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PINGO
A model for prediction of regional- and interregional freight transport

Version 1

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Preface

In spring 2001 the Ministry of Transport and Communications invited a selection of research institutes to send project proposals to program for overall transport research (POT). The first part of our project proposal about implementation and calibration of a SCGE model for Prediction of regional and INterreGiOnal freight transport (PINGO) got financial support from POT.

This report describes the work we have accomplished as part of the project. The main project workers were msc env dev econ Olga Ivanova, cand oecon Viggo Jean-Hansen and dr scient Arild Vold.

Arild Vold has been the project leader and worked out the broad structure of the model. Olga Ivanova has refined and implemented the model and Viggo Jean-Hansen has obtained the necessary data. As part of the work to decide on the final model structure and the necessary data, there have been numerous good and fruitful discussions between the three co-workers.

We want to thank Knut Sandberg Eriksen, Harald Minken and Farideh Ramjerdi for comments on draft versions of the report. We would also like to thank Kjell Werner Johansen who has been responsible for quality assurance, and Laila Aastorp Andersen who has provided secretarial assistance.

Oslo, April 2002
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Sammendrag:

PINGO
Prognosemodell for regional og interregional godstransport
Versjon 1

For transportplanlegging på nasjonalt nivå trengs prognoser for hvordan økonomien og miljøet på lang sikt påvirkes av demografiske endringer, nye transportavgifter, infrastrukturinvesteringer innen transportsektoren, og økonomisk vekst.

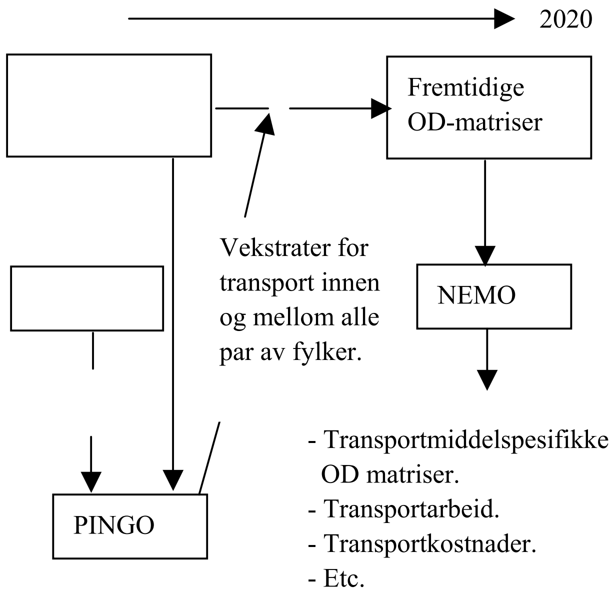
Samferdselsdepartementet har gitt Transportøkonomisk institutt (TØI) i oppdrag å konstruere en såkalt ”Spatial Computable General Equilibrium” (SCGE) model, eller regionalisert generell likevektsmodell, med hovedvekt på godstransport og prognoser for vekstrater for nasjonal godstransport innen og mellom fylker i Norge og mellom fylker i Norge og andre land. Denne rapporten beskriver utvikling og implementering av den første versjonen av SCGE modellen som har fått navnet PINGO (Prognosemodell for regional og INterregional GOdstransport).

Det som skiller PINGO fra andre modeller av denne typen er at den inneholder leveransestrukturen av gods mellom par av fylker. PINGO predikerer vekstrater for godstransport (1) innen fylker i Norge, (2) mellom fylker i Norge og (3) mellom fylker i Norge og andre land.

Inngangsdata til PINGO er prognoser for fremtidige sosiale og demografiske forhold og OD matriser for godstransport innen og mellom fylker i et basisår og kostnader ved godstransport. Kostnader ved godstransport kan hentes fra NEMO[1]. Kalibrering av PINGO blir vanligvis basert på kostnader ved godstransport i et basisår (1999), mens påfølgende modellkjøringer kan baseres på kostnader, der nye drivstoffavgifter, infrastrukturinvesteringer etc., inkluderes (Figur 1.1).

Tilgang til arbeidskraft i fylkene er den eneste variabelen som må settes eksogent, men det er også mulig å sette øvrige variable eksogent, for eksempel priser på varer eller arbeidskraft. De variable vi velger eksogent bestemmes av brukeren i henhold til formålet med analysen.

PINGO kan brukes til å beregne hvordan transportvolumer påvirkes av endrede transportkostnader, endret tilgang til arbeidskraft og endringer i eksport og importpriser. Den kan også brukes for å beregne hvordan transportvolumer påvirkes av teknologiendringer, investeringer i transportinfrastruktur, endringer i konsumentenes preferanser og endringer i distriktspolitikken (for eksempel mer eller mindre overføringer til utvalgte fylker).



Figur 1.1. Skjematisk representasjon av koblingen mellom NEMO og PINGO.

Varegruppene i PINGO er: ***(1)*** *Mat,* ***(2)*** *Fisk,* ***(3)****Thermo,* ***(4)*** *Transportmidler/maskiner,* ***(5)*** *Stykkgods,* ***(6)*** *Tømmer og trelast,* ***(7)*** *Mineraler og steinprodukter,* ***(8)*** *Kjemiske produkter,* ***(9)*** *Metaller og malmer,* ***(10)*** *Flytende bulk,* ***(11)*** *Reparasjonstjenester,* ***(12)*** *Andre tjenester,* ***(14)*** *fysisk kapital.* NEMO inneholder samme varegrupper bortsett fra tjenestene. Verken NEMO eller PINGO har eksplisitt representasjon av råoljeproduksjo-

[1] Siste versjon av NEMO (NEttverksMOdell for godstransport) er beskrevet i Vold et al. (2002).

nen på Kontinentalsokkelen, men i PINGO representeres inntektene fra denne aktiviteten implisitt som overføringer fra det offentlige.

Den første versjonen av PINGO representerer tilbud og etterspørsel av varer for 1997 i en såkalt "Social Accounting Matrix (SAM)". Denne brukes som inputdata for modell estimering. SAM inneholder en rad per vare eller produksjonsfaktor per fylke og representerer markedet for denne vare/produksjonsfaktor. Tilbud og etterspørsel representeres ved henholdsvis positive og negative elementer.

SAM matrisen vi bruker i PINGO representerer Norges 19 fylker pluss en region for alle andre land. Den inneholder data fra det Fylkesvise Nasjonalregnskapet, data fra den nasjonale nettverksmodellen for godstransport i Norge (NEMO), Utenrikshandelsstatistikken og andre kilder.

Kolonnene i matrisen representerer input og output for produksjons- og investeringssektorene, agenter og sektorer for import og eksport, og etterspørsel og initiale ressurser for konsumenter og det offentlige. Transport av hver varegruppe innen hvert fylke og mellom alle par av fylker er representert i del-matriser i SAM som ikke ligger på diagonalen. Siden matrisen representerer en likevektssituasjon, har vi at hver radsum og kolonnesum er null. "Varer" vi kaller operativt overskudd og handelsbalanse, sikrer dette ved at de inkluderes som balanserende faktorer i de sektorvise regnskapene.

For hvert fylke representerer PINGO ni produksjonssektorer, en investeringssektor, ti vareagenter som produserer "samlevarer" (en for hver varegruppe), to tjenesteagenter (en for hver type tjeneste), en tjenestesektor (som produserer to tjenester og bruker mye varer som input), en investeringssektor (som produserer fysisk kapital til fylket den er lokalisert i, og der den fysiske kapitalen bindes til fylket) og et representativt hushold per fylke (som kjøper og konsumerer varer og tilbyr arbeidskraft). På nasjonalt nivå er det en transportsektor som selger transporttjenester, en import- og en eksportsektor og en sektor for myndighetene.

Vareagentene kjøper transporttjenester fra den nasjonale transportsektoren og produksjonen av en bestemt varegruppe fra alle fylker og fra andre land for å produsere en tilsvarende "samlevare" som kan konsumeres eller brukes som en innsatsfaktorfaktor i fylket der vareagenten er lokalisert. Vareagentene kan tolkes som grossister, mens tjenesteagentene står for reparasjons- og andre tjenester. Bare privat konsum er representert eksplisitt i modellen, mens offentlig konsum er inkludert som en del av overskuddet eller underskuddet i fylkene.

Selv om PINGO er en SCGE modell, har den i prinsippet den samme strukturen som en CGE (Computable General Equilibrium) modell. Det var derfor mulig å utvikle en løsningsalgoritme basert på standard teori for generelle likevektsmodeller. Produsentenes og konsumentenes tilbud og etterspørsel ble formulert som et generelt likevektsproblem. Husholdenes nyttefunksjoner ble formulert som vanlige funksjoner med konstant substitusjonselastisitet (CES-funksjoner) og produktfunksjonene ble formulert som "nestede" funksjoner med konstant substitusjonselastisitet (NCES-funksjoner).

Output-strukturen ble spesifisert som funksjoner med konstante transformasjonselastisiteter (CET-funksjoner). CET-funksjonene ligner CES-funksjonene og kan beskrives fullstendig ved å spesifisere representative produksjonsandeler av ulike varegrupper og transformasjonselastisiteter mellom dem[2].

Vi brukte programvaren MPSGE[3] for å formulere og løse det generelle likevektsproblemet som et såkalt "Mixed Complementary Problem" (MCP). Programvaren er basert på forutsetninger om at alle produsenter og konsumenter er informert om alle priser og tar dem for gitt, og at produksjons- og investeringssektorene og agentene er profittmaksimerende. Videre er det forutsatt at konsumentene er nyttemaksimerende innenfor rammene som husholdningsbudsjettene tillater, der budsjettet dekker alle levekostnader, inklusive bokostnader som er representert som en del av konsumentens overskudd. MPSGE beregner likevekts priser og volumer når modellen er riktig spesifisert ved produktfunksjoner, nyttefunksjoner, initiale resurser etc. og den tilhørende SAM matrisen.

Fire test cases ble analysert for å verifisere modellen. For hver test analyserte vi

1) totale transportstrømmer inn i og ut av fylkene.
2) import til – og eksport fra andre land (kun test case 3).
3) total produksjon og konsum i fylkene.
4) en proxy for gjennomsnittlig distanse.

I *Test case 1* anvendte vi PINGO for en situasjon der tilgangen på arbeidskraft i Oslo øker med 6% relativt til basissituasjonen. Resultatene demonstrerte en skarp økning i transportstrømmene til og fra Oslo, noe vi kunne forvente på grunn av produksjonsøkningen som følger av bedre tilgang til arbeidskraft (siden det er forutsatt at arbeidskraft er en begrenset resurs, det er ingen arbeids-

[2] CET-funksjonene har samme funksjonelle form som CES-funksjonene. Den eneste forskjellen er navnet på substitusjonselastisiteten. I dette tilfellet kalles den transformasjonselastisiteten mellom outputs, dvs. output fra sektorene i basisåret. Elastisitetene i første versjon av PINGO ble satt i henhold til "kvalifiserte gjetninger". Men det er en intensjon at senere versjoner skal inneholde estimater fra mer sofistikerte estimeringsprosedyrer.

