricity, gas, steam and hot water supply	0.19	0.12
41	Collection, purification and distribution of water	0.64	0.08
45	Construction	0.23	0.05
50-52	Sale, maintenance and repair; Wholesale and commission trade. Retail trade,	0.52	0.29
55	Hotels and restaurants	0.48	0.30
60	Land transport; transport via pipelines	0.40	0.16
61	Water transport	0.26	0.17
62	Air transport	-0.07	-0.28
63	Supporting and auxiliary transport activities; activities of travel agencies	0.44	0.08
64	Post and telecommunications	0.34	0.16
65-67	Financial intermediation, except compulsory social security	26.94	19.30
70	Real estate activities	0.22	0.18
71	Renting of machinery and equipment and of personal and household goods	0.23	0.08
72	Computer and related activities	-0.01	-0.45
73	Research and development	0.59	0.08
74	Other business activities	0.56	0.26
75	Public administration and defence; compulsory social security	23.25	0.00
80	Education	3.12	0.60
85	Health and social work	1.27	0.61
90	Sewage and refuse disposal, sanitation and similar activities	0.49	0.21
91	Activities of membership organisation n.e.c.	0.24	-0.70
92	Recreational, cultural and sporting activities	1.21	0.93
93-95	Other service activities, Private households with employed persons	1.67	1.38

Gross return is operating surplus divided by the capital stock; net return is operating surplus less depreciations divided by capital stock.

In industry 32 exports fell from 136 to 95 billion between 2000 and 2001. In industry 13 exports fell from 5 to 4 billion between 2000 and 2001. In order to increase capital return to more realistic values in these industries, exports were increased by 30 billion in industry 32 and 0.5 billion in industry 13.

The return is unrealistically high in the financial industry. It is assumed that this is due to the fact that financial intermediation services indirectly measured (FISIM) was overestimated in national accounts. The household consumption of financial services was reduced by 26.5 billion and so was output in industry 65. The increase in output in industries 13 and 32 and the decrease in output in industry 65 resulted in an increase in capital return of 4000. The increase in capital income was distributed among domestic households, foreign citizens and government according to their share of total capital income.

In industries 10, 36, 62 and 72 returns on capital were increased by redistribution of labour cost to operating surplus. In industries 18, 22, 23, 29, 30 and 75 returns on capital were decreased by redistribution of operating surplus to labour cost. In total, these manipulations cancelled out, so that total labour income remained unchanged. Table A.3 shows gross and net return on capital after these manipulations.

In Table A.3 it can be seen that, with the exceptions of the governmental sectors 75, 80 and 85, all net returns for the sporting and recreation industry 92 and other services 93 now fall between 0.2 and 0.65. For the latter industries it is assumed that the operating surplus is more accurate than the value of the capital stock. The SAM after these manipulations is probably more likely to describe an economy in long run equilibrium.

