The EMEC model: Version 2.0

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Sammanfattning*

Konjunkturinstitutets allmän jämviktsmodell EMEC (Environmental Medium term EConomic model) har under 10 års tid kontinuerligt utvecklats och använts i utredningssammanhang. Den nya modellversionen, EMEC 2.0, som beskrivs i föreliggande uppsats, är en väsentlig utveckling av en tidigare modellversion. Det är framför allt transportefterfrågans bestämning som har utvecklats i modellen så att både hushåll och företag nu har möjlighet att substituera mellan skilda transportslag. Detta har också medfört att den tidigare samfärdselsektorn har delats upp i flera transportslag och att hushållens privata transporter delats upp på arbetsresor och fritidsresor. El-produktion och värmeproduktion har också delats upp i separata sektorer. I syfte att förbättra representationen av energiintensiva sektorer bildar metallverk och jord - och stenvaruindustri egna sektorer tillika med att läkemedelsindustri inte längre ingår i kemisk industri utan bildar en egen sektor. Det är också möjligt att studera fördelningseffekter av miljöpolitik genom att hushållen fördelats på sex grupper efter inkomst och regional hemvist.

Modellen har 26 näringslivssektorer och en offentlig sektor. Företag, hushåll och offentlig sektor efterfrågar 33 sammansatta varor och tjänster som insatsvaror samt för investeringar och privat konsumtion. De sammansatta varorna framställs av importerade varor och inhemskt producerade varor som även kan exporteras. Näringslivet och offentlig sektor använder dessutom arbetskraft, realkapital, transporter och energi som insatsfaktorer i produktionen av varor och tjänster. Näringslivets aktivitet och hushållens konsumtion medför miljöföroreningar. Det är i första hand olika slags förbränning som medför utsläpp av koldioxid, svaveldioxid, kväveoxider och partiklar men även produktionsprocesser bidrar till luftutsläppen. Tilldelning av utsläppsrätter omfattar anläggningar inom järn- och stålindustri, raffinaderier, massa- och pappersindustri, mineralindustri samt inom el- och värmeproduktion. I modellen förekommer emellertid inte uppgifter om enskilda anläggningar så därför räknas all produktion i aktuella sektorer till den s.k. handlande sektorn.

De ekonomiska aktörerna reagerar på priser inklusive skatter genom att företagen byter till relativt billigare produktionsfaktorer och genom att hushållen byter till relativt billigare konsumtionsvaror. Modellens långsiktiga karaktär innebär att marknadens aktörer hinner anpassa sig fullt ut till de prisförändringar som äger rum när ekonomin rör sig mot ett nytt jämviktsläge. Detta antas vara en acceptabel förutsättning på 10–20 års sikt. Hur stora anpassningarna blir vid en given prisförändring beror på aktörernas känslighet för prisförändringar. Aktörernas priskänslighet är en bedömningsfråga grundad på ett mycket varierande empiriskt underlag. Styrkan i den ekonomiska tillväxten styrs i modellen av tillgången på produktionsfaktorer, såsom arbetskraft och kapital, och på teknisk utveckling mätt som arbetsproduktivitet. Tillgången på arbetskraft, priset på kapital och arbetsproduktivitetens utveckling är exogent givna utanför modellen. Det är också möjligt att låta begränsningar för miljöutsläpp inverka på tillväxtens storlek och inriktning.

*In Swedish

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Abstract

The present paper introduces a new version of an applied general equilibrium model of the Swedish economy: *E*nvironmental *M*edium Term *Ec*onomic Model (EMEC). The model is used at NIER for analysing economic implications for households and firms of the Swedish environmental policy. The economy and the environment interact in the model and thus, we can analyse the economic implications of various environmental policy measures, such as a CO_2-tax, a CO_2-ceiling and CO_2-trading. The model captures also ancillary benefits of climate policy for NO_x, SO_2, PM10 and PM20. This new version of EMEC, in addition, analyses the effects of road user charges and the economic impact of environmental policy measures on six types of households, as transport demand is represented in a much more detail and as households are distributed, by disposal income and residence. Furthermore, the model distinguishes 26 industries, 33 composite commodities, 26 consumer goods, two kinds of labour and eight pollutants. The model produces results for endogenous variables, which can be interpreted fully in terms of the model's theory, data and the assumptions underlying the exogenous variables.

Keywords: CGE-model; Sectors; Pollutants; Factors of production; Substitution; Sweden

1. Introduction

EMEC[1] is a computable general equilibrium (CGE) model of the Swedish economy developed and maintained by the National Institute of Economic Research (NIER) for analysis of the interaction between the economy and the environment. The present paper reports on a new version of this model.[2] The model was used for the first time in the Swedish Medium Term survey (MTS) of 1999/2000 (reported in SOU 2000:7) but also in the MTS of 2003/04 (reported in SOU 2004:19). It was used also for analysing the economic implications of the Kyoto agreement on CO_2 restrictions (reported in SOU 2000:23 and by Nilsson (2002)), for analysis of economic effects on Sweden of EU's system of emission trading (reported in SOU 2005:10, SOU 2003:60 and by Östblom (2003a), (2003b), (2004a)) and for analysis of Sweden's climate strategy (kontrollstation 2004) reported in (Sveriges klimatstrategi) and by Östblom (2004b). Sulphur abatement cost functions were introduced in the model by Östblom (2002). Also, a feedback effect on health and labour productivity of nitrogen oxide pollution was introduced by Östblom and Samakovlis (2004).

The political will of correcting for the externalities of road transports are growing in the EU and the implementations of road user charges (kilometre taxes) are discussed in many EU countries. Also, the Swedish Road Tax Commission has proposed a kilometre tax for heavy trucks in Sweden (reported in SOU 2004:63). To analyse the economic effects of a kilometre tax, therefore, transport demand of the household sector as well as transport demand of the industry sector are represented in a much more detail in the present version of the model (EMEC 2.0).[3]

EMEC is a static CGE-model with 26 industries and 33 composite commodities and a public sector producing a single commodity. Produced goods and services are exported and used together with imports to create composite commodities for domestic use. Composite commodities are used as inputs by industries and for capital formation. In addition, households consume composite commodities and there are 26 consumer commodities.

Production requires primary factors (two kinds of labour and capital) as well as inputs of materials, transports and energy. The use of fuel inputs in current production and households' fuel consumption emit carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), sulphur dioxide (SO_2), nitrous oxide (N_2O), nitrogen oxides (NO_x) and particulate matter (PM10, PM25).

The supply of each type of labour is exogenous for the economy as a whole, while capital is supplied to the economy at a given price. All factors can move freely between domestic sectors. Perfect competition and no economies of scale in production are assumed for all markets. The small country assumption is adopted for tradable goods and the problem of overspecialization is handled by the Armington assump-

[1] Environmental medium term economic model.

[2] CGE modelling has been used by applied economists for a long time and are increasingly influential in policy making. A thorough review of the field is given by Dixon, P. and Paramenter, B.R. (1996) and an exellent guiding in how to construct a CGE-model is presented by Dixon, P., Paramenter, B.R, Powell, A. and Wilcoxen, P (1992). The use of CGE models is now a well established tool for environmental policy analysis as reviewed by Bergman, L. (2005). For a model of EU countries see e.g. European commission (1995) and for Swedish models see Östblom, G. (1999) and Hill, M. (2001).

[3] CGE modelling of transport demand was performed by e.g. Kremers, H., Nijkamp, P., and Rietvald P. (2002), Steininger, K. (2002), Johnsson, R. (2003) and Nilsson, C. (2004).

tion for imports and by a relative price dependent supply function for exported goods. [4]

Households are distributed into six subgroups by disposal income and by place of residence. The model runs with exogenous interest rate and is closed with an exogenous ratio of the current account. The foreign price level is chosen as numeraire.

The use of energy by firms or households is subject to an energy tax and pollution taxes.[5] Tax exemptions due to the use of CO_2 permits or for other reasons are reflected in the estimated tax rates. Consumer goods are also subject to a value-added tax as well as other indirect taxes. The use of labour is subject to social security fees and households pay income tax on labour income. Firms and households react on prices, including taxes, and adjust their mix of inputs or their bundle of consumer goods by substituting away from the relatively dearer input or good.

The representative firm is assumed to choose an optimal mix of two types of labour and an optimal mix of energy in three stages. The firm, then, decides upon the mix of labour and physical capital in the creation of value added as well as the mix of energy and material in the creation of energy-material input. The various outputs and inputs must be transported, and the firm chooses an optimal transport solution (which allows for the use of several transport modes) in two steps. An optimal mix of value added and energy-material input is chosen at the highest level, to produce the firm's output. Another kind of substitution relates to goods of the same classification. Domestic goods are non-perfect substitutes for foreign goods in domestic as well as foreign use; i.e. in imports as well as in exports.

The motives for modelling transport demand in EMEC are discussed in section 2 which follows after this introduction. The aggregates and data of the model are presented in Section 3. All equations are given in Section 4. Calibration procedures and choice of parameter values are briefly discussed in Section 5. Section 6 concludes the paper. Technical definitions of goods and factors are given in Appendix A, which also includes a list of variable names. Appendix B shows the equations for the CES price aggregation of various consumer commodities.[6] Appendix C is a short introduction to CES aggregation.

2 The modelling of transport demand

Freight transports by roads, measured as transport work (tonne-km), as well as the CO_2 emissions of these transports increased in relation to economic growth (GDP), as concluded by Åhman (2004) for Sweden 1980-2002. Personal transports by roads, measured as transport work (person-km), as well as the CO_2 emissions of these transports also increased but less than GDP or private consumption, according to SIKA (2005). The increasing external costs of road transports are becoming less accepted in many EU countries and the will of correcting for the externalities of road transports are growing among member states as discussed by Hammar (2006a). Road user charges (kilometre taxes) have been, or are discussed to be, implemented in many EU countries. The Swedish Road Tax Commission has proposed a kilometre tax for heavy trucks in Sweden, and the design of such a tax is discussed by Hammar

[4] Domestic goods of the same statistical classification are non-perfect substitutes for imported goods, which are of a different origin. This treatment of imports was pioneered by Armington (1969).

[5] Also, the levels of various emissions can be bounded in the model to give the corresponding shadow prices of emission.

[6] Constant Elasticity of Substitution (CES).

(2006b). Also, transportation is subject to other taxes and fees, which aim at reducing its externalities and emissions to the air.

To capture the economic effects of a kilometre tax within a CGE framework, the transport demand of households and firms must be modelled with the options of adjusting to the changes of transportation costs. The present version of EMEC exhibits such adjustment mechanisms when the households and firms choose among a number of transportation modes for work trips and leisure trips, as well as firms' transportations of inputs and outputs.

Households gain utility of consumption and work trips. The utility function is separable in the utility of work trips and the utility of consumption. The utility of work trips is set in proportion to households' labour supply. Households maximize the utility of consumption and work trips according to a budget constraint. The utility of leisure trips is derived from the utility of consumption. A variety of transportation modes differing in transportation costs can be used for work trips and leisure trips. Equations of the households' transport demand were derived by Nilsson (2004) and are presented in section 4.1.

The flows of commodities relate to production and consumption of commodities in the economy, and thus economic activity brings about demand for carriers of commodity flows. Production demands materials and energy inputs, which are substitutes for labour and capital in the model. Firms are cost minimizing in the choice of labour, capital, energy, materials and various transport modes for producing outputs. In the model, thus, firms adapt to price changes, due to e.g. a kilometre tax, when choosing among a number of transport modes for the commodity flows. Equations of the firms' transport demand are presented in section 4.2.