[3] MPSGE ("mathematical programming system for general equilibrium analysis") er en utvidelse av programmeringsspråket GAMS (Rutherford, 1995).

ledighet, og arbeid ikke kan flyttes fra et fylke til et annet). Økende produksjon i Oslo stimulerer produksjonsvekst i regioner som er knyttet til Oslo gjennom interregional handel, slik at transportstrømmene i disse regionene også øker. Proxy for gjennomsnittlig distanse indikerer en liten vekst i transportdistanse per tonn vare.

Test case 2 skiller seg fra tidligere test case ved at vi øker tilgangen til arbeidskraft med 5% ikke bare i Oslo, men også i alle andre fylker. PINGO predikerer økende produksjon i alle regionene og korresponderende endringer i transportstrømmene som oppstår i disse regionene. Det meste av økningen skjer i Oslo, Rogaland og Hordaland. Vi vet at dette er fylkene som veier tyngst i Nasjonalregnskapet. Vi kan altså konkludere at modellen gjenspeiler dette i økonomisk forstand og med hensyn til transportstrømmer. Proxy for gjennomsnittlig transportdistanse reduseres i forhold til basissituasjonen, noe vi kan forklare ved at produksjonsmulighetene i regionene forbedres og behovet for varer dekkes i større grad av varer produsert i eget eller nærliggende fylke.

Test case 3 ble gjennomført for å vurdere effekten en 5% økning i prisen på importerte varer vil ha på de regionale transportstrømmene. Som en generell effekt får vi at alle regioner får redusert import. De største effektene får vi for Østfold, Akershus og Oslo. Dette er regioner vi assosierer med den største andelen av total import. Den prosentvise endringen i import for regionene er temmelig lik (omtrent – 4.5%), med unntak av Troms, der importen reduseres med 8.5%. Produksjon og transportstrømmer inn og ut reduseres for alle fylker med unntak av Østfold, der produksjon og transportstrømmer inn og ut øker. Konsumet reduseres i alle fylker. Proxy for gjennomsnittlig transportdistanse ble også redusert som følge av økte importpriser. De avvikende resultatene for Østfold skyldes at Østfold i stor grad brukes som transittpunkt (inntollingssted) for importstrømmer som går videre til alle andre regioner, mens dette empiriske faktum ikke reflekteres i modellen på grunn av manglende data. I nåværende versjon av PINGO forbrukes alle inntollede varer i fylket de inntolles i. En korreksjon må derfor gjøres for at modellen skal respondere adekvat ved endringer som påvirker importen.

I *Test case 4* undersøker vi effekten av en 2% økning i prisen på varegruppe 10 (flytende bulk), som inkluderer bensin og olje som er viktige innsatsfaktorer i transportsektoren. Produksjon og transport inn og ut av fylkene reduseres for alle fylkene med unntak av Østfold, mens konsum reduseres for alle fylker. Avvikene for Østfold skyldes de samme problemene vi fikk for Test case 3. Vi får en liten reduksjon i proxy for gjennomsnittlig transportdistanse.

Det generelle inntrykket er at modellen oppfører seg kvalitativt riktig, men at noen modifikasjoner trengs for å representere importaktiviteten på en bedre måte. Det er også andre forbedringsmuligheter. De viktigste er å:

- modifisere importaktiviteten.
- forbedre estimering av substitusjonselastisiteter i produkt- og konsumfunksjoner.
- tillate at arbeidskraft og kapital kan flyttes mellom fylker.
- segmentere husholdningene.
- tillate stordriftsfordeler i produksjonen.
- forbedre metoder for å sette opp fremtidige basisår.

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Summary:

PINGO
A model for prediction of regional and interregional freight transport
Version 1

Forecasts for how the economy and the environment is affected by demographic changes, new transport taxes, infrastructure investments within the transport sector, and economic growth are needed to assist the Norwegian government for long-term planning of transport infrastructure provision, regional development, environmental policy and taxes.

The Ministry of Transport and Communication commissioned the construction of a Spatial Computable General Equilibrium (SCGE) model of the Norwegian economy emphasising freight transport and forecasts of growth rates for national freight movement within and between counties in Norway and between counties in Norway and other countries. The task was entrusted to the Institute of Transport Economics (TØI). This report describes development and implementation of the first version of the SCGE model for prediction of regional- and interregional freight transport, which is named PINGO.

The main advantage of PINGO compared to earlier approaches to this kind of modelling is the structure of freight delivery and receiving between counties.

Input to PINGO includes forecasts of future social and demographic conditions and OD matrices for freight transport within and between counties in a base year (1999) and freight transport costs. The freight transport costs can be obtained from NEMO[1]. Calibration of PINGO is usually based on freight transport costs in a base year, whereas subsequent runs can be based on freight transport costs where new fuel taxes, infrastructure investments etc., can be included (Figure 1.1).

Endowments of the consumers are the only exogenous variables that need to be fixed in the model, but almost all other variables can optionally be set exogenously, e.g. prices on any good or labour can be fixed or endogenously determined. The variables to be made exogenous are determined by the user according to the aims of his analysis.

PINGO predicts the long-term effects of the new transport costs on freight transport within and between counties for each of the ten commodity groups that are represented in NEMO, while accounting for changed population in the counties and economic development. Growth rates from PINGO for freight transport within and between counties and between counties in Norway and other countries can subsequently be used to update the OD-matrices that are used as input to NEMO, whereat NEMO can be used to calculate corresponding figures for tonne kilometres, environmental costs etc. at a different levels of aggregation.

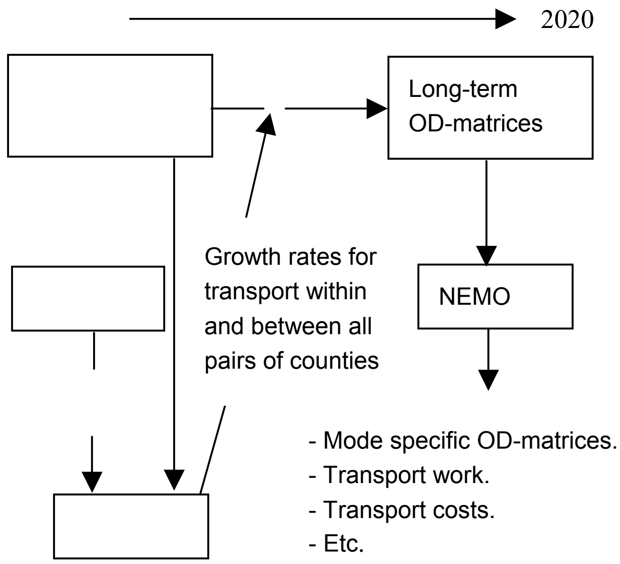

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Figure 1.1. Schematic view of the interplay between NEMO and PINGO.

[1] see Vold et al., 2002, for a description of NEMO (NEtwork MOdel for freigt transport).

PINGO can be used to assess how transport volumes are affected by changed transportation costs, changes in labour endowments, and changes in export or import prices. It can also be used to assess how transport volumes are affected by changes in the technology, investment plans in transport infrastructure, changes in consumer tastes and changes in regional governmental policy (e.g., more or less transfers to selected counties).

The commodity groups in PINGO are: ***(01)** food, **(02)** fish, **(03)** thermo, **(04)** vehicles/machinery, **(05)** general cargo, **(06)** timber and wood ware, **(07)** coal, sand and gravel, **(08)** chemical products, **(09)** metals and ore, **(10)** bulk commodities (liquid), **(11)** reparation services, **(12)** other services, **(13)** physical capital (i.e., tangible assets).* These are the same commodity groups that are used in NEMO, except that NEMO does not include services but subdivides Fish in fresh and frozen good. Neither NEMO nor PINGO has explicit representation of the crude oil production on the Continental shelf but the income from this activity is implicitly represented as transfers from the government.

The first version of PINGO represents supply and demand of commodities for the base year 1999 in a Social Accounting Matrix (SAM), which is used as input data and for model estimation. The SAM includes one row per commodity or factor of production per county, which represents the market for this commodity/factor of production. Supply and demand is represented by positive and negative elements, respectively.

The SAM matrix used in PINGO represents Norway as divided into 19 regions plus one region that corresponds to all other countries. It contains data collected from National Accounts by County (Statistics Norway), data from the national network model for freight transport in Norway (NEMO), the Foreign Trade Statistics and other sources.

The columns in the SAM matrix represent inputs and outputs for production and investment sectors, agents and sectors for import and export, and demands and endowments for the consumers and the government. Transport of each commodity within each county and between all pairs of counties is represented on the off-diagonal sub matrices of the SAM. Since the matrix represents an equilibrium situation, we have that each row and column sums are zero. The operative surplus and trade balance commodities assure this balance, which are included as balancing factors in the sector accounts.

For each county PINGO represents nine production sectors, one investment sector, ten commodity agents that produce pooled commodities (one for each commodity group), two service agents (one for each service), one service sector (that produces two services and uses a lot of goods as input), one investment sector (that produces physical capital for the county where it is located, where physical capital is bounded to county where it is produced), and one representative household (that buys and consumes commodities and supplies labour). On the national level there is a transport sector that sells transport services, one import and one export sector as well as the government.

The commodity agents determine the amounts of commodities to be transported within and between the counties as well as from abroad and perform transportation using transport services. Each commodity agent buy transport services from the national transport sector and output of a commodity group from all counties and from other countries to produce a corresponding pooled commodity that can be consumed or used as an input factor in the county where the commodity agent is located. The commodity agents can be interpreted as the wholesalers, while the service agent trade repair and other services. Only private consumption is explicitly represented in the model, with the public being part of factors we use for balancing markets.

Although PINGO is a SCGE model, it has in principle the same structure as a CGE (Computable General Equilibrium) model. Thus, it was perfectly adequate to base the development of a solution algorithm on standard theory for general equilibrium models. The producers and consumers were formulated in terms of a general equilibrium problem. The household's utility functions were formulated as standard functions with Constant Elasticity of Substitution (CES-functions) and the production functions were formulated in terms of Nested functions with Constant Elasticity of Substitution (NCES-functions).

The structure of the outputs was specified as functions with Constant Elasticity of Transformation (CET functions). CET functions are similar to CES functions and may be completely described by specifying representative shares of outputs and elasticities of transformation between them[2].

We used the MPSGE[3] software to formulate and solve the general equilibrium problems as "Mixed Complementary Problem" (MCP). The software is based on the assumptions that all producers and consumers are

[2] CET functions have the same functional form as the CES functions. The only difference is the name of the elasticity of substitution between the variables. In this case it is called the Elasticity of Transformation between the outputs. Representative share coefficients are estimated using representative coefficients i.e. outputs of the sectors in the base year. Elasticities in the first version of PINGO were set according to "qualified guesses". It is the intention, however, that later versions should include estimates from a more sophisticated estimated procedure.

[3] MPSGE (*mathematical programming system for general equilibrium analysis*) is an extension of the GAMS programming language (Rutherford, 1995).

well informed about all prices and take them as given, and that production- and investment sectors and agents maximizes profit. It is further assumed that the consumers maximize their total utility constrained by their household budgets, where the budgets covers all costs of living including the housing rent, which is included as a part of the consumer operating surplus. MPSGE computes equilibrium prices and quantities when the model is properly specified in terms of production functions, utility functions, endowments etc. and the accompanying SAM.

Four test cases were analysed in order to verify the model. For each test case we report:

1) Total transport flows into and out of the counties.
2) Import to and export from other countries (only test case 3).
3) Total production and consumption in the counties.
4) A proxy for average distance.