Table A.3 Gross and net return on capital after adjustments

NACE	Explanation	gross	net
01	Agriculture, hunting and related service activities	0.13	0.04
02	Forestry, logging and related service activities	0.54	0.49
05	Fishing, fish hatcheries and fish farms; service activities incidental to fishing	0.41	0.25
10-12	Mining of coal, lignite, uranium and thorium; extr. of peat, crude petroleum and gas	0.32	-0.17
13	Mining of metal ores	0.2	-0.07
14	other mining and quarrying	0.13	0.08
15-16	Manufacture of food, beverages and tobacco products	0.41	0.19
17	Manufacture of textiles	0.46	0.27
18	Manufacture of wearing apparel, luggage, handbags, and footwear;	0.34	-0.05
20	Manufacture of wood and of products of wood, cork, straw and plaiting materials	0.37	0.2
21	Manufacture of pulp, paper and paper products	0.35	0.22
22	Publishing, printing and reproduction of recorded media	0.65	0.12
23	Manufacture of coke, refined petroleum products and nuclear fuels	0.64	0.4
24	Manufacture of chemicals and chemical products	0.45	0.34
25	Manufacture of rubber and plastic products	0.34	0.13
26	Manufacture of other non-metallic mineral products	0.53	0.35
27	Manufacture of basic metals	0.28	0.1
28	Manufacture of fabricated metal products, except machinery and equipment	0.48	0.25
29	Manufacture of machinery and equipment n.e.c.	0.65	0.41
30	Manufacture of office machinery and computers	0.37	-0.58
31	Manufacture of electrical machinery and apparatus n.e.c.	0.63	0.39
32	Manufacture of radio, television and communication equipment and apparatus	0.52	-0.09
33	Manufacture of medical, precision and optical instruments, watches and clocks	0.51	0.35
34	Manufacture of motor vehicles, trailers and semi-trailers	0.36	0.18
35	Manufacture of other transport equipment	0.46	0.3
36	Manufacture of furniture, Recycling; manufacturing n.e.c.	0.2	0.03
40	Electricity, gas, steam and hot water supply	0.19	0.12
41	Collection, purification and distribution of water	0.64	0.08
45	Construction	0.23	0.05
50-52	Sale, maintenance and repair; Wholesale and commission trade. Retail trade,	0.52	0.29
55	Hotels and restaurants	0.48	0.3
60	Land transport; transport via pipelines	0.4	0.16
61	Water transport	0.26	0.17
62	Air transport	0.2	-0.01
63	Supporting and auxiliary transport activities; activities of travel agencies	0.44	0.08
64	Post and telecommunications	0.34	0.16
65-67	Financial intermediation, except compulsory social security	0.44	-7.2
70	Real estate activities	0.22	0.18
71	Renting of machinery and equipment and of personal and household goods	0.23	0.08
72	Computer and related activities	0.18	-0.26
73	Research and development	0.59	0.08
74	Other business activities	0.56	0.26
75	Public administration and defence; compulsory social security	22.45	-0.8
80	Education	3.12	0.6
85	Health and social work	1.27	0.61
90	Sewage and refuse disposal, sanitation and similar activities	0.49	0.21
91	Activities of membership organisation n.e.c.	0.24	-0.7
92	Recreational, cultural and sporting activities	1.21	0.93
93-95	Other service activities, Private households with employed persons	1.67	1.38

Gross return is operating surplus divided by the capital stock; net return is operating surplus less depreciations divided by capital stock.

Re-exports are not allowed in the model. Thus export can never be larger than total domestic production. In the original data, export exceeds domestic production for three commodities due to re-export of imported goods. To make the dataset consistent with the model, an equal amount was subtracted from both import and export of these three goods.[8]

Treatment of secondary products

Secondary products were removed so that no commodity is produced in more than one industry. To calculate the vector of inputs that should follow the output to its main producing industry, industry-specific technological coefficients were calculated with the Bohlin Widell method (Bohlin Widell 2006). Table A.4 shows the cost shares for light fuel oil in different industries in the original data as well as after redistribution of secondary products using different technological assumptions. For most industries the cost shares of fuel oil do not change much due to the redistribution of secondary products.

In NACE 10 all technological assumptions but ITA brings the use of light fuel oil below the cut off for small cells in the SAM. In NACE 40 and NACE 50-52 a huge part of the redistribution is redistribution of retail selling of electricity from NACE 40 to NACE 50-52. Using the ITA, the trading companies are assumed to use as much fuel oil as the producers of electricity and heat. Therefore the cost shares of NACE 40 are unchanged. The cost shares in NACE 50-52 increase a lot since their original cost share was much lower than the cost shares in production of electricity and heat.