3 Aggregates and data of the model

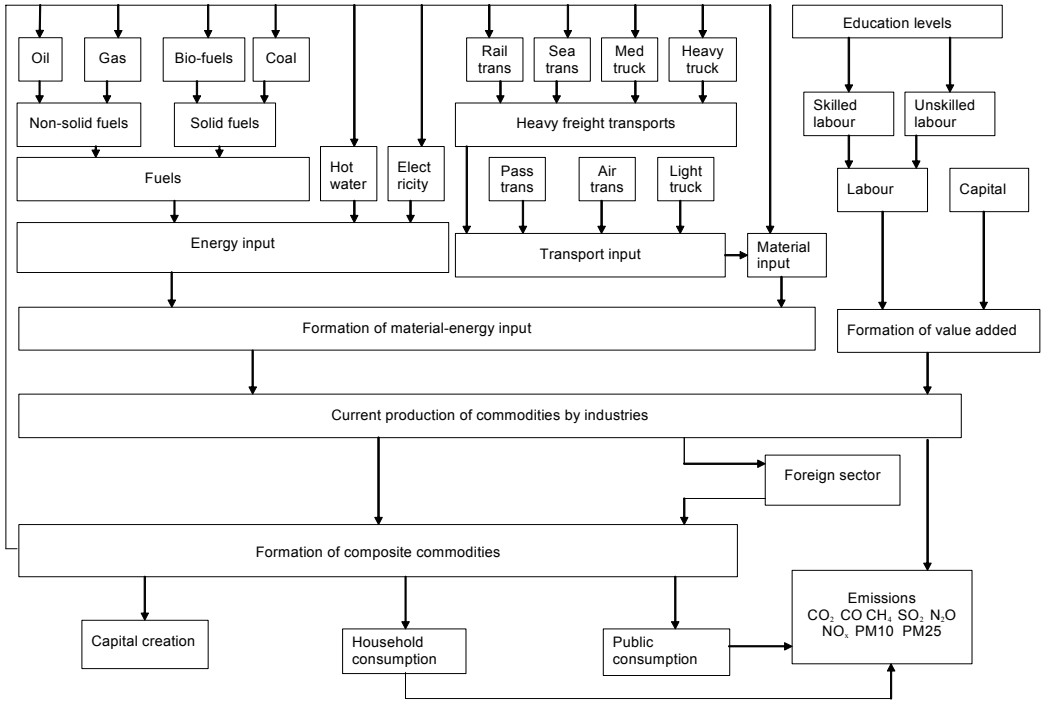
The database of *EMEC* includes input-output data for 69 business sectors, 85 commodities, 150 consumer goods, and seven educational groups of labour, a stock of capital, six groups of households, 33 energy carriers and 8 pollutants, which permits a wide range of aggregation possibilities. Data are aggregated to more manageable dimensions, and the present model distinguishes 27 producing sectors - 26 business sectors and a public sector: 1. Agriculture, 2. Fishery, 3. Forestry, 4. Mining, 5. Other industries, 6. Mineral products, 7. Pulp and paper mills, 8. Drug industries, 9. Other chemical industries, 10. Iron and Steel industries. 11. Non-iron metal industries, 12. Engineering, 13. Petroleum refineries, 14. Electricity supply, 15. Steam and hot water supply, 16. Gas distribution, 17. Water and sewage, 18. Construction, 19. Rail road transports, 20. Road goods transports, 21. Road passenger transports, 22. Sea transports, 23. Air transports, 24. Other transports, 25. Services, 26. Real estate and a public sector. The 27 sectors produce 33 commodities in fixed proportions and two commodities are not produced but imported (coal and crude petroleum). The model distinguishes between skilled and unskilled labour. Aggregation schemes, definitions and data sources are given in Appendix A.

The relatively high intensity of skilled labour in the public sector implies that different growth rates for public services[7] may have substantial effects on the market for skilled labour and indirectly on the competitiveness of the most important exporting sectors of the model economy. The potential competition for resources is even more

[7] Note that in the National Accounts, productivity growth is set to zero in the public sector.

evident in the market for real capital between the exports oriented capital-intensive sector, the letting of dwellings and energy production.

Figure 1 Flows of commodities, factors and emissions in *EMEC



*The arrows indicate the direction of flows.

4 Equations of the model

Besides households and firms, the model economy includes also a public sector and a foreign sector. The economic agents use resources such as labour, capital, energy and the environment to achieve wealth. Households maximize utility subject to an income restriction, firms maximizes profit subject to resources restrictions, disposal of public services are subject to a budget constraint and the foreign sector's import and export activities are govern by an exogenously given trade balance. The demands and supplies of commodities and resources are cleared by market prices and there are also shadow prices for emitting pollutions the air. All of these activities are taken care of in the model by a number of equations for final demands, input demands, total domestic demand an output, emissions of pollutants, price setting, market clearing and emission constraints.

4.1 Final demands

Private consumption

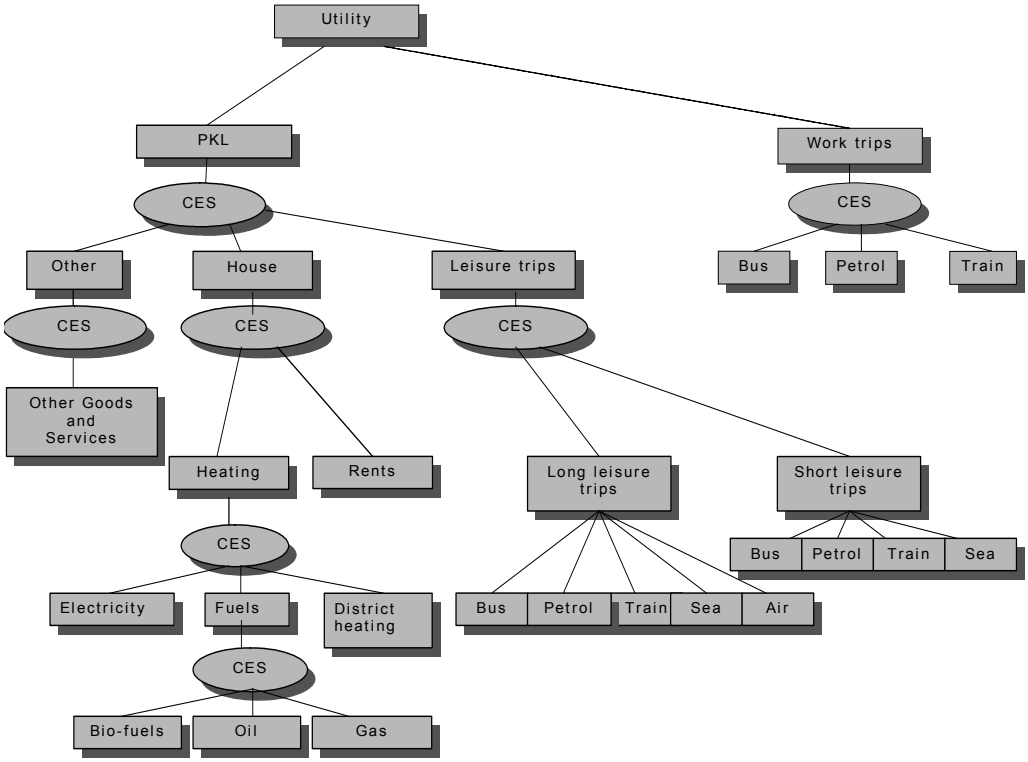
The model has six representative consumers or consumer groups, h, maximizing the utility of consumption and work trips. The six consumer groups are: low income group in big city areas, high income group in big city areas, low income group in population centres, high income group in population centres, low income group in sparsely populated areas high income group in sparsely populated areas The utility

functions ($UTOT_h$) are four-level constant elasticity of substitution (CES) functions, and figure 2 depicts the nested structure of the utility function for a household. [8]

At the top level of the consumption tree, utility is separable into work trips and consumption of goods and services. Work trips are a perfect complement to labour supply, and therefore households choose among various transport modes, according to their preferences, in order to fulfil the amount of work trips needed in proportion to their supply of labour.

At the second level of the consumption tree, the consumption of goods and services are separated into three main categories of consumer goods: goods related to housing (i.e. rents and energy), leisure trips and a third category of all other goods and services. The housing commodity is a CES-aggregate of rents and heating, which in turn is a CES-aggregate of fuel, district heating and electricity. Fuel is a CES-aggregate of the various fuels used for combustion (excluding motor fuels), i.e. oil, gas, coal, bio-fuels. Leisure trips are a composite of long leisure trips and short leisure trips. Finally, the composites long leisure trips and short leisure trips are CES-aggregates of the various transport modes: bus, boat, rail, air and car (petrol in figure 2). The third main category constitutes the CES function for consumption of all other goods and services.

Figure 2 Consumer utility function.



[8] The CES function is frequently used in applied general equilibrium modelling to depict the behaviour of firms and households. The CES utility function and its dual expenditure function are used to model households' substitution and demand of commodities. For a short introduction to the use of CES functions for modelling firms' and households' behaviour, see Appendix C.

The budget constraint of households states that consumption expenditures must equal the sum of primary factor (labour and capital) incomes, public transfers net of private investments and payment on foreign debt. The income of labour differs between the six household groups in accordance with benchmark data. We assume, due to the lack of better data, that capital income, transfers and private investments take the same average shares of expenditures for all household groups. Payment on foreign debt is calculated as a residual, equal to consumption expenditures and savings (investments) less factor incomes and transfers.

The consumer allocates his total resources between the need for work trips $WORK_h$, and the consumption of goods and services other than work trips PKL_h.

$$UTOT_h = PKL_h + WORK_h. \quad \textbf{(1)}$$

Differentiation of the minimum expenditure per unit of work trips results in households demand for different types of transport modes *trw* (bus, train and private owned cars) used for work trips $HC_{h,trw}$.

$$HC_{h,trw} = atrw_{h,trw}^{swork_h - 1}\left(\frac{PWORK_h}{PHCS_{h,trw}}\right)^{swork_h} \cdot WORK_h. \quad \textbf{(2)}$$

The variable $WORK_h$ is the aggregate of work trips, and the corresponding price is denoted $PWORK_h$. The variable $PHCS_{h,trw}$ is the price (including taxes), of various transport modes, *trw*. The substitution elasticity is denoted $swork_h$ and $atrw_{h,trw}$ is a calibration constant.

The aggregate of work trips and labour are perfect complements; and thus the aggregate of work trips is in proportion to the supply of labour ($LTOT_h$) for each household group:

$$WORK_h = \beta_h \cdot LTOT_h \ . \quad \textbf{(3)}$$

Where β_h is the proportion of work trips demanded for a unit of labour supply. [9]

The variable PKL_h is a CES aggregate of leisure trips, housing services and other consumer goods and services, i.e. the variables $FRITRANS_h$, $HOUSE_h$ and OVR_h, respectively, at the highest level of aggregation.

$$PKL_h = \left[\left(ak1_h \cdot FRITRANS_h\right)^{\frac{spk-1}{spk}} + \left(ak2_h \cdot HOUSE_h\right)^{\frac{spk-1}{spk}} + \left(ak3_h \cdot OVR_h\right)^{\frac{spk-1}{spk}}\right]^{\frac{spk}{spk-1}} \quad \textbf{(4)}$$

[9] The proportion β is calibrated from base year data and rereflects the share of overtime work in labour supply for the base year. It could also be assumed that β decreases with labour supply as there are reasons to belive that the proportion of overtime work increases with labour supply. This assumption, as well as assumptions of other changes in the composition of labour supply compared to base year data, however, could be taken care of by letting β take values different from the calibrated value.

Leisure trips, $FRITRANS_h$, is a composite of long leisure trips, $LONG_h$, and short leisure trips, $SHORT_h$, which are undertaken by use of the various transport modes, *trs*, including bus transports, boat transports, rail transports and car transports.

Differentiation of the minimum expenditure per unit of short leisure trips demanded, $SHORT_h$ gives the demand of transport modes for short leisure trips, $HC_{h,trs}$ according to the equation (5) at the third level of aggregation. Similarly, differentiation of the minimum expenditure per unit of long leisure trips demanded $LONG_h$, gives the demand of transport modes, *trh* (bus, train, air, sea and car), for long leisure trips $HC_{h,trh}$ according to equation (6) at the third level of aggregation.

$$HC_{h,trs} = atrs_{h,trs}^{sshort_h - 1}\left(\frac{PSHORT_h}{PHCS_{h,trs}}\right)^{sshort_h} \cdot SHORT_h . \quad \textbf{(5)}$$

$$HC_{h,trh} = atrh_{h,trh}^{slong_h - 1}\left(\frac{PLONG_h}{PHCS_{h,trh}}\right)^{sholi_h} \cdot LONG_h . \quad \textbf{(6)}$$

The variables $PSHORT_h$ and $PLONG_h$ are the corresponding prices for short and long leisure trips, respectively. The variables $PHCS_{h,trs}$ and $PHCS_{h,trh}$ are the prices including taxes for various transport modes. The substitution elasticity is denoted $sshort_h$ and $slong_h$, respectively, whereas $atrs_{h,trs}$ and $atrh_{h,trh}$ are the calibration constants.

The demand of short leisure trips and long leisure trips, the variables $SHORT_h$ and $LONG_h$ in equations (7) and (8) respectively, is given by differentiation of the minimum expenditure per unit of aggregate leisure trips demanded, $FRITRANS_h$, with the corresponding price $PFRITRANS_h$, at the second level of aggregation.

$$SHORT_h = ashort_h^{sfritrans_h - 1}\left(\frac{PFRITRANS_h}{PSHORT_h}\right)^{sfritrans_h} \cdot FRITRANS_h , \quad \textbf{(7)}$$

$$LONG_h = along_h^{sfritrans_h - 1}\left(\frac{PFRITRANS_h}{PLONG_h}\right)^{sfritrans_h} \cdot FRITRANS_h . \quad \textbf{(8)}$$

The substitution elasticity is $sfritrans_h$ and the calibrated constants are $ashort_h$ and $along_h$.

The variable for housing services $HOUSE_h$ is a CES aggregate of other housing services (rents), $HC_{h,rents}$ and heating $HEAT_h$. The last variable in turn is a CES aggregate of fuels, electricity and district heating, i.e. the variables $FUEL_h$,

$HC_{h,hel}$ and $HC_{h,heat}$, respectively. The households demand of various fuels, the variable $HC_{h,f}$ (the index f denotes oil, gas and bio-fuel), is given by differentiation of the minimum expenditure per unit of fuel aggregate $FUEL_h$ at the lowest level of aggregation.

$$HC_{h,f} = afuel_{h,f}^{sfuel_h - 1}\left(\frac{PFUEL_h}{PHCS_{h,f}}\right)^{sfuel_h} \cdot FUEL_h . \qquad \textbf{(9)}$$

The corresponding price is $PFUEL_h$, the variable $PHCS_{h,f}$ is the prices of various fuels, $sfuel_h$ is the substitution elasticity and $afuel_{h,f}$ is a calibration constant.