In *Test case 1,* we applied PINGO for a situation where labor endowment for Oslo increases by 6% relative to the "benchmark" situation. The results demonstrated a sharp increase in transportation flows originating in Oslo, which should be expected because of the increase in production caused by labor endowment growth (since it is assumed that labour is a limited resource, there is no unemployment, and labour can not be moved from one county to an other county). The increasing production in Oslo stimulates production growth in regions that are connected with Oslo through interregional trade, so that transportation flows originating in these regions also increase. The proxy for average distance indicates a small increase in the transportation distance per ton of commodity.

Test case 2 differs from the previous test case in that we increase labor endowment by 5% not only in Oslo but also in all other counties. PINGO predicts increased production in all the regions and corresponding changes in transportation flows originating from the regions. Most of the increase is located in Oslo, Rogaland and Hordaland. We know that theses are the counties with the greatest figures in the national accounts. Therefore we may conclude that the model correctly predicts that these regions are the most economically important, and the ones that are associated with the largest transportation flows. The proxy for average transport distance is reduced relative to the base year. An explanation is that production possibilities of the regions have improved due to increased labor endowments, needed amounts of commodities are now produced in the nearest regions and there is less need for long-distance transportation.

Test case 3 was run in order to investigate the effect that a 5% increase in the price of imported goods will have on the transportation flows (e.g., added import tax). An overall effect is the reduction in imports going to all the counties relative to the benchmark situation. The greatest effects are found for Østfold, Akershus and Oslo respectively, which is reasonable, since these are the counties that are associated with the largest shares of the total imports. The percentage change in import for the counties is quite similar (about - 4.5 %), except for Troms that has and 8% reduction in imports. The increased price on imported goods reduces production and transportation flows, except for Østfold where production and originating and terminating transportation flows increases. However, consumption is reduced in all counties. The average distance of transportation was also reduced. The anomalous results for Østfold is due to Østfold's role as a transit point (custom) for much import to other counties and that the model due to the lack of necessary data does not reflect this empirical fact. The first version of PINGO uses all the import in the county where custom is declared. A correction is needed to make the model work adequately for changes that affects the import.

In *Test case 4* we investigate the effect of a 2% increase in the price of commodity group 10 (bulk commodities), which includes petrol and oil that are important inputs in the transportation sector. There is a reduction in production and originating and terminating transportation flows for all counties, except for Østfold, whereas consumption is reduced for all counties. These anomalies for Østfold are due to the same problems that were outlined under the description of test case 3. There is a small reduction in the average transportation distance.

The overall impression is that the model behaves qualitatively appropriate, but that some modifications are needed to adequately represent the import activity, i.e., Østfold is used as the transit point for a lot of import flows going to all other counties and this empirical fact is not reflected by the model due to the lack of necessary data. Other proposals for future work concern estimation of substitution elasticities, labour mobility and household groups, economics of scale and improving the suggested methods to set up a future benchmark year with PINGO.

Contents

1 Introduction

Freight transport is crucial for the economy since production and consumption of commodities is located in different places. Reduced monetary and time costs of transportation enable firms to sell their products more cheaply, which in turn stimulates greater demand, gives rise to economic growth, but can of course affect emissions and environmental degradation.

Forecasts for how the economy and the environment is affected by demographic changes, new transport taxes, infrastructure investments within the transport sector, and economic growth are needed to assist the Norwegian government for long-term planning of transport infrastructure provision, regional development, environmental policy and taxes.

Canada, USA and Italy already have models for forecasting transport demands between and within counties and use them successfully in regional planning. Most of the models are implemented in the framework of Spatial Computable General Equilibrium (SCGE) modelling. The theoretical basis for such models is a complete Arrow-Debreu economy under perfect competition, where transport is considered as an input factor into production of goods and services, representing a cost to individual businesses. Some regional SCGE models are based on the assumption that transport services are imported from some external supplier. Others incorporate the transport sector into the economy and represent its production technology using CES-functions.

In Norway we have the regional economic models REGARD (Johansen, 1997) and REGION-2 (Sørensen and Toresen, 1990). Both models forecast economic development in Norwegian counties, which includes inputs to the production sectors, production and consumption. Total transport of commodities out of and into each of the counties are assessed, but not the transported amount of commodities between pairs of counties. REGION-2 uses a fixed relationship between inputs in the production sectors, which means that the share of different inputs in production of commodities is not sensitive to price changes. Hence, REGION-2 does not contain any producer behaviour (Sørensen and Toresen, 1990, s.10).

The real network model for freight transport within Norway and between Norway and other countries (NEMO, Vold et al., 2002) assess OD matrices for transport costs and OD matrices for transport volumes between pairs of counties in a base year (1999). NEMO assigns the volumes in the OD matrices to the links in the transport network in a way that minimises the total costs of transport (System Optimum).

Even if NEMO alone cannot forecast future freight volumes with the different transport modes, it gives a good starting point for building a regional economic model that makes forecasts also for transport between pairs of counties in Norway. Earlier approaches to project transport volumes from NEMO to a future year includes application of the CGE model GODMOD (Jensen and Eriksen, 1997) and REGARD (Madslien, Jule and Jean-Hansen, 1998). The use of GODMOD was TOI's first attempt to use CGE models for this purpose. GODMOD represents the economy in a theoretically plausible way but includes no spatial description, whereas with REGARD there is the opposite.

To take a step further, the Ministry of Transport and Communication therefore commissioned the construction of a SCGE model of the Norwegian economy emphasising freight transport and forecasts of growth rates for national freight movement within counties and between pairs of counties in Norway and between counties in Norway and other countries. The task was entrusted to the Institute of Transport Economics (TØI). This report describes development and implementation of the first version of this SCGE model, which is named PINGO.

PINGO is a slightly modified version of the SCGE model developed by Bröcker (1998). The major difference is that the Bröcker’s model does not include an explicit transport sector, whereas PINGO includes explicit representation of a transport sector as well as import and export activities. Bröcker assumes that a certain percentage of the transported commodity itself is used during transportation (iceberg effect), where the amount of the commodity used during transportation, depends upon its type and travel distance.

Input to PINGO includes OD matrices for freight transport within and between counties in a base year and freight transport costs. The freight transport costs can be obtained from NEMO. Calibration of PINGO is usually based on freight transport costs in a base year, whereas subsequent runs can be based on freight transport costs where new fuel taxes, infrastructure investments etc., can be included (Figure 1.1). PINGO predicts the long-term effects of the new transport costs on freight transport within and between counties for each of the ten commodity groups that are represented in NEMO, while accounting for changed population in the counties and economic development (i.e., new taxes, new production technology etc.). Growth rates for freight transport within and between counties from PINGO can subsequently be used to update the OD-matrices, whereat NEMO can be used to calculate corresponding figures for tonne kilometres, environmental costs etc. at a different levels of aggregation.

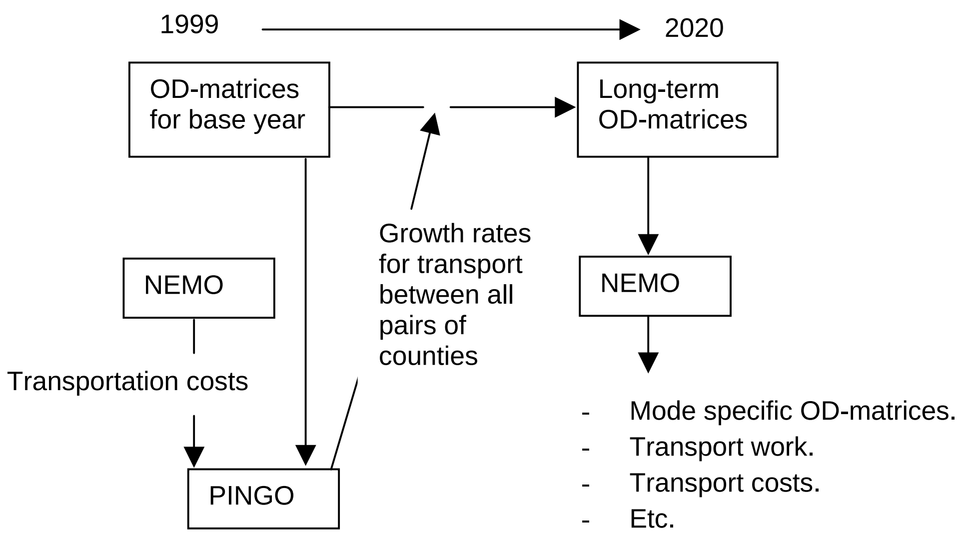

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Figure 1.1. A schematic view of the interplay between NEMO and PINGO.

The main advantage of PINGO compared to earlier approaches to this kind of modelling is the structure of freight delivery and receiving between counties.

The first version of PINGO is described in chapter 2 and the collection and treatment of data that are used as model input and for model estimation is described in chapter 3. Results from four test cases are presented in chapter 4, and a procedure for how to apply the model to make forecasts is described in chapter 5. Chapter 6 contains future perspectives for the model development and the appendixes include detailed information about CES functions and a simple test case.

2 Description of PINGO

Although endowments of the consumers are the only exogenous variables that need to be fixed in the model, there is the option to set almost all variables in PINGO exogenously. The variables to be made exogenous are determined by the user according to the aims of his analysis. Some examples of possible exogenous variables and their use in the analysis performed with the model are given in the test cases presented in chapter 4.

2.1 Structure of the model

In order to determine how to subdivide Norway in regions that are suitable for PINGO we considered the advantages and disadvantages of a detailed subdivision. With a detailed subdivision, we are potentially more able to assess variations at local level. The need for data and computational resources increases with increasing number of regions. National Accounts Statistics by County is available for the 19 Norwegian counties, but it is much more difficult to obtain data for smaller regions.

We decided to use the 19 Norwegian counties as regions and a single region to represent all foreign countries in PINGO (Figure 2.1). Neither NEMO nor PINGO represent Svalbard and there is no explicit representation of the crude oil production on the Continental shelf but the income from this activity is implicitly represented in PINGO as transfer of money from the government to the households in the counties[1].

PINGO includes 10 *commodity groups* and 2 types of *services*. Each county shelters 9 different *production sectors* that produces the 10 commodity groups, one *service sector* that produces the 2 services and one *investment sector* that produces physical capital for the county where it is located, where physical capital is bounded to county where it is produced.

There is final demand by 19 representative *households* (one household per county). On the national level there is a *national transport sectors*, an *import sector*, an *export sector* and a *government sector* that balances the economy.

There are 10×19 *commodity agents* (one agent per commodity and county) and 2×19 *service agents* (one agent per service and county). The commodity agents can be interpreted as the wholesalers or retailers who use output of a commodity group from all counties and other countries and transport services, carried out by the national transportation sector, to produce a *pooled commodity* corresponding to one of the commodity group. Only the pooled commodity can be consumed or used as an input factor in the county where the commodity agent is located. The service agents trade repair and other services.

[1] In most of the counties there are large positive figures for the households' operating surplus commodities, which may be interpreted as transfers from the government to the households.

There is no distinction between different types of labour in PINGO, and the endowment of labour in each county is fixed (i.e., it is assumed that labour is a limited resource, there is no unemployment, and labour is immobile between the counties).