Using the CTA, the retail sellers in electricity are assumed to use as much fuel oil as other retail sellers in the economy. Therefore a very small amount of the use of fossil fuels is redistributed to NACE 50-52. The cost shares of NACE 50-52 are almost unchanged, while they increase significantly for NACE 40 since total output decreases much more than the use of fuel oil. Since CTA seems to be a more realistic assumption in this case, it is a preferable choice. We use CTA but with a small weight on ITA (0.0001) to get unique solutions.

[8] The sizes of the adjustments were for commodity CPA05 1.2 billions, CPA18 1.4 billions and CPA30 1.3 billions.

Table A.4 Cost shares for light fuel oil in different industries

NACE	Original data	ITA 1 CTA 0	ITA 1 CTA 1	ITA 0.0001 CTA 1	ITA 0 CTA 1
01	0.51	0.49	0.52	0.53	0.53
02	0.24	0.24	0.24	0.25	0.24
05	0.00	0.00	0.00	0.00	0.00
10	0.14	0.19	0.00	0.00	0.00
13	0.16	0.16	0.16	0.17	0.17
14	1.14	0.86	0.91	1.17	1.17
15	0.10	0.10	0.10	0.10	0.10
17	0.13	0.13	0.13	0.14	0.14
18	0.08	0.08	0.08	0.09	0.08
20	0.07	0.07	0.07	0.07	0.07
21	0.02	0.02	0.02	0.02	0.02
22	0.01	0.01	0.01	0.01	0.01
23	0.01	0.01	0.01	0.01	0.01
24	0.04	0.04	0.03	0.04	0.04
25	0.10	0.10	0.10	0.11	0.10
26	0.73	0.71	0.79	0.80	0.80
27	0.09	0.09	0.09	0.10	0.10
28	0.09	0.09	0.09	0.10	0.10
29	0.04	0.04	0.03	0.04	0.04
30	0.01	0.00	0.00	0.00	0.00
31	0.01	0.01	0.00	0.01	0.00
32	0.00	0.00	0.00	0.00	0.00
33	0.01	0.01	0.01	0.01	0.01
34	0.02	0.02	0.00	0.01	0.01
35	0.01	0.01	0.01	0.01	0.01
36	0.06	0.06	0.06	0.07	0.06
40	0.51	0.47	0.47	0.78	0.78
41	0.00	0.00	0.00	0.00	0.00
45	0.12	0.12	0.12	0.12	0.12
50-52	0.01	0.05	0.05	0.01	0.01
55	0.01	0.01	0.02	0.01	0.01
60	0.00	0.01	0.01	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00
63	0.02	0.02	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00
70	0.06	0.06	0.06	0.06	0.06
71	0.02	0.02	0.04	0.02	0.03
72	0.00	0.00	0.01	0.00	0.00
73	0.01	0.01	0.03	0.01	0.02
74	0.00	0.01	0.02	0.01	0.01
75	0.05	0.05	0.05	0.06	0.06
80	0.02	0.02	0.02	0.02	0.02
85	0.02	0.02	0.02	0.02	0.02
90	0.00	0.03	0.02	0.00	0.00
91	0.09	0.09	0.09	0.10	0.10
92	0.03	0.04	0.03	0.03	0.03
93	0.00	0.00	0.00	0.00	0.00

Calculation of the aggregated SAM

The SAM was aggregated to reduce the number of industries and commodities in order to simplify the solution of the model. Moreover, industry 40 and 23 were disaggregated into different activities using the industry technology assumption. Table A.5 shows the activities in the model and the commodities they are producing after the aggregation and disaggregation.