The households' demand of the various energy carriers used for heating, fuels $FUEL_h$, electricity $HC_{h,hel}$, and district heating $HC_{h,hheat}$, is given by differentiation of the minimum expenditure per unit of aggregate heating $HEAT_h$, with the corresponding price $PHEAT_h$, at the third level of aggregation.

$$FUEL_h = aheat1_h^{sheat_h - 1}\left(\frac{PHEAT_h}{PFUEL_h}\right)^{sheat_h} \cdot HEAT_h \qquad \textbf{(10)}$$

$$HC_{h,hel} = aheat2_h^{sheat_h - 1}\left(\frac{PHEAT_h}{PHCS_{h,hel}}\right)^{sheat_h} \cdot HEAT_h \qquad \textbf{(11)}$$

$$HC_{h,hheat} = aheat3_h^{sheat_h - 1}\left(\frac{PHEAT_h}{PHCS_{h,hheat}}\right)^{sheat_h} \cdot HEAT_h \qquad \textbf{(12)}$$

Where the variable $PHCS_{h,hel}$ is the price of electricity, the variable $PHCS_{h,hheat}$ is the price of district heating, $PFUEL_h$ is the fuel price, $sheat_h$ is the substitution elasticity and $aheat1_h$, $aheat2_h$, $aheat3_h$ are calibrated constants.

Households' demand of heating and other housing services (*rents*), $HEAT_h$ and $HC_{h,rents}$, respectively, are given by differentiation of the minimum expenditure per unit of housing $HOUSE_h$ with its corresponding price $PHOUSE_h$, at the second level of aggregation.

$$HEAT_h = ahouse1_h^{shouse_h - 1}\left(\frac{PHOUSE_h}{PHEAT_h}\right)^{shouse_h} \cdot HOUSE_h \qquad \textbf{(13)}$$

$$HC_{h,rents} = ahouse2_{h}^{shouse_h - 1}\left(\frac{PHOUSE_h}{PHCS_{h,rents}}\right)^{shouse_h} \cdot HOUSE_h \quad \textbf{(14)}$$

Where $shouse_h$ is the substitution elasticity, $ahouse1_h$ *and* $ahouse2_h$ are calibrated constants.

Households' demand of goods and services excluding transport services and housing services, $HC_{h,fno}$ is given by differentiation of the minimum expenditure function per unit of other goods and services, OVR_h, with the corresponding price $POVR_h$ at the second level of aggregation.

$$HC_{h,fno} = aovr_{h,fno}^{sovr_h - 1}\left(\frac{POVR_h}{PHCS_{h,fno}}\right)^{sovr_h} \cdot OVR_h \quad (\textbf{15})$$

The variable $PHCS_{h,fno}$ is the price including taxes for goods and services other than transport and housing services, $sovr_h$ is substitution elasticity and $aovr_{h,fno}$ is a calibrated constant.

Consumers maximize $UTOT_h$ taking market prices as given, subject to the budget constraint in equation (16):

$$\sum_{fn} PHC_{fn} \cdot HC_{h,fn} \le PL_h \cdot LTOT_h + PC_h \cdot C_h + T_h - S_h \quad \textbf{(16)}$$

The left hand side of equation (16) is total expenditures of goods and services (incl. work trips), *fn*, which must be less than or equal to the sum of primary factor incomes (labour income, $PL_h \cdot LTOT$, and capital income, $PC_h \cdot C_h$), lump-sum government transfers, T_h, and less household's savings, S_h, for a household group, *h*. Transfers to a household group, T_h, is a given share, $transfshr_h$, of total government transfers, *TRANSFERS*. Savings of a household group, S_h, is a given share, $invshr_h$, of total investments, *INVS,* less the trade balance attributed to a household group as a given share, $fdeptshr_h$, of total exports, *EXPL*, and imports, *IMPL*, in current prices. Total investments are financed by the gross savings of the economy i.e. the sum of households' savings and the trade balance. Labour and capital income, savings, transfers and the trade balance are distributed among household groups according to their base year shares.

$$T_h = transfshr_h \cdot TRANSFERS\,. \quad \textbf{(17)}$$

$$S_h = invshr_h \cdot INVS - fdeptshr_h \cdot (EXPL - IMPL) \quad \textbf{(18)}$$

Total supply of skilled labour, *LSS*, and unskilled labour, *LSU*, is exogenously given and each household supplies a fixed ratio, $skshr_h$, of skilled labour, LSK_h, and a fix ratio, $unskshr_h$, of unskilled labour, $LUNSK_h$, according to base year data.

$$LSK_h = skshr_h \cdot LSS \quad \textbf{(19)}$$

$$LUNSK_h = unskshr_h \cdot LSU \quad \textbf{(20)}$$

The value of consumed goods and services other than work trips, $PKL_h \cdot PPK_h$, equals the value of total consumption, $\sum_{fn} PHC_{fn} \cdot HC_{h,fn}$, less the value of work trips, $PWORK_h \cdot WORK_h$, and thus:

$$PKL_h \cdot PPK_h = \sum_{FN} PHC_{FN} \cdot HC_{h,FN} - WORK_h \cdot PWORK_h \quad \textbf{(21)}$$

Where PPK_h is the price of consumption excluding work trips and $PWORK_h$ is the price of work trips.

The categories of goods and services consumed, *FN*, by various households are transformed to composite goods, PK_{pr}, of private consumption by the matrix $CONS_{h,pr,fn}$.

$$PK_{pr} = \sum_{h} \sum_{fn=1}^{26} CONS_{h,pr,fn} \cdot HC_{h,fn} \quad \textbf{(22)}$$

Public consumption

Public goods and services are produced by a single government agent and consumed by households and firms. Total public consumption, *OKL*, is given exogenously, and the government's budget constraint is accommodated through endogenously scaling of lump sum transfers, *TRANSFERS*, to households. The government has income from taxes on labour income, *TAXL*, consumption, *TAXC*, and production, *TAXP*. The government's budget constraint is:

$$OKL = TAXL + TAXC + TAXP - TRANSFERS\,. \quad \textbf{(23)}$$

Fixed investment and changes in stocks

The change in capital stock is net investments accumulated at the end of the period for which the model is solved. The capital stock is assumed to grow at a uniform yearly rate, *r*, over the period and this determines net investment in each sector, $NINV_i$, for the last year of the period. Replacement is related to the capital stock by an exogenous depreciation rate, dep_i. The capital stock is C_i and gross investment is thus given by:

$$INV_i = NINV_i + dep_i \cdot C_i \quad i = 1,...,26. \tag{24}$$

Where $NINV_i = \frac{C_i}{1+r_i} \cdot r_i$

Changes in stocks, LA, are exogenous.

Exports

We adopt the assumption of a small open economy for Sweden, where its products have small shares of total demand in world markets and, therefore, any quantity of exported goods must be sold at a given world market price. Hence, the export demand for Swedish products will be totally elastic. To avoid overspecialization in a model with more traded products than production factors, we assume product differentiation between exported products and products sold on the domestic market. Products intended for export are sold at world market prices, while products supplied on the domestic market are sold at domestic prices and the relative price dependent export supply function, thus introduced, is derived in section 4.3.

4.2 Input demands

Gross output, Z_i is produced by means of value added, FV_i and an energy-material aggregate, ME_i at the highest level of aggregation. The nested structure of production is shown in Figure 3 and the top level of CES aggregation is given by equation (25).[10]

$$Z_i = \left[\left(afv_i \cdot FV_i \right)^{(sz_i - 1)/sz_i} + \left(ame_i \cdot ME_i \right)^{(sz_i - 1)/sz_i} \right]^{sz_i/(sz_i - 1)} \tag{25}$$

At each succeeding level, the inputs of skilled and unskilled labour, capital, various energy carriers, materials and transports are aggregated in the same manner by CES or Leontief functions.

Demand for energy, materials and transports

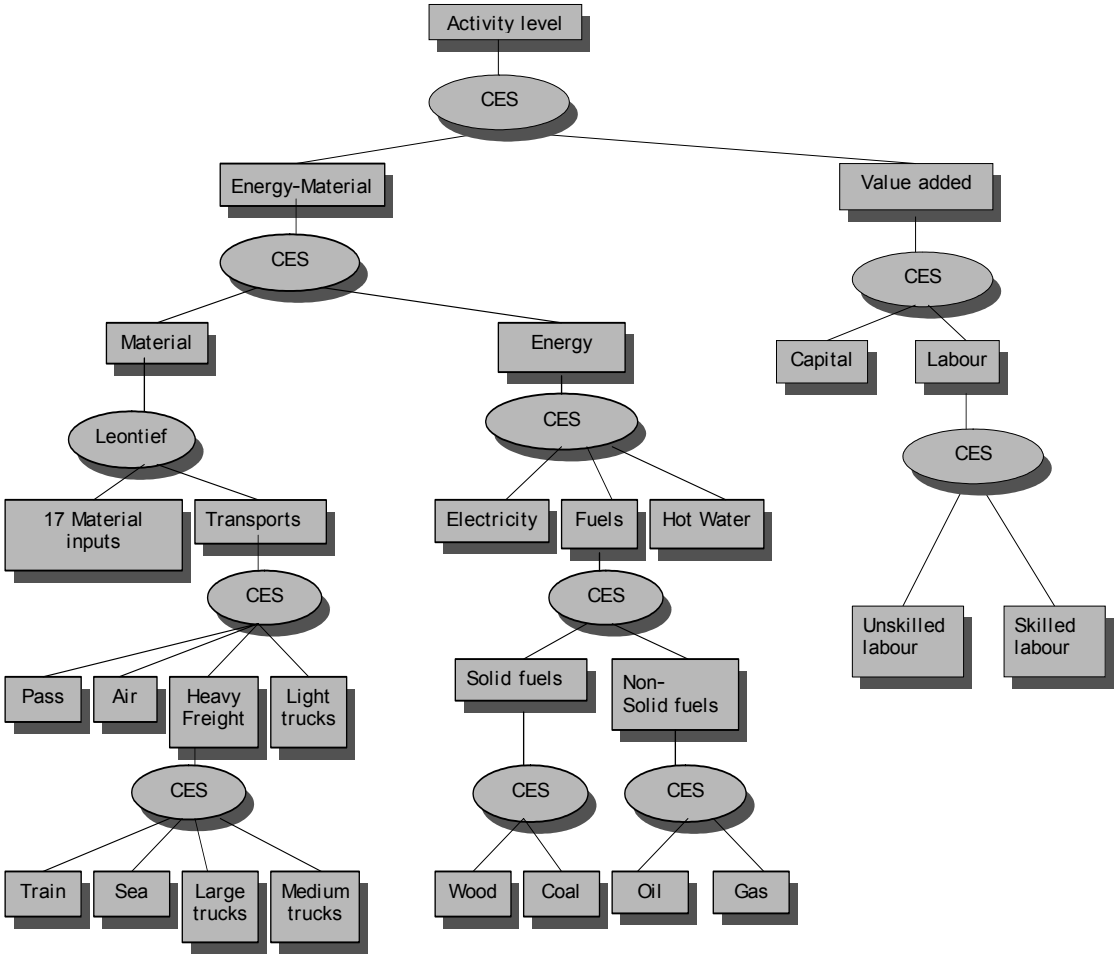
CES-functions are used to aggregate bio fuels, $IO_{bio,\,i}$, and coal, $IO_{coal,\,i}$, into solid fuels, SFU_i, as well as to aggregate heating oils, $IO_{oil,\,i}$, and gas, $IO_{gas,\,i}$, into liquid fuels, LF_i, at the lowest level of aggregation. Solid fuels and liquid fuels, in turn, are aggregated into fuels, FU_i, at the next level of aggregation. At the third level of aggregation, fuels, electricity, $IO_{el,\,i}$, and hot water, $IO_{hot,\,i}$, are aggregated into energy, E_i.

Material, M_i, is a Leontief aggregation of all other intermediate inputs (excl. energy inputs) including transports. The aggregate transport service is, in turn, a CES-aggregation of passenger transport, $IO_{passtp,i}$, air transport, $IO_{airtp,i}$, light truck transports, $IO_{llb,i}$, and heavy freight transport, $FRGT_i$. Heavy freight transport is a CES-aggregation of train transports, $IO_{train,\,i}$, sea transports, $IO_{sea,i}$, large truck transports, $IO_{slb,i}$, and medium truck transports, $IO_{mlb,i}$. The corresponding prices are, $PDS_{pr,i}$ for goods and services at the bottom levels while the prices of energy aggregates are, $PSFU_i$ (solid fuels), PLF_i (liquid fuels), and PE_i (total energy aggregate). The transport

[10] The CES function is frequently used in applied general equilibrium modelling to depict the behaviour of firms and households. The CES production function and its dual cost function are used to model substitution and demand of firms' inputs. For a short introduction to the use of CES functions for modelling firms' and households' behaviour, see the Appendix C.

prices are $PFRGT_i$ (heavy freight transport) and PTP_i (aggregate transports). The price of material is PM_i and the price of the energy-material aggregate is PME_i. The substitution elasticities are *slf, ssf, sf,* and see for the energy branch of the CES-aggregation tree, while the transport elasticities are *stp* and *sfrgt*. The calibration constants of the demand equations are: *be1, be3, be4, be5, blf, bsf, be2, bf, btr,* and *bfrgt*.