There is no explicit representation of profits/losses, monetary investments, taxes/subsidies from the government and many other things in the sectors in PINGO. Due to the complexity of such realistic modelling and certain data requirements we have chosen to represent all factors not taken explicitly into account by the *operating surplus commodity* that is used to balance the sectors accounts. The operating surplus commodity is county specific and is either produced or consumed by the sectors. Operating surplus is interpreted as input to production when the producers receive profit and as output when they face losses.

A later version of PINGO will hopefully represent more components in an explicit way, however, and less components as part of the operating surplus commodity.

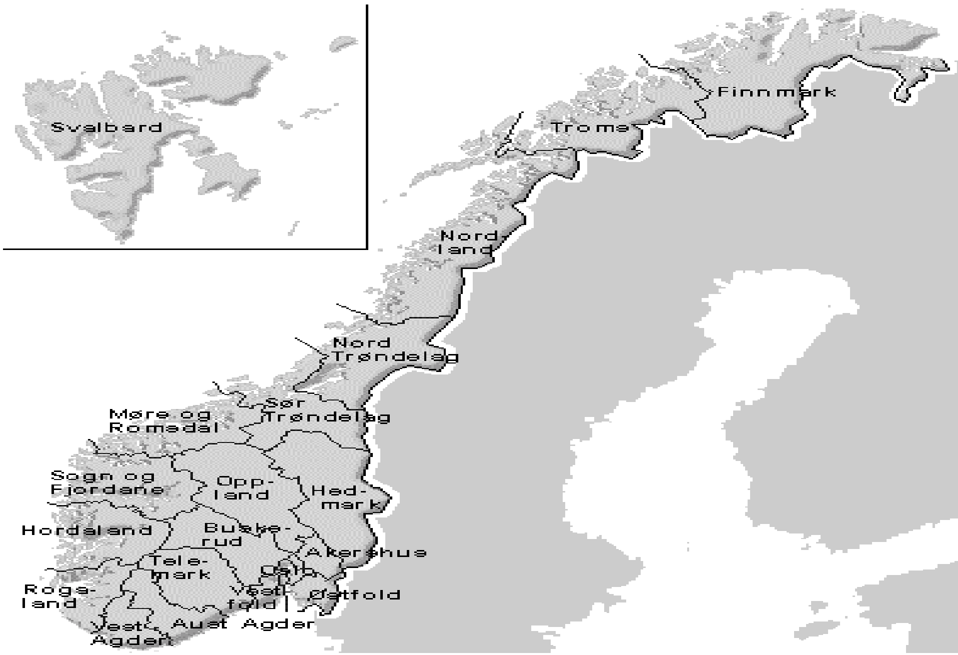

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Figure 2.1. Counties in Norway: 01 Østfold, 02 Akershus, 03 Oslo, 04 Hedmark, 05 Oppland, 06 Buskerud, 07 Vestfold, 08 Telemark, 09 Aust-Agder, 10 Vest-Agder, 11 Rogaland, 12 Hordaland, 14 Sogn and Fjordane, 15 Møre and Romsdal, 16 Sør-Trøndelag, 17 Nord-Trøndelag, 18 Nordland, 19 Troms, 20 Finnmark

2.2 The Social Accounting Matrix

We use a Social Accounting Matrix (SAM) to represents an equilibrium situation where all the economic agents[2] and goods in PINGO are represented. The columns of the matrix

[2] An economic agent can be a production sector, investment sector, service sector, commodity agent, service agent or a representative household, or the national transport sector, import sector, export sector and the government.

represent the economic agents accounts while its rows represent markets for goods and factors of production. Transport of each commodity within each county and between all pairs of counties is represented on the off-diagonal sub matrices of the SAM. Positive elements in the columns are outputs of goods or endowments of factors of production, while negative are inputs or demands. Economic equilibrium implies that all economic agents and markets are in balance, i.e., that rows and columns have zero sums, respectively.

Although the SAM matrix used in PINGO represents the Norwegian economy as divided into 19 counties plus one county that corresponds to all other countries, we used a SAM matrix for only two counties with synthetic data but with the same structure that is used in the full-scale version of PINGO to verify a small-scale prototypical version of the PINGO model (Table 2.2).

There are two production sectors, one transport sector, and one sector for private consumption. There are two commodity groups, commodity agents, and a national transport sector. A national authority may transfer money in terms of subsidies and taxes, which is part of the balancing factors in the economy. The small-scale version was verified, but we do not present any of the results in this report.

Table 2.2. A stylistic Social Accounting Matrix (SAM)

		Region 1						Region 2									
		Sector 1	Sector 2	Tr agent 1	Tr agent 2	Household	Inv sector	Sector 1	Sector 2	Tr agent 1	Tr agent 2	Household	Inv sector	Transp sector	Import	Export	Government
Region 1	good 1	1630	100	-420	0	0	0	0	0	-500	0	0	0	0	0	-780	0
	good 2	330	2100	0	-980	0	0	0	0	0	-800	0	0	0	0	-620	0
	pool good 1	-20	-200	1647	0	-1077	-350	0	0	0	0	0	0	0	0	0	0
	pool good 2	-330	-35	0	2129	-1247	-490	0	0	0	0	0	0	0	0	0	0
	labor reg2	-550	-580	0	0	2051	0	0	0	0	0	0	0	-31	0	0	0
	phys capital	-870	-1291	0	0	0	2181	0	0	0	0	0	0	-30	0	0	0
	oper surplus	-130	-94	0	0	270	-206	0	0	0	0	0	0	0	0	0	130
Region 2	good 1	0	0	-850	0	0	0	2500	230	-1200	0	0	0	0	0	-680	0
	good 2	0	0	0	-720	0	0	120	1800	0	-850	0	0	0	0	-350	0
	pool good 1	0	0	0	0	0	0	-80	-630	2354	0	-1204	-440	0	0	0	0
	pool good 2	0	0	0	0	0	0	-780	-80	0	1984	-944	-300	0	0	0	0
	labor reg2	0	0	0	0	0	0	-520	-590	0	0	2115	0	-25	0	0	0
	phys capital	0	0	0	0	0	0	-1352	-680	0	0	0	1744	-12	0	0	0
	oper surplus	0	0	0	0	0	0	-88	-70	0	0	-67	35	0	0	0	190
	tr reg1-reg2	0	0	-5	-7	0	0	0	0	-4	-6	0	0	25	0	0	0
	tr abroad-reg1	0	0	-5	-12	0	-15	0	0	0	0	0	0	36	0	0	0
	tr abroad-reg2	0	0	0	0	0	0	0	0	-10	-8	0	-9	27	0	0	0
	good1 imp	0	0	-360	0	0	0	0	0	-640	0	0	0	0	1800	0	0
	good2 imp	0	0	0	-410	0	0	0	0	0	-320	0	0	0	730	0	0
	capital imp	0	0	0	0	0	-230	0	0	0	0	0	-150	0	380	0	0
	trade bal corr	0	0	0	0	0	0	0	0	0	0	0	0	0	-2910	3430	-320

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2.2.1 Balance for economic agents

The production sectors in the counties choose inputs and outputs according to cost minimising and profit maximising behaviour, respectively, taking into account the market prices (see Appendix 1). Balanced production of the ten commodities, ten pool commodities, two services, two pooled services, the physical capital and the operating surplus commodity by the economic agent *s* in a county *r* in an equilibrium situation can be represented by the following production possibilities set

$$f_{sr}(X_{s1r},...,X_{s26r,}H_{s1r},...,H_{s20r},H_{s26r}H_{s27r},T_{s1r},...,T_{s170r})=0,$$

where X_{sir}, i = 1,…26, denotes output, H_{sir}, i = 1,…,26 denotes inputs of all produced goods plus inputs of county specific labour provided by households H_{s27r} and T_{sjr}, j = 1,…,170 denotes inputs of the various transport services. To achieve this balance, the amount of operating surplus commodity produced/consumed is calculated in such a way that the accounts for each sector balance.

Households in the counties perform consumption activities by selling their labor endowments to the production sectors and using the received income on the consumption of pool commodities. To achieve the balance of the activities for the households the operating surplus commodity is used.

Except for the economic agents on the county level there are also a number of production sectors at the national level such as the transport sector, the export and import sectors as well as the government sector. The balance of the activities for these economic agents is achieved by adjusting the produced/consumed amount of the trade balance commodity.

2.2.2 Balance for economic markets

Positive figures in the SAM correspond to inflow of goods and factors of production in the economy while negative to their outflow. According to the principle of the sign the whole model may be divided into a part for *supplies and outputs* and a part for *demands and inputs*. The two parts are supplementing in the sense that the supplies and outputs provides inflow of commodities, services and factors into the economy, whereas the demands and inputs represents the use of all available commodities, services and factors of production.

The sum of *supplies and outputs* of good *i* in county *r* is

$$Q_{ir} = \sum_{s} X_{sir} + \sum_{r'} ZM_{ir'r} + I_{ir} + \sum_{s} GX_{sir} ,$$

where $ZM_{ir'r}$ denotes delivery of goods from county *r'* to county *r*, I_{ir} denote import to county *r*, where imported goods is used in the county where it is imported, and GX_{s26r} denotes the operating surplus commodity if it represents supplies. Here the list of elements, which are non-zero in this equation, depends on whether the equation represents commodities, physical capital or services (*X*), pooled commodities or pooled services (*ZM* +*I*) or operating surplus commodities (*GX*).

Outputs of transport services needed to transport the total amount of commodities from county r' to *r* that is produced by the national transport sector is denoted

$$Q_{r'r} = TX_{r'r} .$$

The export sector buys commodities from the counties in order to export them abroad, and earn trade balance commodity in the amount *EX*. The trade balance is also possibly produced or consumed by the government sector in the amount *GB* if the value of export is less than the value of import and vice versa, respectively (i.e., operating surplus commodity in the amount *GB* is produced by the government in order to cover the trade balance deficit in case when the value of export is less than the value of import.). Thus, the output of the trade balance commodity becomes

$$Q_B = EX + \max\{0, GB\} .$$

The *demands and inputs* part of the model includes the households consumption of pooled commodities (*C*), the need for inputs (*H*) of pool commodities and pool services, labour and physical capital, delivery of goods in producer prices to other counties (*ZL*), export of goods from the counties to other countries (*A*) and demand and input of operating surplus commodities in the amounts (*G*). The demand and inputs of commodity *i* in county *r* become

$$R_{ir} = C_{ir} + \sum_s H_{isr} + \sum_{r'} ZL_{irr'} + A_{ir} + \sum_s G_{sir}$$

The list of the elements that are non-zero in this equation depends on whether the equation represents commodities, pooled commodities, services, pooled services, labour, physical capital or operating surplus commodities.

Demand for the transport services is given by

$$R_{r'r} = \sum_s H_{sr'r} ,$$

where $H_{sr'r}$ denotes input of the transportation between counties r' and *r* into the production of sector *s* in county *r*.

The demand equation for the trade balance commodity is $R_B = IH - \min\{0, GB\}$, where *IH* denotes demand of the trade balance commodity of the import sector and *GB* is the amount supplied or demanded by the government if the value of export is less than the value of import and vice versa.

Balance of the economic markets requires that Q_{ir} - R_{ir} = 0, $Q_{r'r} – R_{r'r}$ = 0 and $Q_B – R_B$ = 0, where the demands of a county *r* are supplied by deliveries from other counties and foreign countries (see Figure 2.2). This balance is obtained by adjusting the government's production/consumption of the operating surplus commodity, where main part of these adjustments is the taxes/subsidies that make up the price difference between seller and buyers market prices.