Table A.5 The activities in the model and the commodities they are producing

Activities	Commodities
A01	C01
Agriculture, forestry, fishing	Products of agriculture, hunting and related services, Products of forestry, logging and related services, Fish and other fishing products; services incidental of fishing
A10	C10
Mining and quarrying	Coal and lignite; peat ,Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying, Uranium and thorium ores, Metal ores, Other mining and quarrying products
A15	C15
Manufacturing of food, textile and wearing apparel	Food products and beverages, Tobacco products, Textiles, Wearing apparel; furs leather and leather products
A20	C20
Manufacturing of wood and of products of wood, publishing	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials, Printed matter and recorded media
A20bio	C20bio
Prod. of biofuel	Biofuel
A21	C21
Manufacturing of pulp, paper and paper products	Pulp, paper and paper products
A232A	C232A
Manufacturing of Gasoline	Gasoline
A232C	C232C
Manufacturing of Jet fuels	Fuel for aeroplanes
A232D	C232D
Manufacturing of diesel	Diesel
A232E	C232E
Manufacturing of Light fuel oil	Light fuel oil
A2327	C2327
Manufacturing of heavy fuel oil	Heavy fuel oil
A23O	C23O
Manufacturing of other commodities in CPA23	Other commodities in CPA23
A24	C24
Manufacturing of other energy intense products	Chemicals, chemical products and man-made fibres, Rubber and plastic products, Other non-metallic mineral products, Basic metals

Table A.5 continued

Activities	Commodities
A30 Other manufacturing	C30 Office machinery and computers, Electrical machinery and apparatus n.e.c. Radio, television and communication equipment and apparatus, Medical, precision and optical instruments, watches and clocks, Motor vehicles, trailers and semi-trailers, Other transport equipment, Furniture; other manufactured goods n.e.c. Secondary raw materials
A401 Electricity	C401 Electricity
A402 Gas	C402 Gas
A403 Hot water supply	C403 Steam and hot water
A41 Distribution of water. Construction	C41 Collected and purified water, distribution services of water, Construction work
A50-52Retail trade	C50-52 Sale, maintenance and repair; Wholesale and commission trade. Retail trade
A55 Hotels, financial services, post	C55 Hotel and restaurant services Supporting and auxiliary transport services; travel agency services, Post and telecommunication services, Financial intermediation services, except insurance and pension funding services, Insurance and pension funding services, except compulsory social security services, Services auxiliary to financial intermediation
A60 Land transports	C60 Land transport; transport via pipeline services
A61 Water Transports	C61 Water transport services
A62 Air transports	C62 Air transport services
A70 Real estate activities, Renting of equipment, R&D	C70 Real estate services, Renting services of machinery and equipment without operator and of personal and household goods Computer and related services, Research and development services
C74 Other business activities	C74 Other business services
A75 Public services	C75 Public administration and defence services; compulsory social security services, Education services, Health and social work services
A90 Other service activities	C90 Sewage and refuse disposal services, sanitation and similar services, Membership organisation services n.e.c. Recreational, cultural and sporting services, Other services

Calculations of carbon emissions

Carbon emissions from domestic production are calculated from the use of fossil fuels times the coefficient for carbon emission in Table 3.6. Total domestic emissions of CO_2 are equal to 34 million tonnes in the base model, i.e., roughly half of total emissions in reality. The divergence could be explained by the fact that not all sources of CO_2 are taken into account and errors in data. Since emission of CO_2 is calculated from taxes actually paid, tax evasion and firm specific tax reductions may explain part of the divergence.[9]

Table 3.6 Carbon emissions used in the calculations

Energy	carbon emission	source
Gasolin	2.375 kg/l	calculated from tax rate
Jet fuel	2.855 kg/l	assumed
Diesel	2.855 kg/l	calculated from tax rate
Light fuel oil	2.855 ton/m3	calculated from tax rate
Heavy fuel oil	2.855 ton/m3	calculated from tax rate
Natural gas	2.136 ton/m3	calculated from tax rate
Other fossil fuels	0	Not included in the calculations.
Electricity net trade	0.835 kg/kWh	Statistics Denmark.*
Domestic electricity	0	

**As a comparison, coal condensing plants, which are most often marginal production have emissions of 1.0 (Werner, 2001)*

[9] We study the industry-specific reductions of energy taxes; within each industry there are also some firms getting even higher reductions due to extra energy intensity in their production.