Figure 3 The input-activity specification in *EMEC*



Every CES production functions have a dual cost function, and differentiation of the associated minimum unit cost functions yield demand equations of various inputs. Sectoral demand equations for oil, $IO_{oil,i}$, and gas, $IO_{gas,i}$ are arrived at by differentiating the minimum cost per unit of liquid fuels LF_i at the lowest level of aggregation:

$$IO_{oil,i} = be1_i^{slf_i - 1} \cdot \left(\frac{PLF_i}{PDS_{oil,i}} \right)^{slf_i} \cdot LF_i \qquad i = 1,...26. \tag{26}$$

$$IO_{gas,i} = be3_i^{slf_i - 1} \cdot \left(\frac{PLF_i}{PDS_{gas,i}} \right)^{slf_i} \cdot LF_i \qquad i = 1,...,26. \tag{27}$$

Differentiation of the minimum cost per unit of solid fuels SFU_i gives sectoral demand for bio-fuels, $IO_{bio,i}$, and coal, $IO_{coal,i}$,:

$$IO_{coal,i} = be4_i^{ssf_i - 1} \cdot \left(\frac{PSFU_i}{PDS_{coal,i}} \right)^{ssf_i} \cdot SFU_i \qquad i = 1,...,26. \tag{28}$$

$$IO_{bio,i} = be5_i^{ssf_i - 1} \cdot \left(\frac{PSFU_i}{PDS_{bio,i}} \right)^{ssf_i} \cdot SFU_i \qquad i = 1,...,26. \tag{29}$$

Differentiation of the minimum cost per unit of fuels FU_i gives sectoral demand for liquid fuels LF_i and solid fuels SFU_i :

$$LF_i = blf_i^{sf_i - 1} \cdot \left(\frac{PFU_i}{PLF_i} \right)^{sf_i} \cdot FU_i \qquad i = 1,...,26. \tag{30}$$

$$SFU_i = bsf_i^{sf_i - 1} \cdot \left(\frac{PFU_i}{PSFU_i} \right)^{sf_i} \cdot FU_i \qquad i = 1,...,26. \tag{31}$$

Differentiation of the minimum cost per unit of energy E_i gives sectoral demand for electricity, $IO_{el,i}$, hot water, $IO_{hot,i}$, and fuels, FU_i:

$$IO_{el,i} = be2_i^{see_i - 1} \cdot \left(\frac{PE_i}{PDS_{el,i}} \right)^{see_i} \cdot E_i \qquad i = 1,...,26. \tag{32}$$

$$IO_{hot,i} = be6_i^{see_i - 1} \cdot \left(\frac{PE_i}{PDS_{hot,i}} \right)^{see_i} \cdot E_i \qquad i = 1,...,26. \tag{33}$$

$$FU_i = bf_i^{see_i - 1} \cdot \left(\frac{PE_i}{PFU_i} \right)^{see_i} \cdot E_i \qquad i = 1,...,26. \tag{34}$$

Differentiation of the minimum cost per unit of heavy freight transport $FRGT_i$ gives sectoral demand for transport services by train ($IO_{train,i}$), sea ($IO_{sea,,i}$), large truck transports ($IO_{slb,i}$) and medium truck transports ($IO_{mlb,i}$). The various heavy freight transport modes are indexed by *gtr*.

$$IO_{gtr,i} = btp_{gtr,i}^{sfrgt_i - 1} \cdot \left(\frac{PFRGT_i}{PDS_{gtr,i}} \right)^{sfrgt_i} \cdot FRGT_i \quad i = 1,...,26.; \tag{35}$$

gtr=train, sea, mlb and slb

Differentiation of the minimum cost per unit of aggregate transport TP_i gives sectoral demand for transport services by heavy freight transport ($FRGT_i$), Passenger transports ($IO_{passtp,i}$), air transports ($IO_{airtp,i}$) and small trucks ($IO_{llb,i}$):

$$FRGT_i = bfrgt_i^{stp_i - 1} \cdot \left(\frac{PTP_i}{PFRGT_i} \right)^{stp_i} \cdot TP_i \qquad i = 1,...,26. \tag{36}$$

$$IO_{trp,i} = btp_{trp,i}^{stp_i - 1} \cdot \left(\frac{PTP_i}{PDS_{trp,i}} \right)^{stp_i} \cdot TP_i \qquad i = 1,...,26. \tag{37}$$

$$trp = passtp, airtp, llb$$

The intermediate demand of various material $IO_{pr,i}$ is a Leontief aggregate and the input coefficients, $insm_{pr,i}$ are defined as shares of total use of materials M_i in equation (38). The intermediate demand for aggregate transports TP_i is also a Leontief aggregate and the transport coefficients $tpinsm_{pr,i}$ are defined as shares of transports in total use of materials, in equation (39).

$$IO_{pr,i} = insm_{pr,i} \cdot M_i, \qquad \text{for all } pr \neq 4,6,15,17,19 - 21,\ 24 - 30. \tag{38}$$

$$TP_i = \sum_{pr=24}^{30} tpinsm_{pr,i} \cdot M_i \tag{39}$$

Differentiation of the minimum cost per unit of material-energy composite ME_i, with the price PME_i, gives sectoral demand for materials M_i, with the price PM_i, and sectoral demand of energy E_i with price PE_i:

$$M_i = bm_i^{sme_i - 1} \cdot \left(\frac{PME_i}{PM_i} \right)^{sme_i} \cdot ME_i. \quad i = 1,...,26. \tag{40}$$

$$E_i = be_i^{sme_i - 1} \cdot \left(\frac{PME_i}{PE_i} \right)^{sme_i} \cdot ME_i. \quad i = 1,...,26\,. \tag{41}$$

Where sme_i is the substitution elasticity, and bm_i and be_i are calibration constants.

The highest CES-aggregation level combines the energy-materials composite and the value added to output of commodities Q_i with prices PQ_i. Factor demand of the energy-materials composite ME_i is obtained by differentiation of the unit cost function of output:

$$ME_i = ame_i^{sz_i - 1} \cdot \left(\frac{\sum_{pr} PQ_{pr} \cdot OUT_{i,pr}}{PME_i} \right)^{sz_i} \cdot Z_i \qquad .i = 1,...,26. \tag{42}$$

Where sz_i is the substitution elasticity, ame_i is a calibration constant, $OUT_{i,pr}$ is the share of good *j* produced in sector *i* and Z_i is the activity in sector *i*.

Demand for labour and capital

All sectors, including public services, use skilled labour, unskilled labour and capital in a two-level CES aggregation function[11]. At the lowest level of aggregation, skilled and unskilled labour is aggregated to composite labour, which in turn is aggregated with capital to value added at the top level.

Differentiation of the minimum cost per unit of composite labour AT_i, with wages WT_i, gives sectoral demand for skilled labour ATS_i and unskilled labour ATU_i, with the corresponding wages WTS and WTU :

$$ATS_i = als_i^{sat_i - 1} \cdot \left[\frac{WT_i}{WTS \cdot wsk_i} \right]^{sat_i} \cdot AT_i. \qquad i = 1,...,26 \tag{43}$$

$$ATU_i = alu_i^{sat_i - 1} \cdot \left[\frac{WT_i}{WTU \cdot wuk_i} \right]^{sat_i} \cdot AT_i. \qquad i = 1,...,26. \tag{44}$$

Where sat_i is the substitution elasticity, als_i and alu_i, are calibration constants, wuk_i and wsk_i are parameters explaining the wage differences between sectors.

Differentiation of the minimum cost per unit of value added FV_i, with price PFV_i, gives sectoral demand for labour AT_i and capital C_i, with prices PC_i and WT_i, respectively.

$$AT_i = al_i^{sfv_i - 1} \cdot \left(\frac{PFV_i}{(1 + tw) \cdot WT_i} \right)^{sfv_i} \cdot FV_i. \qquad i = 1,...,26. \tag{45}$$

$$C_i = ac_i^{sfv_i - 1} \cdot \left(\frac{PFV_i}{(1 + tc) \cdot PC_i} \right)^{sfv_i} \cdot FV_i. \qquad i = 1,...,26. \tag{46}$$

Where sfv_i is the elasticity of substitution, al_i and ac_i, are calibration constants and tw and tc are taxes on labour and capital, respectively.

[11] The different kinds of labour are defined in Appendix A.

At the top level of CES-aggregation, the energy-materials composite and value added are combined to gross output. Factor demand of value added is obtained by differentiating the unit cost function of output:

$$FV_i = afv_i^{sz_i-1} \cdot \left(\frac{\sum_{pr} PQ_j \cdot OUT_{i,pr}}{PFV_i} \right)^{sz_i} \cdot Z_i. \qquad i = 1,...,26. \tag{47}$$

4.3 Total domestic demand and output

Domestic demand in basic values

All components of demand are measured at constant prices in basic values. Total domestic demand in basic values, DZ_i, for each commodity, except for commodity 32 (Services incl. trade), is:

$$DZ_{pr} = \sum_i IO_{pr,i} + PK_{pr} + inv_{pr} \cdot INVS + la_{pr} \cdot LA, \quad pr = 1,...,31,33. \tag{48}$$

To obtain total domestic demand for, *pr*=32, we must add also the trade margins to equation (48), where the term $\sum_i IO_{pr,i}$ is intermediate use, PK_{pr} is private consumption, $inv_{pr} \cdot INVS$ is investment, and $la_{pr} \cdot LA$ is the change of stocks.

Domestic demand of output and imports

Domestic consumers, including firms and producers of public services, are assumed to treat domestic goods as imperfect substitutes for imported goods classified in the same category. A CES-function, describes this trade-off between demand of produced goods QH_{pr}, and imported goods, IMP_{pr}, in creation of the composite good, DZ_{pr} supplied at the domestic market. For the public sector DZ_{Gov} is public consumption and equals QH_{Gov}.

$$DZ_{pr} = \left[\left(aqi_{pr} \cdot QH_{pr} \right)^{(sdz_{pr}-1)/sdz_{pr}} + \left(am_{pr} \cdot IMP_{pr} \right)^{(sdz_{pr}-1)/sdz_{pr}} \right]^{sdz_{pr}/(sdz_{pr}-1)} \qquad pr = 1,...,33. \tag{49}$$

Where sdz_{pr} is the substitution elasticity, and am_{pr} and aqi_{pr} are calibration constants.

The CES-function in (49), together with the constraint of no profits in creation of the composite good, gives demand for imports, IMP_{pr}, at prices $PIMP_{pr}$ and PDZ_{pr}.

$$IMP_{pr} = am_{pr}^{sdz_{pr}-1} \cdot \left(\frac{PDZ_{pr}}{PIMP_{pr}} \right)^{sdz_{prr}} \cdot DZ_{pr} \; . \qquad pr = 1,...,33. \tag{50}$$

Where sdz_{pr} is the substitution elasticity and am_{pr} is a calibration constant.

Supply of output for domestic use and for export

The firm decides on the optimal mix of output for the domestic market, QH_{pr}, sold at domestic prices, PQH_{pr}, and output for the export market, EXP_{pr}, sold at world market prices PW_{pr}. The trade off between domestic supply and export of produced goods, Q_{pr}, is described by a CET-function.

$$Q_{pr} = \left[\left(aq_{pr} \cdot QH_{pr} \right)^{(se_{pr}-1)/se_{pr}} + \left(ae_{pr} \cdot EXP_{pr} \right)^{(se_{pr}-1)/se_{pr}} \right]^{se_{pr}/(se_{pr}-1)} \qquad pr = 1,...,33 \tag{51}$$

The export supply function is:

$$EXP_{pr} = ae_{pr}^{se_{pr}-1} \cdot WM_{pr} \cdot \left[\frac{PQ_{pr}}{PW_{pr}} \right]^{se_{pr}} \cdot Q_{pr} \qquad pr = 1,...,33. \tag{52}$$

Where se_{pr} is a substitution elasticity, WM_{pr} is an index of export market size and the calibration constants are ae_{pr} and aq_{pr}.

Output of the public sector Q_{Gov} is set equal to the exogenously given public consumption *OKL* or equally DZ_{Gov}.

4.4 Emissions of pollutants

Carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x), nitrous oxide (N_2O), carbon monoxide (CO), methane (CH_4) and particulate matter (PM10, PM25) are emitted by production in the use of materials and fuel inputs and by households in the consumption of fuels.

The model evaluates the emissions as a function of the energy use and the material input for industries and the energy use for households. Total emissions of CO_2, SO_2, NO_x, N_2O, CO, PM10, PM25 and CH_4 in the use of energy and materials in production are given by:

$$EM_{po} = \sum_{pr} \sum_{i} emcoef_{pr,po,i} \cdot IO_{pr,i} + \sum_{i} emcoefm_{po,i} \cdot M_i \tag{53}$$

Where $emcoef_{e,po,i}$ are emission coefficients in the use of energy carriers, pr = 4, 6, 15, 16, 18, 19 and 20, and $emcoefm_{po,i}$ are emission coefficients in the use of mate-

rials M_i for emissions *po* = CO_2, SO_2, NO_x, N2O, CO, PM10, PM25 and CH4 in sector *i*.

Total emissions in the use of energy by households are given by:

$$EMH_{po} = \sum_{h}\sum_{fn} emhcoef_{fn,po} \cdot HC_{h,fn} \qquad \textbf{(54)}$$

Where $emhcoef_{en,po}$ are the coefficients for emission of CO_2, SO_2, NO_x, N_2O, CO, PM10, PM25 and CH_4 in private consumption of the energy commodities (household goods *fn*=17, 18, 19, 20, 21, 22, 23, 24).