The trade balance commodity is finally used to simultaneously balance the government sector and the import and export activities, where the amount of the trade balance commodity in the government sector is interpreted as the national surplus or the national deficit depending on its sign. The amount of trade balance commodity that is finally needed to balance the government sector and the import and export activities also balances the market for the trade balance commodity, which is the consequence of a well-known property of matrices (Hardley, 1973). Thus all rows and columns of the SAM ultimately sum to zero.

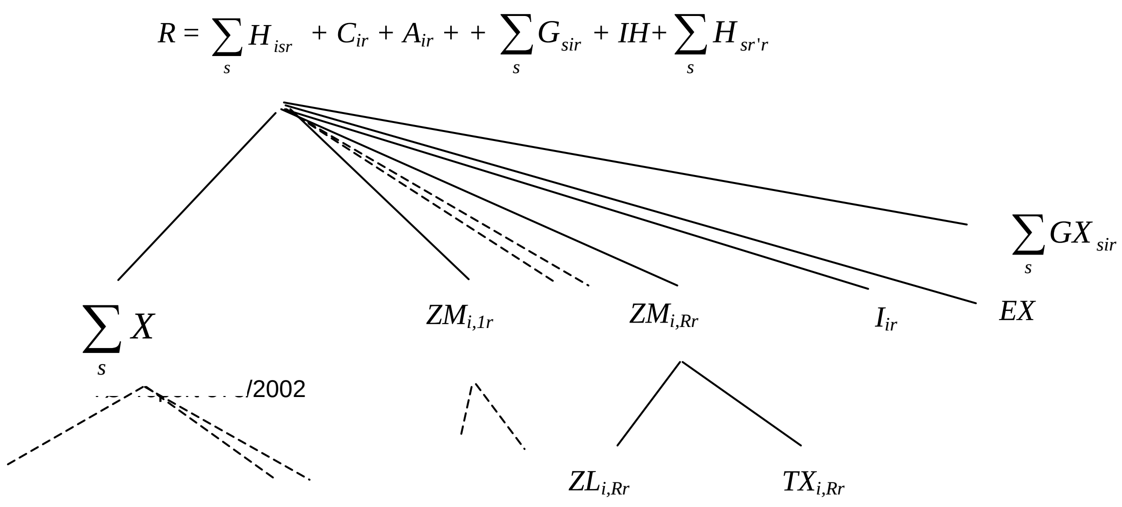

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Figure 2.2. Schematic view of the demand (*R*) of commodity *i* in county *r* and the supply (*Q*) of commodity *i* from all counties and other countries, where *R* is represented as the output at the "top" level and *Q* is represented as input at lower levels. An equilibrium situation requires that *R* - *Q* = 0.

2.3 Goods groups and economic agents in PINGO

2.3.1 Commodities and services in the model

Vold et al., (2002) choose 10 commodity groups for use in NEMO based on the requirements (1) that commodity groups can be linked to well-defined business sectors, (2) that the collection of commodities within each commodity group should have approximately the same requirements for transport quality (and thus transport costs), (3) that available data are sufficient to construct base year OD matrices for the commodity groups, and (4) that the shares of the commodity groups that are produced should vary little among the municipalities.

The commodity groups in PINGO are similar to those in NEMO, except that PINGO also includes a commodity group for physical capital (which is also a primary factor in production), whereas fish is not subdivided into fresh and frozen good in PINGO. The following groups of goods (commodities or services) are represented in PINGO:

***(01)** food, **(02)** fish, **(03)** thermo, **(04)** vehicles/machinery, **(05)** general cargo, **(06)** timber and wood ware, **(07)** coal, sand and gravel, **(08)** chemical products, **(09)** metals and ore, **(10)** bulk commodities (liquid), **(11)** reparation services, **(12)** other services, **(13)** physical capital.*

The fact that most available data sources group commodities according to business sectors, put strong constraints on how the commodity groups could be further aggregated to NEMO commodities. It is our opinion, however, that the groups are also relevant with respect to transport quality. Food, fish, thermo (food that require cooling or freezing while transported), and liquid bulk are all commodities with special requirements for transport quality. Chemical products and liquid bulk are both commodities that are classified as dangerous goods.

2.3.2 Production, service and investments

PINGO's production sectors produce different types of commodities using primary factors of production (labour and physical capital) as well as pool commodities and pooled services as inputs. The service sectors in their turn produce two types of services using the same types of inputs as the production sectors.

We have grouped and aggregated the 174 sectors that are represented in National Accounts Statistics by County (NAC) and the corresponding production of goods into a set of PINGO sectors for each county:

(01) food production, (02) fisheries, (03) timber, wood ware, paper and cardboard, (04) production of masses, (05) hardware production, (06) chemical industries, (07) production of metals and metal products, (08) bulk production, (09) high value products. There is also a sector for private and public services (10) in each county, and one (11) investment sector in each county that produces physical capital using pool commodities and county specific labour as input factors. An investment sector can only use labour from the county where it is located and produce physical capital for use in the county where it is located for maintenance of existing capital and new investments. The investment sectors themselves may use physical capital for production; hence figures for outputs of the investment sectors represent outputs of physical capital net of its intermediate consumption. Amounts of physical capital produced by each county specific investment sector is equal to the annual investments in the county, which include newly made investments as well as investments made to cover capital depreciation.

The largest output commodity from a sector is defined as the primary commodity for the sector. Other output commodities are termed secondary (Table 2.1, se also Jean-Hansen, 2001).

The primary good produced by the food production sector is the thermo commodity, whereas food and general cargo are secondary products. The fisheries produce fish as a primary commodity and thermo goods as a secondary commodity and so on. General cargo is a primary commodity in three PINGO sectors (sectors 3, 4 and 9). Food is not the primary commodity in any sector, but the secondary product in the food production sector.

Production technology for the production sectors is described by two level CES functions (Figure 2.3). The elasticity of substitution between labour and physical capital is 1, which corresponds to Cobb-Douglas technology and the elasticity of substitution between pool commodities is zero, which corresponds to Leontief technology. The elasticities of substitution between primary factors and the intermediate input goods are zero. It is further assumed that outputs from the production sectors are produced in fixed proportion, i.e., the elasticity of transformation between outputs is zero.

The operating surplus commodity is used (produced) in fixed proportion to other inputs (outputs). Hence there is a fixed rate of profit (loss) for each producer, derived from the base year situation.

Table 2.1. Production of primary and secondary commodities in the sectors represented by PINGO. Figures in brackets show the share of the total production of that is produced as secondary commodities

Sector in PINGO	Primary and secondary commodities								
1 Food production	Food (99)		Thermo		General cargo (10)					
2 Fisheries		Fish	Thermo (8)							
3 Timber, wood ware, paper and cardboard					General cargo	Timber and wood ware (99)		Chemical products (1)		
4 Production of masses					General cargo		Coal, sand and gravel (98)	Chemical products (1)	Metals and ore (2)	
5 Hardware production				Vehicles/ machinery					Metals and ore (3)	
6 Chemical industries					General cargo (2)			Chemical products	Metals and ore (1)	Bulk commodities (liquid) (1)
7 Production of metals and metal products				Vehicles/ machinery (8)			Coal, sand and gravel (1)		Metals and ore	
8 Bulk production							Coal, sand and gravel (1)			Bulk commodities (liquid)
9 High value products				Vehicles/ machinery (1)	General cargo			Chemical products (2)		
10 Private and public services										
The share of the production of the commodity as a primary commodity in one or several sectors.	0	100	91	91	87	0	0	96	94	100

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Investment sectors produce physical capital with Leontief technology and county specific pooled commodities as inputs (Figure 2.4).

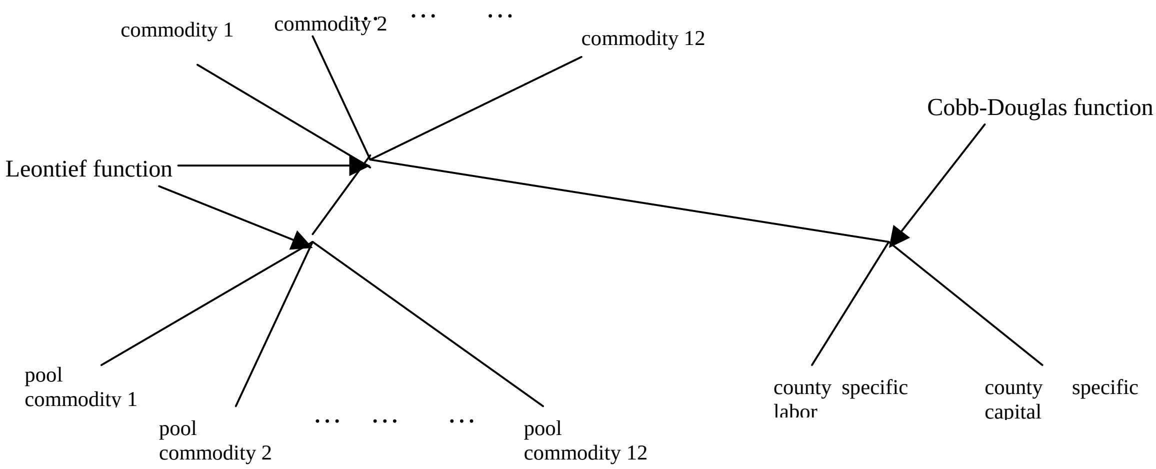

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Figure 2.3. Production tree for the production sectors.

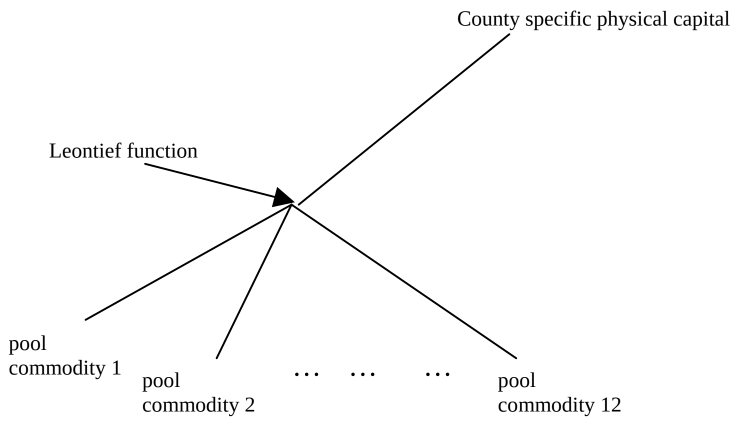

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Figure 2.4. Production tree for the investment sectors.

2.3.4 Transport services and agents

Since the transportation undertaken by the production sectors themselves is not represented as part of the National Accounts statistics, we had to make the assumptions that the costs for transport services are similar irrespective of whether they are organised by a specialised transport company or whether they are organised by the production sectors themselves. PINGO represents a national transport sector that undertakes transport of all commodities between all pairs of counties in Norway and between counties in Norway and other countries. The national transport sector is considered internal to the economy in the sense that the inputs are domestic labour from the respective counties that receives the transported goods and physical capital and pooled commodities.

A two level CES function represents the technology of the national transport sector. Input factors encompass labor from different counties and pooled commodities. The labor from different counties is merged with zero elasticity of substitution at the "bottom" level and various pooled commodities are merged likewise. Labor and pool commodities are then used in fixed proportions in order to produce transport services at the "top" level (Figure 2.5). The elasticity of transformation for the transportation sector production function is set at a large value, so that production of one transportation service may be perfectly substituted for the other.

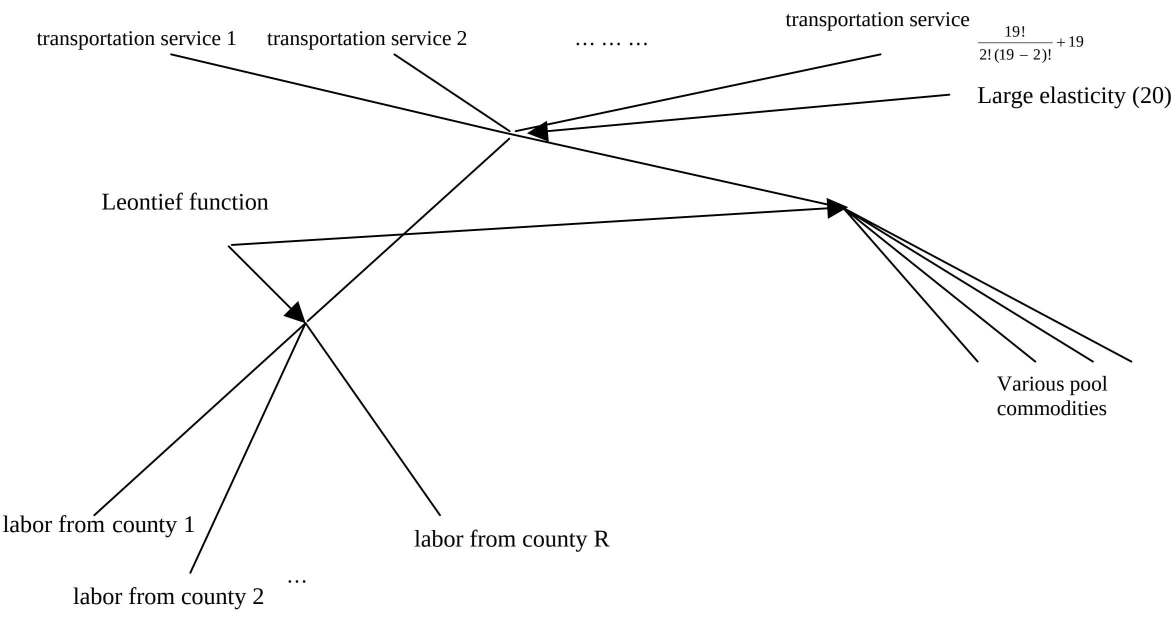

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Figure 2.5. Production tree for the transport sector.

Each of the 10 commodity groups in PINGO is associated with a commodity agent. His activity can be thought of as being separated into two parts: one part is to use transport services to transport commodities from all counties to the county where the agent is located; the other is merging the amounts arrived into the pool. The commodity agents use transport services for transport of a commodity group from one or several domestic counties and foreign countries into a pooled commodity[3] that is sold and used as input or for consumption in the county where the commodity agent is located.

The prices of pool commodities depend on the producer prices in the counties and the transportation costs. Commodity agents incur costs of transporting commodities from different counties, as well as prices of commodities from these counties. If the price of a produced commodity is reduced in a specified county, then the commodity agents tend to use more of the commodity from this county and less from other counties. The amount that is substituted depends on the relative prices as well as on the elasticity of substitution for the agents.

At the “bottom” level of the commodity agent’s CES function, commodities from the counties and transport services are used in some fixed proportions according to Leontief technology. At the “top” level, the commodity agent is merging the transported commodities into a pool (Figure 2.6).

We have assumed rather large elasticity of substitution (20) between the same types of goods produced in different counties. It is our intention, however, to estimate this elasticity according to appropriate estimation methods and empirical data in future versions of PINGO.

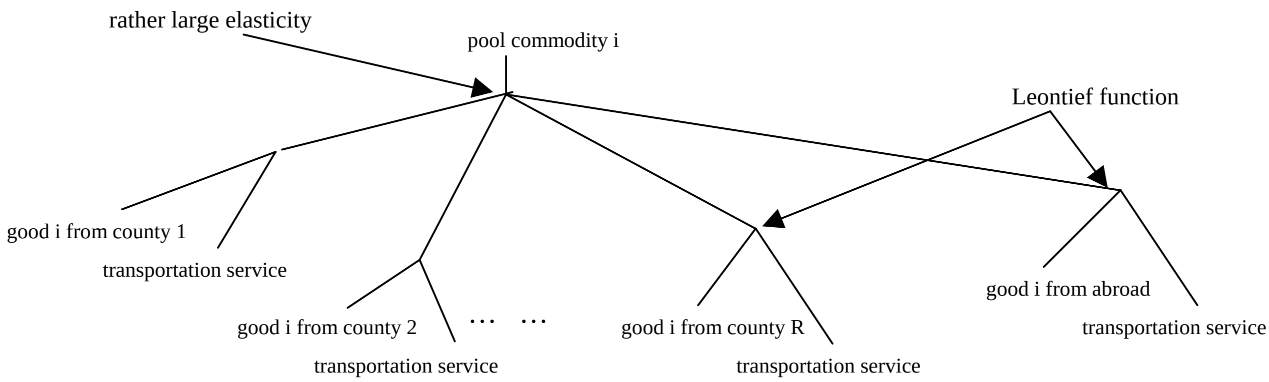

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Figure 2.6. Production tree for the commodity agents.

Two service agents in each county corresponding to the two types of services are represented in order to account for the difference between producer and consumer prices of the services. The amount of services produced by the service sector is in producer prices while the amount of services produced by the service agents are in consumer prices. The services produced by the agents are called pool services and they are used in the production of the commodities and in the production of physical capital. Transport connected with services is relatively minor as compared to transport of commodities and is not included in the first version of PINGO.

[3] Moses and Chenery (1990) introduced the so-called pooling concept.

2.3.5 Import/Export

The share of imported commodities depends on the price of imported goods including cost insurance and freight (CIF) as compared with the prices of domestic production, and of course the exchange rates.

Import and export activities are performed by the national import and export sectors. The export sector uses domestic commodities from different counties in order to produce the *trade balance commodity*, which may be thought of as foreign currency. It can be used to buy the imported goods or it can be saved as *national surplus* **.**

The import sector in its turn produces imported commodities using the trade balance commodity alone. The more goods are imported from abroad the greater is the demand for the trade balance commodity. The price of the trade balance commodity can be interpreted as the exchange rate between domestic currency and some aggregate of all foreign currencies. If the price level in Norway decreases relative to price levels in other countries, the exchange rate increases, hence there is less import and/or more export.

The activity level of the export sector is driven by the demand for the trade balance commodity, which in its turn depends upon the demand for imported goods. The greater is the demand of imported goods (which may be the case when labour endowments of the households are increased) the greater is the activity level of the export sector and amounts of exported domestic goods increase proportionally.

A trade balance deficit appears if the demand for import exceeds the value of the produced trade balance commodity. In this case the government imposes taxes on the production sectors and households in the amounts that finance the trade balance deficit.

However, the value of import cannot be much higher than the value of export since the government has limited possibilities to finance the trade balance deficit i.e. to produce the trade balance commodity.

2.3.6 Representative households

In PINGO there is neither distinction between the types of households nor the types of labour. There is one representative household in each Norwegian county in the model. Households income available for consumption comprise income from labour minus income taxes and taxes paid by the production sectors (i.e., social costs etc.), income from transfers[4] (social security) minus direct income tax, borrowings and profits earned from ownership in the production sectors, where the profit is the enterprises net of capital depreciation and new investments.

It is assumed that households use all income from available labour endowment to buy pooled commodities for consumption. Thus, the household's operating surplus commodity represents all their incomes except wage that is used to buy pool commodities, i.e., transfers from the authorities, distributed profit of the sectors and income taxes, and some other income and spending of the households.

Commodities like cars, furniture, electrical units and clothes are assumed consumed in the year they are bought.

[4] Transfers can be an important alternative or supplement for counties with weak production activities and weak income generation. Income generates purchasing power and consumption, which makes the foundation for production activities and employment, which may affect the regional development.

Representative household's preferences for different pool commodities provided by the respective commodity agents in each county are fully specified by their CES utility function that are fully described by representative consumption bundles and a zero elasticity of substitution between different commodities (Figure 2.7).

The households maximise their total utility constrained by the budgets, where the budget covers all costs of living including the services and housing rent, i.e., assuming non-satiation of the household's utility function the budget gives us its expenditure level.

It can be noticed that the utility functions do not include services. The reason is that there were no data available on the consumption of services by the households. But the present version of PINGO includes household's expenditures on services as part of the operating surplus commodity for consumers.

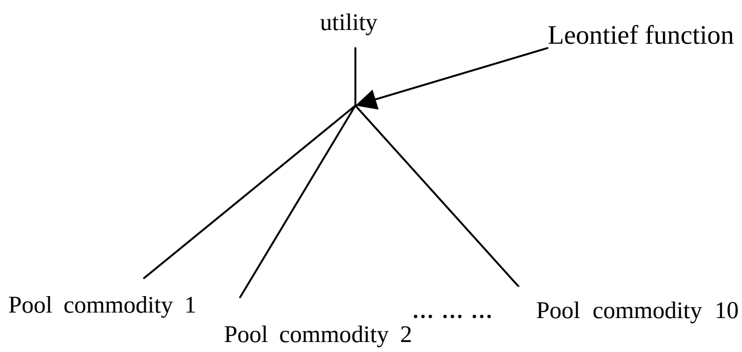

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Figure 2.7. Schematic view of the utility function for the county specific households.

2.3.7 Government sector

The national government sector is a balancing agent in the model. It produces/consumes both operating surplus commodities and trade balance commodity in amounts that clear the markets for these commodities. Production/consumption of the operating surplus commodities by the government sector is interpreted as subsidises/taxes for the respective counties. Production of the trade balance commodity is performed when it is necessary to finance the trade balance deficit and taxation of the counties. On the other hand when there is a trade balance surplus the counties may be subsidised**.**

2.4 Equilibrium conditions

We make the assumption that all economic agents in PINGO are well informed about all prices and act as the price-takers, and we assume that the producers adjust the prices in order to maximise profit, whereas the households are utility maximising consumers and owners of the labour endowments (see Appendix 1).

The profit maximising input-output coefficients $\mathbf{A}(\mathbf{P})$ are functions of prices $\mathbf{P}$ and production levels of all agents in the economy and are calculated per unit of production level. Let $\mathbf{A}(\mathbf{P})$ represent the general input-output matrix with coefficients for various goods in the economy, where each column include inputs (negative) and outputs (positive) in a sector (input-output vectors) and where rows includes all inputs and outputs of a factor.