4.5 Price setting

We assume constant returns to scale and mobile factor inputs between sectors. Domestic supply is then completely elastic for each good. Prices of goods are determined only by factor prices given by equilibrium in factor markets. The supply of imports is also completely elastic, and the prices of imports and exports are exogenous world market prices.

WTS and WTU are equilibrium wages on the two labour markets. The two types of labour are assumed perfectly mobile between sectors. The wage levels actually observed for each category of labour, however, differ among sectors. These initial distributions of wages, wsk and wuk, are kept unchanged in simulations. For each sector, the wage cost per hour of aggregated labour WT_i is given by:

$$WT_i \cdot AT_i = WTS \cdot wsk_i \cdot ATS_i + WTU \cdot wuk_i \cdot ATU_i \qquad i = 1,...,26 \qquad \textbf{(55)}$$

The price of capital PC_i is defined as the cost of using one unit of real capital:

$$PC_i = [r_i \cdot R + dep_i] \cdot PINV, \qquad i = 1,...,26. \qquad \textbf{(56)}$$

Where R is the average level of the real rate of return before taxes. The distribution of return to capital among sectors, r_i, as well as the distributions of wages are exogenous and can be observed for the calibration year .[12]

CES-aggregation of composite labour and capital to value added together with the assumption of perfect competition give the value added price PFV_i in terms of the factor prices WT_i and PC_i at optimal factor allocation with the factor taxes tw and tc:

$$PFV_i \cdot FV_i = (1+tw) \cdot WT_i \cdot AT_i + (1+tc) \cdot PC \cdot C_i \qquad i = 1,...,26 \qquad \textbf{(57)}$$

[12]This formulation of the model could be questioned as well as the corresponding assumption about wage differentials for homogenous labour. There may be several explanations for the observed sectoral differences in real rates of return and the most obvious is that no adjustment has been made for taxes. Another explanation is differences in risk. It is also important that the calibration year is unlikely to exhibit a long run equilibrium position for all sectors. For labour one might also add that under the two categories of labour there is a structure of skill that may differ between sectors.

PDZ_{pr} is the price of the composite good DZ_{pr} on domestic markets when it leaves the combined plant-import harbour, and it is calculated from the import price $PIMP_{pr}$ and the price of domestic commodities in basic values PQH_{pr}. Trade margins and commodity taxes are added to this price before the good reaches the ultimate consumer. It is assumed that trade margins are added in equal proportion to all uses of the composite good except for exports. This is obviously a major simplification.[13] Firstly, some of the trade margins are levied on exports, which can be seen from IO-data. Also, trade margins are much larger for private consumption (retail plus wholesale) than for intermediate goods (wholesale only). A more detailed account of trade margins will, however, greatly complicate the equations of the model.

$$PDZ_{pr} \cdot DZ_{pr} = PIMP_{pr} \cdot IMP_{pr} + PQH_{pr} \cdot QH_{pr} \qquad pr = 1,...33. \qquad \textbf{(58)}$$

It is assumed that the price of trade margins follows the domestic price of the commodity 32 Services, PDZ_{32}, rather than the price of the commodity itself. This seems a reasonable assumption in the medium and long run. Domestic prices PD_{pr} including trade margins are:

$$PD_{pr} = \left(PDZ_{pr} + hm_{pr} \cdot PDZ_{32}\right)/\left(1 + hmk_{pr}\right), \quad pr = 1,...,33. \qquad \textbf{(59)}$$

Trade margins can be changed exogenously by the parameter hm_{pr}. The parameter values of hmk_{pr} are calibration constants.

Commodity taxes levied on the inputs of production include VAT, other indirect commodity taxes and subsidies, energy tax, carbon tax, sulphur tax and a kilometre tax for large truck transports. The tax on energy, environmental taxes and the kilometre tax are based on quantities, while the net of VAT, other indirect commodity taxes and subsidies are ad valorem.

The prices of energy and material inputs in production including taxes are given by:

$$PDS_{pr,i} = PD_{pr} \cdot \left(1 + itp_{pr}\right) + itpe_{i.pr} + itpSO2_{i,pr} + itpCO2_{i,pr} + itpKM_{i,pr} \qquad \textbf{(60)}$$

for $i = 1,...,25 \quad and \quad pr = 1,....33$,

Where itp_{pr} is the ad volorem net tax on inputs of good *pr* and $itpe_{i,pr}$, $itpSO2_{i,pr}$, $itpCO2_{i,pr}$ and $itpKM_{i,pr}$ are energy tax, sulphur tax, carbon tax or permit price and kilometre tax for large truck transports, respectively, on good *pr* in sector *i*. The energy tax and the environmental taxes are specific to various industries so as to allow for tax exemptions. Permit trading is analysed with $itpCO2_{i,pr}$ equal to the permit price for trading sectors.

The variable $PDS_{pr,i}$ are equilibrium prices, including taxes, on the goods markets for all commodities and must be aggregated to have the prices PE_i, PFU_i,

[13] Trade margins may make up for a substantial part of the ultimate price for some goods.

PLF_i and $PSFU_i$ of the corresponding energy aggregates *E* (total energy), *FU* (fuels), *LF* (liquid fuels) and *SFU* (solid fuels). The CES-aggregation of PE_i is:

$$PE_i = \left[\left(\frac{PFU_i}{bf_i} \right)^{1-see_i} + \left(\frac{PDS_{el,i}}{be2_i} \right)^{1-see_i} + \left(\frac{PDS_{hot,i}}{be6_i} \right)^{1-see_i} \right]^{\frac{1}{1-see_i}} \qquad i = 1,...,26 \qquad \textbf{(61)}$$

Where the CES-aggregation of the price of fuels PFU_i is

$$PFU_i = \left[\left(\frac{PLF_i}{blf_i} \right)^{1-sf_i} + \left(\frac{PSFU_i}{bsf_i} \right)^{1-sf_i} \right]^{\frac{1}{1-sf_i}} \qquad i = 1,...,26 \qquad \textbf{(62)}$$

and the CES-aggregation of the prices of liquid fuels PLF_i and solid fuels, $PSFU_i$ are:

$$PLF_i = \left[\left(\frac{PDS_{oil,i}}{be1_i} \right)^{1-slf_i} + \left(\frac{PDS_{gas,i}}{be3_i} \right)^{1-slf_i} \right]^{\frac{1}{1-slf_i}} \qquad i = 1,...,26 \qquad \textbf{(63)}$$

$$PSFU_i = \left[\left(\frac{PDS_{coal,i}}{be4_i} \right)^{1-ssf_i} + \left(\frac{PDS_{bio,i}}{be5_i} \right)^{1-ssf_i} \right]^{\frac{1}{1-ssf_i}} \qquad i = 1,...,26 \qquad \textbf{(64)}$$

Also, the prices *PFRGT* and *PTP* of heavy freight transport (*FRGT*) and aggregate transports) (*TP*), respectively, are derived by aggregating the prices $PDS_{pr,i}$.

$$PTP_i = \left[\sum_{trp} \left(\frac{PDS_{trp,i}}{btp_{trp,i}} \right)^{1-stp_i} + \left(\frac{PFRGT_i}{bfrgt_i} \right)^{1-stp_i} \right]^{1/1-stp_i} \qquad \begin{array}{l} i=1,...,26 \\ trp=passtp,airtp,llb \end{array} \qquad \textbf{(65)}$$

Where the price of heavy freight transport $PFRGT_i$ is:

$$PFRGT_i = \left[\sum_{grt} \left(\frac{PDS_{grt,i}}{btp_{gtr,i}} \right)^{1-sfrgt_i} \right]^{1/1-sfrgt_i} \qquad \begin{array}{l} i=1,...,26 \\ gtr=train,sea,\ mlb,slb \end{array} \qquad \textbf{(66)}$$

The price of materials is given by the following Leontief aggregation:

$$PM_i = \sum_{pr \neq 4,6,15,17,19-21,24-31} PDS_{pr,i} \cdot insm_{pr,i} \cdot \qquad i = 1,...,26$$

The CES-aggregation of composite energy and materials to an energy-material aggregate, together with the assumption of perfect competition yield the energy-material

price PME_i in terms of the prices PM_i and PE_i at optimal allocation of energy carriers.

$$PME_i = \left[\left(\frac{PM_i}{bm_i} \right)^{1-sme_i} + \left(\frac{PE_i}{be_i} \right)^{1-sme_i} \right]^{\frac{1}{1-sme_i}} \qquad i = 1,...,26. \tag{67}$$

Commodity prices PQ_j are computed from the relation of no profits in production, i.e. total revenue equals total costs for all firms at activity Z_i:

$$\sum_j PQ_j \cdot OUT_{ij} \cdot Z_i = PFV_i \cdot FV_i + PME_i \cdot ME_i \qquad i = 1,...,26. \tag{68}$$

The tax base for VAT is assumed to consist of mainly private consumption, although other components of demand can be taxed. Private consumption is also subject to energy tax, $itce_{fn}$, carbon tax, $itcCO2_{fn}$, sulphur tax, $itcSO2_{fn}$ and other indirect taxes and subsidies, $itci_{fn}$. Prices of consumer categories, including indirect commodity taxes, $PHCS_{h,fn}$, are given by:

$$PHCS_{h,fn} = \left(1 + itcmoms_{fn} + itci_{fn}\right) \cdot PHC_{h,fn} + itce_{fn} + itcSO2_{fn} + itcCO2_{fn} + itcNOx_{fn} \qquad i = 1,...,26 \tag{69}$$

Where:

$$PHC_{h,fn} = \sum_{pr} PD_{pr} \cdot CONS_{h,pr,fn}, \qquad i = 1,...,26 \tag{70}$$

For the aggregate consumption, excluding work trips, of a household, PKL_h the price, PPK_h, is given by:

$$PPK_h = \left[\left(\frac{POVR_h}{ak3_h} \right)^{1-spk_h} + \left(\frac{PHOUSE_h}{ak1_h} \right)^{1-spk_h} + \left(\frac{PFRITRANS_h}{ak2_h} \right)^{1-spk_h} \right]^{1/1-spk_h} \tag{71}$$

Where the prices $POVR_h$, $PHOUSE_h$ and $PFRITRANS_h$ also are CES-aggregates as shown in appendix B.

For the aggregate of a household's work trips, $WORK_h$, the price, $PWORK_h$, is given by:

$$PWORK_h = \left[\sum_{trw} \left(\frac{PHCS_{trw,h}}{atrw_{trw,h}} \right)^{1-swork_h} \right]^{1/1-swork_h} \quad (72)$$

The price of labour (the unit net labour income) for a household, PL_h, is given by:

$$PL_h = sskshr_h \cdot WTS + unsskshr_h \cdot WTU \quad (73)$$

Investments in all sectors are assumed to consist of composite good aggregated with the shares inv_{pr} making the aggregate price $PINV$ of the common investment good equal to:

$$PINV = \sum_{pr=1}^{32} inv_{pr} \cdot PD_{pr} \quad (74)$$

Finally the price of investments in stocks is:

$$PLA = \sum_{pr=1}^{32} la_{pr} \cdot PD_{pr} \quad (75)$$

4.6 Market clearing, closure rules, numeraire and emission constraints

Factor supply is either exogenous, making factor prices endogenous, or completely elastic with exogenous factor prices. The latter alternative may seem more relevant for capital and is chosen for the current version of *EMEC*. Some interesting results could be obtained by applying this approach also to skilled labour, remembering that the time perspective may be long enough to treat the economy as open, not only in goods- and capital-markets, but also in segments of the labour market. Nevertheless, the current version of the model is run with exogenous labour supply.

The equilibrium conditions simply state that demand equals supply of production factors *LSK*, *LUNSK* and *CS*:

$$\sum_h LSK_h = \sum_{i=1}^{26} ATS_i. \quad (76)$$

$$\sum_h LUNSK_h = \sum_{i=1}^{26} ATU_i \quad (77)$$

$$CS = \sum_{i=1}^{26} C_i \quad (78)$$

The model must include a relation for the current account to link the income and expenditure sides of the economy and to determine overall savings. To be more specific, consumer expenditures in $UTOT_h$ must be determined. This can be accomplished by letting either household savings or the current account (trade balance) or the gross-savings ratio to be exogenous. In the last case, disposable incomes must be computed to determine consumption expenditures consistent with the exogenous household savings. In the present version of EMEC, we maximize the level of private consumption expenditures, consistent with the exogenous current account ratio. Finally, the exchange rate is the numeraire and the foreign price level is set exogenously.

We can also run the model with restrictions on the emission levels, $EBAR_{po}$:

$$EMTOTAL_{po} \leq EBAR_{po}, \qquad po = CO_2, SO_2, NO_x, N_2O, PM10, PM25, CO, CH_4. \qquad \textbf{(79)}$$

5 Calibration and Parameter Values

Most CGE-models are calibrated for a specific year using an elaborated database. Prices of the calibration year are chosen as the base for price indices. The conventional choice of base year is the latest year for which a set of complete National Accounts exists. The calibration procedure runs along standard lines. We assume static equilibrium with perfect competition and solve for unknown constants of the utility function and the production functions. The model solution of the calibration year reproduces observed prices and quantities. Substitution elasticities in the CES- and CET-aggregators must be specified before calibration. The figures given in Table 1 are used in the present version of the model.