We formulate PINGO as the following Mixed Complementarity Problem (MCP) where a vector $(\mathbf{P}^*, \mathbf{X}^*)$ with **P*** denoting prices of goods and **X*** denotes outputs, represents a general equilibrium in the economy if and only if:

(1) No activity earns positive profit: $-\mathbf{A}(\mathbf{P}^*)^T \mathbf{P}^* \geq 0$

(2) No commodity is in excess demand: $Q(\mathbf{P}^*) - R(\mathbf{P}^*) \geq 0$

(3) No prices or activity levels are negative: $\mathbf{P}^* \geq 0$, $\mathbf{X}^* \geq 0$

An activity earning negative profit is not operated and a non-zero activity level **y*** gives zero profit: $\left[-\mathbf{A}(\mathbf{P}^*)^T \mathbf{P}^*\right]^T \mathbf{y}^* = 0$,

(4) A commodity in excess supply is free, and a positive price implies market clearing by Walras' Law: $\left[\mathbf{Q}(\mathbf{P}^*) - \mathbf{R}(\mathbf{P}^*)\right]^T \mathbf{P}^* = 0$.

Equilibrium prices and activity levels $(\mathbf{P}^*, \mathbf{X}^*)$ are fully defined by the endowments of the consumers, which are the only exogenous variables that need to be fixed in the model and other variables that optionally exogenously set, e.g. prices on any good or labour can be fixed or endogenously determined.

2.4 Implementation

General equilibrium can be formulated as a system of non-linear equations and solved with a standard non-linear equation solver (see the example in the Appendix) or as a non-linear optimisation problem that is solved with the aid of general optimisation algorithms. Both methods have weaknesses. A better way of solving the problem is to formulate and solve the problem as a Mixed Complementary Problem (MCP) (Mathiesen, 1984).

MPSGE[5] software is used to implement and solve the first version of PINGO as a MCP. In the standard MPSGE model, utility functions are quasi-homothetic and production functions exhibit constant returns to scale.

The utility functions in MPSGE have the CES functional form and are fully specified by the demands in the benchmark situation and the elasticity of substitution between the goods. In the first version of PINGO the elasticity of substitution between consumption goods is supposed to be zero, i.e. CES functions are reduced to the Leontief form.

[5] MPSGE (*mathematical programming system for general equilibrium analysis*) is an extension of the GAMS programming language (Rutherford, 1995). MPSGE is a specialised for solving systems of equations that includes NCES-functions. The MPSGE Software is used to formulate and solve general equilibrium problems as "Mixed Complementary Problem" (MCP).

Production functions in MPSGE are represented by nested constant elasticity of substitution (NCES)[6] functions in order to merge two or more inputs into an intermediate product when the intermediate and not each basic input factor are used to create the final product. The NCES functions includes estimates of reference coefficients for the shares of the different input factors that specify a point on a specific isoquant or indifference curve, and estimates of the elasticities of substitution σ that gives us the curvature of the isoquant or indifference curve, and thus how the isoquant bends around the benchmark point, which is to say how the model responds to price changes.

MPSGE represents the output structure of production sectors in terms of constant elasticity of transformation (CET) functions, which are similar to CES functions. CET functions are fully described by the elasticities of transformation and reference coefficients for shares of output of each commodity and service.

When PINGO is formulated in the MPSGE programming language almost all variables in the model may be fixed or changed exogenously though in the concept of the Walrasian equilibrium the only exogenous variables are endowments of the households. This property of the program allows us to perform different kind of economic analysis with PINGO and gives it additional flexibility. Variables to be made exogenous are determined by the user according to the aims of his research. Some of the examples of possible exogenous variables and their use in the analysis performed with the model are given in test cases in Chapter 4.

MPSGE computes equilibrium prices and quantities when a model is properly specified in terms of production functions, utility functions, endowments etc. and the accompanying Social Accounting Matrix with one row for each commodity and factor input representing equilibrium between supply and demand.

The SAM is used for estimation of the representative share coefficients of the CES and CET functions in the MPSGE modelling system. The reference coefficients for the share of inputs and outputs are estimated in such a way that PINGO reproduces the economic situation in the base year 1999 (i.e., the SAM) if none of the exogenously given variables are changed. If some exogenous variables are changed, however, then PINGO find new values for gross production of each commodity in the counties, budget constraints in the counties, import shares of commodities to the counties, consumption of each commodity in the counties, transport of every commodity within and between the counties and between the counties and other countries and prices of commodities, services and labour, such that equilibrium is reached again in all markets.

While estimation of the reference coefficients for NCES and CET are performed on the basis of the data for the base year, the elasticities of substitution cannot solely be estimated on the basis of data from the base year. There can be need for time series analysis that is rather data and time consuming. That is why the elasticities of substitution were simply set at 0 (Leontief), 1 (Cobb-Douglas) or at some “qualified guess” in the first version of PINGO.

[6] NCES functions are briefly described in Appendix 1

3 Data in the Social Accounting Matrix

For a full-scale version of a SAM in PINGO, we must collect data for all sectors and commodity groups.

National Accounts Statistics present figures at market values that are subdivided in different value sets. There is a total of eight value sets. The producers price (18 values) is subdivided in (10=) basic value (non-zero for services), (11 =) VAT on the basic value, (12 =) special commodity taxes paid by the producer and (13 =) special commodity subsidies. The trade margin (19 values) is subdivided in (14 =) basic value of the trade margin (zero for services), (15 =) VAT on basic value of the trade margin, (16 =) special commodity taxes paid by wholesalers and retailers, and (17 =) subsidies connected with wholesale and retailing activities.

National Accounts Statistics report the gross production and the import in terms of producer prices (18 values), whereas the demand is valued in market prices (18+19 value). This means that the supplies and outputs part of the economy is valuated according to the basic value (10 value) which means that VAT, profit and taxes/subsidies are kept out, whereas the demands and inputs part of the economy is valued in market prices (18+19). Hence, the two parts of the economy are calculated in different value set.

The different value sets have the consequence that rows in the SAM matrix for the economy do not sum to zero. Understanding this fact it is possible to adjust the government supply or demand of the commodities in order to balance the SAM matrix, i.e., we calculate the values of elements for any i and r in the equations to balance the SAM for the benchmark situation, in such a way that $Q - R = 0$ (i.e., rows sums to zero).

Columns in the SAM matrix representing outputs and inputs of the production sectors and households should also sum up to zero. To ensure this we adjust operating surplus. A fully balanced SAM matrix corresponds to the equilibrium in the economy, i.e., rows and columns sum to zero.

3.1 Production

We have collected data for input and output in production from National Accounts by County (NAC) for 1997. The reason why we haven’t collected data for a later year (the base year is 1999) is that NAC is not available for later years. And since the NAC for 1997 is not complete, it has been necessary to separately collect some quantities to make a complete account for the commodities and sectors in PINGO. We do not consider this to be a serious inconsistency, however, since there were few structural changes in the Norwegian economy fro 1997 to 1999 and low inflation rate during this period.

Statistics Norway has aggregated the sectors and goods that are represented in NAC (174 sectors and commodities) to the PINGO-commodities and -sectors as specified by TØI**,** and gross production and inputs of commodities and services in every county. Inputs for production of physical capital (i.e., tangible assets) subdivided by PINGO-commodities for every county were obtained as part of the investment figures from NAC.

This includes figures for both the private and the public sectors. They are included as inputs in PINGO's investment sector for production of tangible assets (i.e., physical capital). From the data we were able to calculate the total output and input in Norwegian counties.

The valuation of the annual consumption of the 10 commodities according to market values amounts to 573 milliards NOK, where quantities that are not subdivided by county, mainly crude oil from the Continental shelf are not explicitly included. The total input to production of services that are subsequently used as inputs to produce commodities and other services amount to 492 milliards NOK where 312 milliards NOK are services and 180 milliards NOK is commodities (Table 3.1).

Table 3.1. Inputs to production of services that are subsequently used as input to production of commodities and other services

Commodities in PINGO Units	Service sector (N10) mrd NOK	Other sectors (N1-N9) mrd NOK	All sectors mrd NOK	Percentage in N10
1 Food	5	12	17	30
2 Fish	2	12	14	11
3 Thermo	6	34	41	15
4 Vehicles/machinery	56	47	103	54
5 general cargo	50	36	86	58
6 Timber and wood ware	17	10	27	62
7 Coal, sand and gravel	2	4	6	32
8 Chemical products	19	24	43	44
9 Metals and ore	5	36	41	13
10 Bulk commodities (liquid)	19	21	41	47
Inputs (commodities)	180	237	418	43
Inputs (services)	311	98	409	76
Total input	492	335	827	59

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The first version of PINGO do only represent production of services that are used as input to inland production of commodities and other services, but we have not made subdivision between services domestically produced and imported.

The value of input of commodities to the service sector amounts to 43 percent of the whole of the commodity input to the Norwegian economy. The service sector uses much timber and wood ware and general cargo (62 and 58 percent, respectively), but less commodities like fish, metals and ore and thermo (11 to 15 percent).

Table 3.2. Shares (percentage) of input to the service sector in different parts of Norway. The rightmost column shows how much the shares deviate relative to the population share in 1999

	Population share	Inputs to the service sector	Deviation from population share
Eastern – Norway	55	62	12,7
Western – Norway	26	29	10,2
Northern – Norway	19	10	-49,9
Norway	100	100	0,0

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The service sector (N10) is well represented in all counties, but to a greater degree in Oslo, Hordaland, Akershus and Rogaland, and to a lesser degree in Northern-Norway (Table 3.2).

The Foreign Trade Statistic (Statistics Norway, 1999) contains information about the amount of Norwegian import and export of commodities and which transport mode that is used to transport the commodity. The Foreign trade statistic represents data such that commodities for export change owner where the commodity is sent out of Norway (delivered ”free on board” – FOB), whereas commodities for import are represented such that the change of ownership takes place where the commodity is tolled in, i.e., cost insurance and freight is paid by the producer (CIF), which correspond to the conventions that are used for ”change of ownership” by the International monetary fond (IMF).

We have aggregated the commodity groups in the foreign trade statistic to NEMO – commodities, and we take advantage of the fact that the statistic were considerably improved from 1997 in that the production county for export were registered, as opposed to earlier statistics were only the place of tolling were registered.

3.2 Interregional delivery

The “SAM” – matrix includes elements for the value of goods that are transported between pairs of counties *ZL* and the corresponding transportation costs *TX*. We need to quantify the value of the transported commodities (basic values) and transport costs per ton commodity between and within counties.

Traditionally it would be difficult to obtain the data that are needed to estimate production functions for the national transport sector and the transport agents. However, with the aid of the national network model for freight transport NEMO (Vold et al., 2002) we may obtain the operating costs of transport between pairs of zones and transported volumes (tonnes) of each commodity between pairs of counties and between Norwegian counties and other countries in the base year. Production accounts for various transport operators for train, road and sea (obtained from Statistics Norway, 1999) made it possible to collect data for primary factors, commodities and services that are used as input to the national transport sector.

OD matrices for the tonnes transported between counties must be transformed to values. Using the following relationship to calculate the price per unit of commodity that is delivered from region r, and then use this price to transform from tonnes to value can do this:

$$p_{ir} = \frac{\sum_{j=1}^{10} X_{ijr}}{\sum_{r'} t_{rr'}^{i}}$$

where j denotes production sector, i denotes commodity group and r and r' denotes domestic counties or foreign countries and $t_{rr'}^{i}$ denote tonnes of commodity i transported between r and r'.