The art of finding elasticity values for all the CES functions of a large CGE model like EMEC seldom includes an econometric estimation of the models equations due to the large amount of data needed and the huge effort of estimating all of the equations. The procedure adopted is instead that of picking the elasticity values by surveying econometric studies concentrating on the estimation of a few of all the relations captured by a CGE model. The elasticity values of substitution are generally "guesstimated" as concluded by Bergman (2005). The elasticity values collected from such partial studies might not interact very well within a general equilibrium framework, so there must always be some kind of judgement approach considering the accuracy of model results, when setting the elasticity values of a CGE model.

The elasticity values of substitution for foreign-domestic goods, energy-material input, input of various energy carriers and input of transport modes was collected by surveying a number of studies, van Leeuwen et. al.(1995), Bovenberg, and Gouldner (1996), Kemfert and Welsch (1997), Kremers et.al. (2002), Steininger (2002), Litman (2005), Koschel, H., (2000), but also a significant influence of judgement determines these elasticity values. The elasticity values of the consumption function are taken from Nilsson (2004), se Table 2.

Estimates of the export/domestic transformation elasticity are rare but Dixon et-al. (1992) has suggested a method of calculating these values from input-output data of the base period. The value of the transformation elasticity is calculated as the industry's share of total revenue accounted for by exports. The method of Dixon et-al. (1992) was applied to the input-output data of 2002 to calculate values of the transformation elasticity, **se**, shown in table 3.

Table 1 Substitution elasticities in production sectors

Production sector	sat	Sfv	Sz	sme	see	sf	slf	ssf	stp	sfrgt
1. Agriculture	1,1	0,5	0,3	0,5	0,6	0,7	0,8	0,9	0,1	0,2
2. Fishery	1,1	0,3	0,2	0,3	0,4	0,7	0,7	0,9	0,1	0,2
3. Forestry	1,1	0,5	0,3	0,4	0,5	0,7	0,8	0,9	0,1	0,2
4. Mining	1,1	0,8	0,3	0,4	0,5	0,6	0,8	0,9	0,1	0,2
5. Other industries	1,1	0,8	0,3	0,4	0,6	1,2	1,3	1,4	0,1	0,2
6. Mineral products	1,1	0,8	0,7	0,9	0,6	1,2	1,3	1,4	0,1	0,5
7. Pulp and paper mills	1,1	0,8	0,7	0,9	1,1	1,2	1,3	1,4	0,1	0,3
8. Drug industries	1,1	0,8	0,3	0,4	0,6	1,2	1,3	1,3	0,1	0,2
9. Chemical industries	1,1	0,8	0,7	0,8	0,9	1,2	1,3	1,3	0,1	0,3
10. Iron & Steel industries	1,1	0,8	0,4	0,5	0,6	1,2	1,3	1,3	0,1	0,5
11. Non-iron metal ind.	1,1	0,8	0,3	0,4	0,5	0,7	0,9	0,9	0,1	0,5
12. Engineering	1,1	0,8	0,6	0,7	0,8	1,2	1,3	1,3	0,1	0,4
13. Petroleum refineries	1,1	0,2	0,1	0,3	0,4	0,8	0,9	0,9	0,1	0,2
14. Electricity supply	1,1	0,3	0,1	0,1	0,3	1,1	1,5	1,5	0,1	0,2
15. Hot water supply	1,1	0,3	0,1	0,1	0,3	1,1	1,5	1,5	0,1	0,2
16. Gas distribution	1,1	0,3	0,1	0,1	0,2	0,2	0,2	0,2	0,1	0,2
17. Water and sewage	1,1	0,3	0,2	0,3	0,4	0,7	0,7	0,7	0,1	0,2
18. Construction	1,1	0,3	0,2	0,3	0,7	0,8	0,9	0,9	0,1	0,2
19. Rail road transports	1,1	0,2	0,2	0,3	0,3	0,2	0,2	0,2	0,1	0,2
20 Road goods transports	1,1	0,2	0,2	0,3	0,3	0,2	0,2	0,2	0,1	0,2
21. Road passenger transports	1,1	0,2	0,2	0,3	0,3	0,2	0,2	0,2	0,1	0,2
22. Sea transports	1,1	0,2	0,2	0,2	0,2	0,3	0,3	0,3	0,1	0,2
23. Air transports	1,1	0,2	0,2	0,3	0,3	0,2	0,2	0,2	0,1	0,2
24. Other transports	1,1	0,8	0,6	0,7	0,8	0,8	0,8	0,8	0,1	0,2
25. Services	1,1	0,8	0,7	0,9	1,1	1,2	1,3	1,4	0,1	0,2
26. Real estate	1,1	0,6	0,5	0,8	1,2	1,2	1,5	1,6	0,1	0,2
27. Public services	1,1	0,7	0,1	0,7	1,1	1,2	1,3	1,4	0,1	0,2

Table 2 Substitution elasticities in consumption

Label of parameter in the consumption function	Elasticity value
swork	0.5
spkl	0.5
sfritrans	0.9
sshort	0.8
sholi	0.7
sfuel	0.5
sheat	0.6
shouse	0.3
sovr	0.9

Table 3 Elasticities of commodities in foreign trade

Commodity	sdz	se
1. Agricultural products	0.4	-1.1
2. Fish	1.4	-6.0
3. Timber	0.4	-1.0
4. Bio fuels	0.4	-1.0
5. Metal ores and stone	0.6	-1.4
6. Coal	0.3	0.0
7. Products n.e.c.	0.7	-1.5
8. Mineral products	0.7	-1.5
9. Pulp and paper	1.1	-1.9
10. Pharmacy products	1.8	-6.3
11. Other chemical products	1.6	-3.0
12. Iron and steel	1.1	-3.0
13. Other metals	1.1	-2.5
14. Engineering products	0.7	-2.7
15. Fuels	1.1	-2.1
16. Motor fuels	1.3	-2.4
17. Other petroleum products	1.3	-2.6
18 Crude petroleum	0.2	-1.0
19. Electricity	0.5	-1.0
20. Steam and hot water	0.5	-1.0
21. Gas	0.5	-1.0
22. Fresh water	0.1	-1.0
23. Building	0.3	-1.0
24. Rail transports	0.5	-1.1
25. Passenger transports	0.5	-1.0
26. Small Truck transports	0.5	-1.0
27. Middle Truck transports	0.5	-1.0
28. Large Truck transports	0.6	-1.3
29. Sea transports	1.1	-4.0
30. Air transports	0.7	-1.5
31. Other transports	0.5	-1.1
32. Business and private services	0.6	-1.2
33. Dwellings	0.3	-1.0

6 Conclusions: future developments

The present paper presents a new version of the Swedish computable general equilibrium model EMEC, which has been developed at the National Institute of Economic Research for analysis of the economy's environmental interactions in a medium term perspective. The model produces results for endogenous variables at a disaggregated level and consistent with economic theory, data and the assumptions underlying the exogenous variables.

This new version of EMEC has a detailed description of transport demand for the industry sector as well as for the household sector. Also, firms and households may substitute a relative dearer transport mode for other transport modes. The new version of the model, thus, is better suited for analysing the impact of road user charges, actually discussed in Sweden, as well as other price inducing policy measures affecting transport services.

Policy measures aimed at reducing polluting emissions might have welfare effects, which differ among regions and among income groups. Also, a policy measure might affect emission levels somewhat different for various regions and income groups due to different patterns of consumption and personal transportation. Such distributional aspects of e.g. climate policy can now be assessed as households are subdivided into two income groups and three regional groups in the new version of EMEC.

The new version has a more detailed representation of the production sectors trading with emission permits within the EU trading system of CO_2 emissions. Also, electricity supply and hot water supply is separated into different subsectors of industry.

All these improvements and extensions of the model structure result in 26 subsectors of industry, 6 household groups, 33 commodities, 26 consumption goods, 18 production factors, which are substitutes, 6 energy carriers and 8 modes of transportation and 8 emissions to the air. The EMEC model is an ongoing project at the National Institute of Economic Research and future development includes the modelling of an endogenous labour supply.

Appendix A: Definitions and Variables

A.1 Definitions and data sources

Sector and commodity classifications

EMEC distinguishes 27 producing sectors - 26 business sectors and a public sector- and 33 produced and/or imported commodities. Table A1 gives the definitions of sectors and Table A2 presents the definitions of commodities in the database. All variables related to production are taken from the System of National Accounts (SNA) but the commodities bio fuels, coal and crude petroleum are not disaggregated in the SNA, but by the authors. The transports by various types of trucks (Commodities 25, 26 and 27) are not distinguished in the SNA, but by the authors in using the "Körsträckedatabas" for 2002. The supply table, the use table, capital stocks and investments by sector are from 2002. All the SNA data were aggregated by the authors to fit the model's definitions of variables.

Classification of private consumption

EMEC distinguishes 26 commodities in private consumption and Table A3 gives the exact definitions of the commodities. All variables related to consumption are taken from the SNA, but the RES database is used by the authors to subdivide transport modes by purposes. The RES database is from 2001.

Households are subdivided into six household groups by disposal income level and by residence according to the Household expenditure survey (HEK) of 1999-2001. The household groups are defined in Table A4.

Labour categories

The distributions of 9 different kinds of labour and their labour income across sectors are taken from the Household expenditure survey (HEK) 2003. The labour categories are defined according to the level of education. Skilled labour includes those with a post high school education and the remaining groups are classified as unskilled labour. Employment and income figures are adjusted to SNA levels by simple scaling.

Emission data

EMEC distinguishes 8 pollutants emitted by the combustion of 5 energy carriers in various production sectors and by households. Carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x), nitrous oxide (N_2O), carbon monoxide (CO), methane (CH_4) and particulate matter (PM10, PM25). Table A5 gives the definitions of energy carriers. All variables related to pollutants and energy carriers are taken from the System of Environmental Accounts (SEA). All the SEA data were aggregated by the authors to fit the model's definitions of variables.

Factor prices

Wages are defined as labour cost per hour. Wages for aggregate labour are taken from SNA. Capital cost, PC, is defined per unit of physical capital valued at 2002 prices

and is computed from SNA as gross operating surplus OS divided by the capital stock C:

$$PC = \frac{OS}{C}, \text{ where } OS = PFV \cdot FV - WT \cdot AT$$

$PFV \cdot FV$ is value added in current prices and $WT \cdot AT$ is the cost of labour.

Dividing PC by the price of investment goods, PI, and subtracting the depreciation rate, δ, yields the net real rate of return on physical capital (before taxes):

$$R = \frac{PC}{PI} - \delta$$

Here, R is the variable used in equilibrating the market for fixed capital in the model. From the definitions above the operating surplus can be expressed as:

$$OS = PFV \cdot FV - WT \cdot AT = PC \cdot C = (R + \delta) \cdot PI \cdot C$$

Table A1 Definitions of private production sectors

Production sector in EMEC	NACE Rev.1*	Sector label in the Swedish National Accounts
1. Agriculture	01	Agriculture and hunting
2. Fishery	05	Fishing
3. Forestry	02	Forestry and logging
4. Mining	13	Metal ore mining
	14	Other mining and quarrying
5. Other industries	15,16	Manufacture of food, beverage and tobacco
	17-19	Textile industries
	20	Manufacture of wood and wood products
6. Mineral products	26	Manufacture of non-metallic mineral products
7. Pulp and paper mills	21	Manufacture of pulp, paper and paper products
	22	Printing and publishing
8. Drug industries	244	Manufacture of pharmaceuticals products
	245	Manufacture of soap and detergents
9. Other chemical industries	24 excl 244,245	Manufacture of chemicals and chemical products
	25	Manufacture of rubber and plastic products
10. Iron & steel industries	271-273	Iron steel basic industries
11. Non-iron metal industries	274-275	Non-ferrous metal basic industries
12. Engineering	28	Manufacture of metal products
	29	Manufacture of mechanical machinery
	30,31	Manufacture of electrical machinery and computers
	32	Manufacture of communication equipment
	33	Manufacture of measuring equipment, etc.
	34,35	Manufacture of transport equipment
	36,37	Other manufacturing industries
13. Petroleum refineries	23	Petroleum refining
14. Electricity supply	401	Electricity
15. Hot water supply	403	Steam and hot water supply
16. Gas distribution	402	Gas manufacture and distribution
17. Water and sewage	41	Water supply and sewage disposal
18. Construction	45	Construction
19. Rail road transports	601	Railway road transports
20 Road goods transports	6024	Road goods transports
21. Road passenger transports	6021-6023	Road passenger transports
22. Sea transports	61	Water transports
23. Air transports	62	Air transports
24. Other transports	63	Other transport activities
	64	Communications
25. Services	50-52	Wholesale and retail trade
	55	Restaurants and hotels
	65	Financial institutions
	66	Insurance
	71-74	Business services
	75,80-85,90-95	Other private services
26. Real estate	70	Letting of dwellings and other real estate

*Nomenclature Général des Activités Economiques dans les Communautés Européennes. The statistical classification of economic activities in the European Community amended in March 1993.

Table A2 Definition of commodities

Commodity in EMEC	CPA code*	Commodity label in the Swedish National Accounts
1. Agricultural products	01	Products of agriculture and hunting
2. Fish	05	Fish and fishing products
3. Timber	02	Products of forestry and logging
4. Bio fuels	02 pt	Wastes from logging
5. Metal ores	13	Metal ores
	14	Other mining and quarrying products
6. Coal	10	Coal
7. Products n.e.c.	15,16	Food products, beverages and tobacco products
	17-19	Textiles and textile products
	20	Wood and wood products
8. Mineral products	26	Non-metallic mineral products
9. Pulp and paper	21	Pulp,paper and paper products
	22	Printed matter
10. Pharmacy products	244	Pharmaceuticals and medical chemicals
	245	Soap,detergents and cosmetics
11 Other chemical products	24 excl 244,245	Chemicals and chemical products
	25	Rubber and plastic products
12. Iron and steel	271-273	Basic iron and steel , tubes and wires
13. Other metals	274,275	Basic non-ferrous metals
14. Engineering products	28	Metal products
	29	Mechanical machines
	30,31	Electric machines and computers
	32	Communication equipment
	33	Measuring equipment
	34,35	Transport equipment
	36,37	Other manufactured products
15. Fuels	23200 pt	Heating oils
16. Motor fuels	23200 pt	Motor gasoline,diesel and jet fuels
17. Other petroleum products	23200 pt	Other refined petroleum products
18. Crude petroleum	11	Crude petroleum
19. Electricity	401	Electricity
20. Steam and hot water	403	Steam and hot water
21. Gas	402	Manufactured and distributed gas
22. Fresh water	41	Collected, purified and distributed water
23. Buildings	45	Construction works
24. Rail transports	601	Rail transports
25. Passenger transports	6021 pt,6023	Passenger transports by bus
	6022	Passenger transports by taxi
26. Large truck transports	6024 pt	Goods transports by trucks > 32 tons
27. Medium truck transports	6024 pt	Goods transports by trucks 3.5 - 32 tons
28. Small truck transports	6024 pt	Goods transports by trucks < 3.5 tons
29. Sea transports	61	Sea transports
30. Air transports	620	Air transports
31. Other transports	63	Other transport products
	64	Communication products
32. Services	50-52	Wholesale and retail trade products
	55	Restaurant and hotel services
	65	Financial services
	66	Insurance services
	71-74	Business services
	75,80-85,90-95	Other private services
33. Dwellings	70	Real estate services

* EU Classification of products by Activity (CPA).

Table A3 Definition of commodities in private consumption

Commodity in EMEC	COICOP code*	Consumption label in the Swedish National Accounts
1. Foods and beverages	1,2	Food, beverages and tobacco
2. Clothing and footwear	3	Clothing and footwear
3. Furniture etc	51	Furniture, carpets and repairs
	52	Household textiles and other furnishings
4. Household goods	531,532	Major household appliances
	54,55	Glassware, tableware and household utensils
	533	Household services
5. Gross rents	41,42	Gross rents and water charges
6. Recreation	9424	Photographic equipment
	9421-3,9425-7	Entertainment and photo services
	941,943	Gambling, lotteries etc.
	951-3	Books, newspapers and magazines
	914,931,932,9341	Other recreational goods and services
7. Private transport	71,9211-3	Personal transport equipment
	721,7222	Repair charges, parts and accessories
	7241	Compulsory tests of cars
8. Road work trips	7321 pt, 735-6 pt	Bus and local traffic, Cabs, Removal
9. Road short leisure trips	7321 pt, 735-6 pt	Bus and local traffic, Cabs, Removal
10. Road long leisure trips	7321 pt, 735-6 pt	Bus and local traffic, Cabs, Removal
11. Rail work trips	7310 pt	Railway transports
12. Rail short leisure trips	7310 pt	Railway transports
13. Rail long leisure trips	7310 pt	Railway transports
14. Sea short leisure trips	734 pt	Sea transports
15. Sea long leisure trips	734 pt	Sea transports
16. Air long leisure trips	733 pt	Air transports
	960	Services of travel agencies and air charter
17. Services	432	Household services excl domestic services
	562	Domestic services
	723,7241,7243-5	Other expenditures on cars
	81	Communication
	911	Radio and television
	915,923	Repairs to recreational goods etc
	935	Veterinary services
	11,121	Services of barber and beauty shops etc
	125,126	Financial services
	941,124,101	Services n.e.c.
	15	Purchases abroad and foreign purchases
	62,63	Medical care and health expenses
18. Goods n.e.c.	912-3,921-2	Other recreational goods
	61,9342,1232	Goods for personal care
	431,561,551,933	Goods n.e.c.
	1212-3,954,12311	Goods n.e.c
19. Electricity	451	Electricity
20. Gas	452	Gas
21 Fuels	453	Heating oils
	454 pt	Other fuels
22. Gasoline work trips	7221 pt	Gasoline
23. Gasoline short leisure trips	7221 pt	Gasoline
24. Gasoline long leisure trips	7221 pt	Gasoline
25. Bio fuels	454 pt	Other fuels
26. Purchased heat	455	Purchased heat

* COICOP (Classification of Individual Consumption by Purpose), is an international classification of private consumption according to A System of National Accounts (SNA), United Nations, 1993

Table A4 Household groups

Household group	Household income	Region
Low income group in big city areas	0 - 240 000	H-region 1, 8, and 9: Stockholm, Gothenburg and Malmö
High income group in big city areas	240 000 - ∞	
Low income group in population centres	0-240 000	H-region 3: Municipalities with more than 90 000 inhabitants within a 30 km radius from the municipal centre and H-region 4: Municipalities with more than 27 000 and less than 90 000 inhabitants within a 30 km radius from the municipal centre and more than 300 000 inhabitants within a 100 km radius from the same point.
High income group in population centres	240 000 - ∞	
Low income group in sparsely populated areas	0-240 000	H-region 5: Municipalities with more than 27 000 and less than 90 000 inhabitants within a 30 km radius from the municipal centre and less than 300 000 inhabitants within a 100 km radius from the same point and H-region 6: Municipalities with less than 27 000 inhabitants within a 30 km radius from the municipal centre.
High income group in sparsely populated areas	240 000 - ∞	

Table A5 Definitions of energy carriers

Energy carrier	Label in the Swedish Environmental Accounts
Fuel oils	Domestic heating oil (EO1)
	Heavy fuel oils (EO2-5)
Gases	LPG
	Gas works gas
	Natural gas
	Coke oven gas
	Blast furnace gas
	LD-gas
Motor fuels	Motor gasoline
	Aviation gasoline
	Diesel oil
	Jet gasoline
	Jet kerosine
Coal	Coal
	Coke
Bio fuels	Wood-fuels
	Black liqour
	Tall oil
	Biogas
	Other biomass
Other fuels	Peat
	Wastes
	Other

A2. Variables and parameters

Index

i	Production sectors
pr	Industry goods
e	Energy goods
f	Fuel types
gtr	Heavy freight transport
h	Household groups
hel	Houshold electricity
hheat	Household district heating
fn	Household goods
ne	Non-energy goods (households)
rents	Housing services
trh	Households' transport modes
trl	Transport mode for long trips
trp	Passenger transport modes
trs	Transport mode for short trips
trw	Transport mode for work trips
fno	Household goods not including transport services, energy or rents
po	Polluting emissions

Variables

AT	Hours worked, aggregate labour
ATS	Hours worked for skilled labour
ATU	Hours worked for unskilled labour
B	Current account
C	Capital stock
CONS	Matrix of consumption goods
CS	Sum of capital stock
DZ	Domestic demand in basic values
E	Demand of energy in basic values
EBAR	Restrictions on total emissions of CO_2, SO_2 and NO_x
EM	Emissions of CO_2, SO_2 and NO_x by industries
EMH	Emissions of CO_2, SO_2 and NO_x by households
EMTOTAL	Total emissions of CO_2, SO_2 and NO_x
EXP	Exports
FRGT	Aggretagte of heavy freight transport
FRITRANS	Aggregate of leisure trips
FU	Demand of fuels in basic values
FUEL	Fuel aggregate
FV	Value added in basic values
HC	Categories of private consumption
HEAT	Household demand of heating
HOUSE	Aggregate good housing
IMP	Imports, cif
INSD	Intermediate use of good

INV	Total gross investment
INVS	Sum of investments
IO	Intermediate demand of goods and services
LA	Changes in stocks
LF	Demand of liquid fuels in basic values
LONG	Long leisure trips
LSK	Supply of skilled labour
LTOT	Labour supply for each household
LUNSK	Supply of unskilled labour
M	Demand of materials in basic values
ME	Demand of the material-energy composite
MET	Emissions of metals by industries
METH	Emissions of metals by households
*NH*3	Emissions of nitrohydrogen in agriculture
NINV	Net investment by investing sector
OUT	Make matrix for produced commodities
OVR	Aggregate other goods and services
PC	Price on capital
PD	Domestic market prices incl. trade margins.
PDS	Price of composite commodity including taxes
PDZ	Basic prices of goods on domestic markets
PE	Price of energy
PFRGT	Price of aggregated heavy freight transport
PFRITRANS	Price of aggregate leisure trips
PFU	Price of fuels
PFUEL	Price of aggregate fuel
PFV	Price of value added
PIMP	Import price
PHC	Prices of various categories in private consumption excl. taxes
PHCS	Price of various categories in private consumption incl. taxes
PHEAT	Price of aggregate heating
PHOUSE	Price of aggregate housing
PINV	Price of investments
PKL	Private consumption
PLA	Price of stocks
POVR	Price of aggregate other goods and services
PLONG	Price of aggregate long leisure trips
PLF	Price of liquid fuels
PM	Price of materials
PME	Price of the material-energy composite
PPK	Private consumption
PQ	Prices of produced goods
PQH	Domestic price of produced goods
PSFU	Price of solid fuels
PSHORT	Price of aggregate short leisure trips
PTP	Price of transports
PW	Export market price
PWORK	Price of aggregate work trips
Q	Produced goods

QG	Public consumption
QH	Domestic demand of produced goods
R	Real rate of return, average level
SFU	Demand of solid fuels in basic values
$SHORT$	Short leisure trips
T	Traded goods
TP	Transport demand
$TRANSFERS$	Total transfers
$UTOT$	Household disposable income
WM	Index for export market
$WORK$	Work trips
WT	Hourly wages for aggrgate labour
WTU	Hourly wages for unskilled labour
WTS	Hourly wages for skilled labor
WTT	Hourly wages for technicians
WTH	Hourly wages for non-technicians
PL	Hourly wages for each household net of tax
Z	Production activity

Parameters

ac	Capital parameter in production function.
ae	Parameter in export function
afv	Value added parameter in production function
$ak1, ak2, ak3$	Parameters in utility function
al	Labour parameter in production function
alu	Parameter for unskilled labour in aggregate labour
als	Parameter for skilled labour in aggregate labour
alt	Parameter for technicians in skilled labour
alh	Parameter for non-technicians in skilled labour
am	Parameter for imports in composite good
ame	Parameter for export of produced goods
aq	Parameter for domestic production in composite good
$atrw$	Parameter for transport modes in the utility of work trips
$atrs$	Parameter for transport modes in the utility of short leisure trips
$atrh$	Parameter for transport modes in the utility of long leisure trips
$along$	Parameter for long leisure trips in the utility of leisure trips
$ashort$	Parameter for short leisure trips in the utility of leisure trips
$afuel$	Parameter for various fuels in the utility of aggregate fuel
$aheat1$	Parameter for aggregate fuel in the utility of heating
$aheat2$	Parameter for electricity in the utility of heating
$aheat3$	Parameter for district heating in the utility of heating
$ahouse1$	Parameter for heat in the utility of housing
$ahouse2$	Parameter for housing services in the utility of housing
$aovr$	Parameter for various goods in the utility of other goods and services
$be1$	Parameter for oil in demand of liquid fuels
$be2$	Parameter for electricity in the demand of energy
$be3$	Parameter for gas in the demand of liquid fuels
$be4$	Parameter for wood in the demand of solid fuels
$be5$	Parameter for coal in the demand of solid fuels

blf	Parameter for liquid fuels in the demand of fuels
bsf	Parameter for solid fuels in the demand of fuels
bf	Parameter for fuels in the demand of energy
bfrgt	Parameter for freight
bm_i	Parameter for materials
btp	Parameter for transports
β	Share of work trips needed for each unit of labour supply
dep	Depreciation rate
emcoef	Coefficients for emissions of CO_2, SO_2, CO, NO_x, CH_4, PM10 and PM25 use of fuels
emcoefm	Coefficients for emissions of CO_2, SO_2, CO, NO_x, CH_4, PM10 and PM25 use of materials
$fdeptshr_h$	Household share of trade balance
hm	Trade margin in current prices
hmk	Trade margin in base-year prices
insm	Input coefficient for materials
inv	Composition of investment good
$invshr_h$	Household share of trade balance
itc	Indirect taxes in consumption
itce	Energy tax in consumption
itcmoms	value added tax
itcNOx	Nitrogen oxide tax in consumption
*itcSO*2	Sulphur tax in production in consumption
*itcCO*2	Carbon tax in production in consumption
itp	Ad volorem net tax on inputs
itpe	Energy taxes in production
itpKM	Kilometre tax in production
*itpSO*2	Sulphur taxes in production
*itpCO*2	Carbon taxes in production
la	Composition of inventory good
r	Real rate of return distribution
sat	Elasticity of substitution between skilled and unskilled labour
sats	Elasticity of substitution between technicians and non-technicians
sdz	Elasticity of substitution between home and foreign goods in domestic use
se	Price elasticity of export demand
sfv	Elasticity of substitution between aggregate labour and capital
swork	Elasticity of substitution between modes used for work trips
sshort	Elasticity of substitution between modes used for short leisure trips
slong	Elasticity of substitution between modes used for long leisure trips
sfritrans	Elasticity of substitution between short and long leisure trips
sfuel	Elasticity of substitution between different fuels
sheat	Elasticity of substitution between electricity, district heating and fuels
sfrgt	Elasticity of substitution for heavy freight transport
shouse	Elasticity of substitution between heating and rents

SKSHR	Household share of skilled labour
sovr	Elasticity of substitution between different other goods and services
slf	Elasticity of substitution between oil and gas
ssf	Elasticity of substitution between wood and coal
sf	Elasticity of substitution between solid fuels and liquid fuels
see	Elasticity of substitution between fuels, hot water and electricity
sme	Elasticity of substitution between material and energy
sz	Elasticity of substitution between value added and the energy-material composite
stp	Elasticity of substitution for aggregate transports
tpinsm	Shares of aggregate transports in total use of materials and the energy carriers oil, coal and bio fuels
tc	Tax on capital
tw	Labour tax incl. employer's contribution to social security
UNSKSHR	Household share of unskilled labour
wsk	Wage cost distribution, skilled labour
wuk	Wage cost distribution, unskilled labour

Appendix B: Prices of household consumption

The price of a household's aggregate consumption, $PPK_{h,}$ is given by :the following CES aggregation

$$PPK_h = \left[\left(\frac{POVR_h}{ak3_h} \right)^{1-spk_h} + \left(\frac{PHOUSE_h}{ak1_h} \right)^{1-spk_h} + \left(\frac{PFRITRANS_h}{ak2_h} \right)^{1-spk_h} \right]^{1/1-spk_h}$$

Where:

$$POVR_h = \left[\sum_{fno} \left(\frac{PHCS_{fno,h}}{aovr_{fno,h}} \right)^{1-sovr_h} \right]^{1/1-sovr_h}$$

$$PHOUSE_h = \left[\left(\frac{PHCS_{rents,h}}{ahouse2_{rents,h}} \right)^{1-shouse_h} + \left(\frac{PHEAT_h}{ahouse1_h} \right)^{1-shouse_h} \right]^{1/1-shouse_h}$$

$$PFRITRANS_h = \left[\left(\frac{PSHORT_h}{ashort_h} \right)^{1-sfritrans_h} + \left(\frac{PLONG_h}{ashort_h} \right)^{1-sfritrans_h} \right]^{1/1-sfritrans_h}$$

Where:

$$PSHORT_h = \left[\sum_{trs} \left(\frac{PHCS_{trs,h}}{atrs_{trs,h}} \right)^{1-sshort_h} \right]^{1/1-sshort_h}$$

$$PLONG_h = \left[\sum_{trh} \left(\frac{PHCS_{trh,h}}{atrs_{trh,h}} \right)^{1-slongi_h} \right]^{1/1-slong_h}$$

$$PHEAT_h = \left[\left(\frac{PHCS_{hheat,h}}{aheat3_h} \right)^{1-sheat_h} + \left(\frac{PHCS_{hel,h}}{aheat2_h} \right)^{1-sheat_h} + \left(\frac{PFUEL_h}{aheat1_h} \right)^{1-sheat_h} \right]^{1/1-sheat_h}$$

Where:

$$PFUEL_h = \left[\sum_f \left(\frac{PHCS_{f,h}}{afuel_{f,h}} \right)^{1-sfuel_h} \right]^{1/1-sfuel_h}$$

Appendix C: CES functions

The CES function is frequently used in applied general equilibrium modelling to depict the behaviour of firms and households. The CES production function and its dual cost function are used to model substitution and demand of firms' inputs. The CES utility function and its dual expenditure function are used to model households' substitution and demand of commodities. Also, aggregate prices are derived from the cost function and the expenditure function. The CES functions used in the equations of the model EMEC are nested, i.e. the variables are aggregated at successively higher levels.

C.1 CES production functions and factor demand

Theory

The outcome of optimal decisions in a static model can be summarized in a few equations. These will be illustrated by functions relating to optimal behaviour of a firm exhibiting a CES production function, but apply also to the CES utility function used for the modelling of household behaviour.

The CES production function $y()$ with the production factors labour L and capital K is often written on the following functional form:

$$y(L,K) = \alpha[\beta L^{\rho} + (1-\beta)K^{\rho}]^{1/\rho}$$

Assuming constant returns to scale (CRS) and no profits in production, cost minimization gives the dual minimum unit cost function expressed in prices with the elasticity of substitution $\sigma = 1/(1-\rho)$:

$$c(p_L, p_K) = \alpha^{-1}[\beta^{\sigma} p_L^{1-\sigma} + (1-\beta)^{\sigma} p_K^{1-\sigma}]^{1/(1-\sigma)}$$

The associated input demand for unit production is derived as the partial derivatives of the unit cost function by use of Shephard's lemma $\frac{\partial c(L)}{\partial p_L} = L$; $\frac{\partial c(K)}{\partial p_K} = K$.

In assuming CRS, the input demand functions will be:

$$L(p_L, p_K) = \alpha^{\sigma-1}\left[\frac{\beta\, c(p_L, p_K)}{p_L}\right]^{\sigma} y \; ; K(p_L, p_K) = \alpha^{\sigma-1}\left[\frac{(1-\beta)c(p_L, p_K)}{p_K}\right]^{\sigma} y$$

The model EMEC

Compared to the expressions given above, the CES aggregators of the model equations in EMEC are somewhat differently formulated. For example, the value-added aggregator corresponding to $y(L,K)$ is written:

$$FV(AT,C) = \left[(al \cdot AT)^{1-1/sfv} + (ac \cdot C)^{1-1/sfv}\right]^{\frac{1}{1-1/sfv}},$$

Where *FV* is value added, *AT* is hours worked, *C* is capital stock, *sfv* is elasticity of substitution and *al, ac* are calibration constants. The associated minimum unit cost function *C,* thus, is :

$$C(WT, PC) = \left[(WT/al)^{1-sfv} + (PC/ac)^{1-sfv} \right]^{\frac{1}{1-sfv}}$$

The associated factor demand functions will be:

$$AT = al^{sfv-1} \cdot \left(\frac{C(WT,PC)}{WT} \right)^{sfv} FV \; ; \; C = ac^{sfv-1} \cdot \left(\frac{C(WT,PC)}{PC} \right)^{sfv} FV$$

By assuming no profits in equilibrium, the value added price *PFV* must equal the unit cost *C(WT,PC)*, and the factor demand equations might be rewritten as they appear in the model:

$$AT = al^{sfv-1} \cdot \left(\frac{PFV}{WT} \right)^{sfv} FV \; ; \; C = ac^{sfv-1} \cdot \left(\frac{PFV}{PC} \right)^{sfv} FV$$

The assumption of no profits in production also gives the expression for a price aggregator in this example.

$$PFV = \left[(WT/al)^{1-sfv} + (PC/ac)^{1-sfv} \right]^{\frac{1}{1-sfv}}$$

This price aggregator as well as the aggregator for value added and the derived demand equations for labour and capital applies to all CES nested input equations of the model.

The relations between *al*, *ac*, α and β are:

$$\alpha = \left[al^{1-1/sfv} + ac^{1-1/sfv} \right]^{\frac{1}{1-1/sfv}} \quad \text{and} \quad \beta = \frac{al^{1-1/sfv}}{al^{1-1/sfv} + ac^{1-1/sfv}}$$

The values of the constants *al* and *ac*, are calibrated by solving the equations with benchmark data of the variables *FV*, *AT*, *C*, *PFV*, *AT* and *PC,* given the substitution elasticity *sfv,*.

$$al = \left\{ \frac{FV}{AT} \cdot \left[\frac{PFV}{WT} \right]^{sfv} \right\}^{\frac{1}{1-sfv}} \quad \text{and} \quad ac = \left\{ \frac{FV}{C} \cdot \left[\frac{PFV}{PC} \right]^{sfv} \right\}^{\frac{1}{1-sfv}}$$

References

Armington, P.S. (1969) "Adjustments of Trade Balances: Some Experiments with a Model of Trade Among Many Countries", *IMF Staff Paper*, 16. .

Caddy, V. (1976) "Empirical Estimates of the Elasticity of Substitution: A Review", Mimeo, Industries Assistance Commission, Melbourne, Australia. .

Bergman, L (2005) "CGE modeling of environmental policy and resource management" in *Handbook of Environmental Economics*, Vol. 3, Eds: Mäler, K.G. and Vincent, J.R., North-Holland, 2005.

Bovenberg, L.A., and Gouldner, L.H. (1996) "Optimal Environmental Taxation in the Presence of Other Taxes: General-Equilibrium Analyses" *The American Economic Review*, Vol. 86, No. 4, pp. 985-1000.

Dixon, P., Parmenter, B.R, Powell, A. and Wilcoxen, P (1992) *Notes and Problems in Applied General Equilibrium Economics*, North-Holland. .

Dixon, P., and Parmenter, B.R (1996) "Computable General Equilibrium Modelling for Policy Analysis and Forecasting" in *Handbook of Computational Economics*, (eds H.M. Amman, D.A. Kendrick and J. Rust), Elsvier.

European commission (1995) *GEM-E3 Computable General Equilibrium Model* for *Studying Economy-Energy-Environment Interactions,* EUR 16714 EN.

Hammar, H., (2006a) *Konsekvenser av en svensk kilometerskatt för tunga lastfordon – Principer bakom, effekter av och kompletterande åtgärder*, Specialstudie Nr 10, Konjunkturinstitutet

Hammar, H., (2006b) *Evaluation of Road Freight Policy in an Economy Wide Perspective – What can We Learn From Economic Models?,* Memo, Konjunkturinstitutet (Forthcoming)

Hill, M. (2001) *Essays on Environmental Policy Analysis: Computable General Equilibrium Approaches Applied to Sweden*, Dissertation, Stockholm School of Economics, Stockholm.

Johnsson, R. (2003) *Transport tax Policy Simulations and Satellite Accounting within a CGE framework*, Dissertation, Uppsala University, Uppsala.

Kemfert, C. and Welsch, H., (1997) *Energy-Capital-Labour Substitution and the Economic Effects of CO_2 Abatement:Evidence for Germany,* Discussion Paper No. V-178-97, Oldenburg University, Germany

Kremers, H., Nijkamp, P. and Rietvald, P. (2002) "A Meta-Analysis of price Elasticities of Transport Demand in a General Equilibrium Framework", *Economic Modelling*, 19: 463-485, Elsevier.

Koschel, H., (2000), *Substitution Elasticities between Capital, Labour, Material, Electricity and Fossil Fuels in German Producing and Service Sectors* . ZEW Discussion Paper No. 00-31.

van Leeuwen, M.J., Visee, H., Laroui, F., (1995) *An Economy Energy Environment Computable General Equilibrium Model for the Netherlands,* SEO, Foundation for Economic Research of the University of Amsterdam.

Litman, T., (2005) *Transportation Elasticities: How prices and other factors affect travel behavior* Report, Victoria Transport Policy Institute, Canada.

Nilsson, C. (2002) *Konsekvenser av restriktioner på koldioxidutsläpp,,* Miljöräkenskaper, Rapport 2002: 1, Konjunkturinstitutet, (in Swedish)

Nilsson, C. (2004) "Household Transport Demand in a CGE-framework" in *Studies in Environmental Economics: Numerical Analysis of Greenhouse Gas Policies*, Dissertation, Stockholm School of Economics, Stockholm.

Oum, T.H., Waters, W.G., and Yong, J.S., (1990) *A Survey of Recent Estimates of Price Elasticities of Demand for transport* WPS 359, The World Bank.

SIKA, (2005), *Prognos för persontransporter år 2020*, SIKA-rapport 2005:8

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Steininger, K. W. (2002) "The Foreign Trade and Sectoral Impact of Truck Road Pricing flr Cross-Border Trade", *Environmental and Resource Economics*, 23: 213-253.

Sveriges klimatstrategi (Kontrollstation 2004), (in Swedish)

Åhman, M., (2004) *A Closer Look at Freight Transport and Economic Growth in Sweden*, Report 5370, Naturvårdsverket

Östblom, G., (1999), *An Environmental Medium Term Economic Model – EMEC*, Working Paper No. 69, Swedish National Institute of Economic Research, Stockholm.

Östblom, G (2002) *Introducing Costs of Sulphur Abatement in the EMEC Model*, Memo 2002:4, National Institute of Economic Research.

Östblom, G., (2003a) "Vinner Sverige på att delta i utsläppshandel?", *Ekonomisk Debatt*, årg 31, nr 8, (in Swedish)

Östblom, G., (2003b) *Samhällsekonomiska konsekvenser för Sverige av begränsad handel med utsläppsrätter enligt EU:s direktiv*, Miljöräkenskaper, Rapport 2003: 1, Konjunkturinstitutet, (in Swedish)

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Östblom, G (2004b) *Samhällsekonomiska kalkyler för Kontrollstation 2004*, Memo 2004:9, National Institute of Economic Research, (in Swedish).

Östblom, G and Samakovlis, E, (2004), *Costs of Climate Policy when Pollution Affects Health and Labour Productivity - A General Equilibrium Analysis Applied to Sweden*, Working Paper No. 93, Swedish National Institute of Economic Research, Stockholm. 2004, submitted to Climate Policy.

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