NAC report only net transport of each commodity group into (*ZM*) and out (*ZL*) of the counties. In such cases, we have that the total delivery of a commodity group out of plus into a county will be greater than the net commodity flow in NAC. However, since the commodities in NAC are relatively small, we have that separate aggregation of positive and negative commodity flows becomes close to the total flow in plus out, i.e., if commodities are very disaggregated it is more probable that they are produced in only one county. For import and export, we obtained separate values for import (*I*) and export (*A*) from the Foreign trade statistic (Table 3.3, 3.4).

There is also a county internal transport of pool commodities for consumption (*C*), and for use as input to production and for investments (*H*) (Table 3.5). For commodities where (Sum in + Sum intern – Sum out) is negative, we have that the commodities have a higher basic value than the price paid by the buyer (i.e., the market value). This implies that the sums of the values (components) from 11 to 17 are negative. This is typically a commodity that have a low profit and/or that are produced by a sector that receives subsidies. There can also be errors in the statistics. We have for instance not assessed the value of changes in stocks, i.e., that the commodity is produced, but is in storeroom and therefore are not sold. These changes are implicitly represented, however together with transfers etc. as part of the balancing factors (*G* and *GX*).

The reason for the low profit for food is probably due to some subsidies (agricultural subsidies is included in commodity trade in the national accounts, i.e., there are large negative 17 values)**.** Fish production is also subsidised, but these are far less since a great part of the fish is exported or further treated in industries. Further treated fish in vacuum packed or packed frozen is part of Food, since this commodity is sold directly in retail stores. For thermo goods, there are consumer subsidies as for food.

Vehicles/machinery has a large surplus since this is a commodity with both a high profit and high and specialised commodity taxes (12 value). This gives a small 10 value, which gives a surplus (Table 3.5). This is what one would expect for a typical situation for a balance of commodities, i.e., the 10 value is less than the 18+19 value (buyers cost). This situation is also representative for commodity 5 general cargos, commodity 8 Chemical products and for commodity 9, metals and ore. The reason for the large imbalance for commodity 10, liquid bulk products, is that this commodity is used as input in the continental shelf and the Norwegian military, which is not explicit part of the PINGO model.

Table 3.3. The aggregated commodity flow into the counties *(*ZM*)* and other countries *(*A*)* in market values (18+19 values). Mrd NOK.

PINGO commodity	Inputs	Export	Sum in
1 Food	17	2	19
2 Fish	14	20	34
3 Thermo	41	1	41
4 Vehicles/machinery	103	30	133
5 General cargo	86	28	114
6 Timber and wood ware	27	1	28
7 Coal, sand and gravel	6	0	6
8 Chemical products	43	22	65
9 Metals and ore	41	31	72
10 Bulk commodities (liquid)	41	19	60
Sum commodities 1-10	418	155	573

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The commodity *Timber and wood products* and the low value commodity *Coal, sand and gravel*, there are large negative values that are not caused by subsidies. These can be commodities that are not sold, but stored. A more likely explanation, however, is that the majority of commodities of this kind is delivered to entrepreneurs in the investments sector and that the input flows were not accounted for in CNA 1997. We have for instance that the new national airport Gardermoen were under construction in 1997 with a large production bulk products that were delivered to this project. NA for Norway do not account for these investments until the project is finalised.

Table 3.4. The aggregated commodity flows from the counties (production) (*ZL*) and imports of commodities to counties (*I*). All figures are valued in basic prices. Milliards NOK.

PINGO commodity	Import	Production	Sum out
1. Food	8	91	99
2. Fish	3	36	38
3. Thermo	4	66	69
4. Vehicles/machinery	94	15	110
5. General cargo	76	100	177
6. Timber and wood ware	4	35	38
7. Coal, sand and gravel	2	50	52
8. Chemical products	22	19	41
9. Metals and ore	8	19	27
10. Bulk commodities (liquid)	5	2	7
Sum commodities 1-10	225	433	658

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Table 3.5. Commodity flows into the counties, intern (18+19) values, internal and out of counties (Milliard NOK)

PINGO commodity	Sum inn (18+19)	Sum intern (18+19)	Sum ut (10)	Inn + intern – ut
1. Food	19	52	99	-28
2. Fish	34	4	38	-1
3. Thermo	41	10	69	-18
4. Vehicles/machinery	133	168	110	191
5. general cargo	114	121	177	58
6. Timber and wood ware	28	2	38	-9
7. Coal, sand and gravel	6	0	52	-46
8. Chemical products	65	12	41	37
9. Metals and ore	72	1	27	46
10. Bulk commodities (liquid)	60	34	7	87
Sum commodities 1-10	573	404	658	318

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3.3 Consumption

There were 2 049 000 households in Norway in 1999 (Statistics Norway, 1999). Total consumption cost (services and commodities) were 268 514 NOK per household in 1999. Total Private consumption amounts to about 548 milliard NOK (46 percent of the GDP in Norway) in 1999, where 305,6 milliard NOK was consumption of commodities and the rest was consumption of services (Figure 3.1).

We applied data from the Consumption survey for private households of Statistics Norway to estimate the total consumption in the years 1998-2000 per household in (1)

Akershus and Oslo, Hedmark and Oppland, (2) the rest of the counties in South-Eastern Norway, (3) Agder and Rogaland, (4) Western Norway, (5) Trøndelag and (6) Northern Norway. The average shares of total consumption in the counties for each of the commodities and services were then used to get the total consumption costs for each of the commodity groups in the counties (Table 3.6).

Table 3.6. Consumption expenditure and investments in Norway (milliard NOK in 1999) subdivided by PINGO-commodties as measured in 18+19 values (milliard NOK)

PINGO commodity	Private consumption	Investments	Sum intern
1. Food	52	0	52
2. Fish	4	0	4
3. Thermo	10	0	10
4. Vehicles/machinery	71	97	168
5. general cargo	116	5	121
6. Timber and wood ware	0	2	2
7. Coal, sand and grave	0	0	0
8. Chemical products	12	0	12
9. Metals and ore	0	1	1
10. Bulk commodities (liquid)	34	0	34
Sum commodities 1-10	300	104	404

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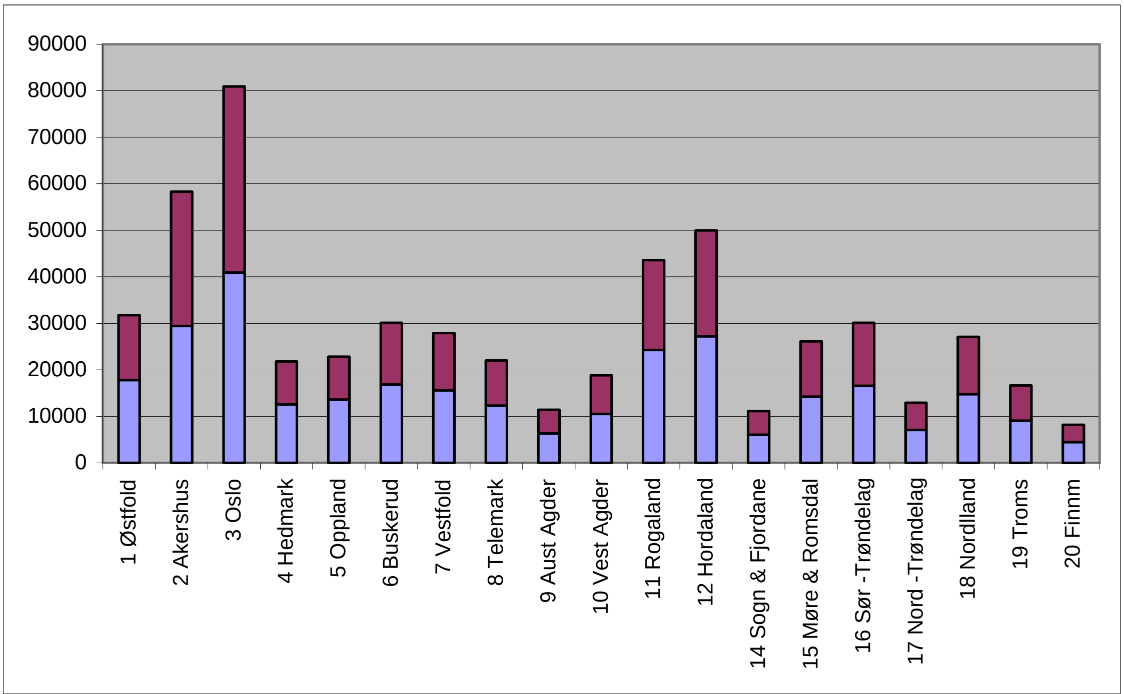

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Figure 3.1. Total private consumption of commodities (lower part of bars) and services in the counties.

4 Test cases

PINGO allows us to carry out many different types of simulation experiments, and to conduct a comprehensive investigation of the economic adjustment processes induced by assumptions about external shocks or by specific hypotheses of economic growth. In order to verify PINGO we may identify whether the model assesses casual relationships among variables and relative magnitudes of variables that are reasonable from a theoretic and intuitive point of view.

There are broadly two classes of simulation experiments for verifying PINGO:

1) Simulations based on the adoption of values for exogenous variables that are different from their values in the benchmark situation.

2) Simulations based on the modification of system parameters relative to values used for the benchmark situation.

The first class includes:

- Changes in available labor endowments in the counties.
- Changes in prices on selected domestically produced or imported commodities.
- Changes in prices on transport or other services.

The second class includes:

- Technological progress and change in the input/output mix
- Adoption of investment plans in transport infrastructure affecting transportation costs and/or carrying capacities
- Changes in consumer tastes
- With the operating surplus commodity it is possible to demonstrate consequences of changes in regional policy.

We have run four test cases for verification of the first version of PINGO. For each test case we report changes in total production and consumption in the counties and freight transport flows between counties as relative to the benchmark situation. Import and export is additionally reported for test case 3.

We also need to report the average distance per unit of goods transported. In lack of a directly available indicator for the average distance, we used the proxy (in NOK):

$$\Sigma = \frac{\sum_{i,j,k} t_{ij}^{k} c_{ij(base)}^{k}}{\sum_{i,j} t_{ij}^{k}},$$

where t_{ij}^{k} is the amount of goods of type *k* in tons transported from county *i* to county *j* and $c_{ij(base)}^{k}$ is the base-case costs of transporting volumes of goods of type *k* from county *i* to county *j*, which is a proxy for the distance between counties *i* and *j*[7].

For the base-case we have that $\sum = 280.17$ NOK.

In *Test case 1*, we applied PINGO for a situation where labour endowment in Oslo increases by 6% relative to the benchmark situation. This increase production (Figure 4.1), and result in a sharp increase in transportation flows originating in Oslo (Figure 4.2). The increase in production in Oslo stimulates production growth in counties that are connected with Oslo through interregional trade, which have the effect that transportation flows that originate and terminate in these counties increases (Figure 4.2 and 4.3).

It is interesting to notice, however, that the total consumption in the Oslo County goes down (Figure 4.4), which is due to reduced price of labor relative to prices of pool commodities in Oslo. Increasing consumption prices can be explained by the fact that there is no substitution between intermediate goods and labor (i.e., Leontief technology, see section 2.3.2), which does not allow the sectors to substitute intermediate goods with now cheap labor and increase production in order to meet increasing demand.

The proxy for average distance becomes $\Sigma_{case1} = 280.399$ NOK, which indicates a small increase in the transportation distance per ton of commodity.

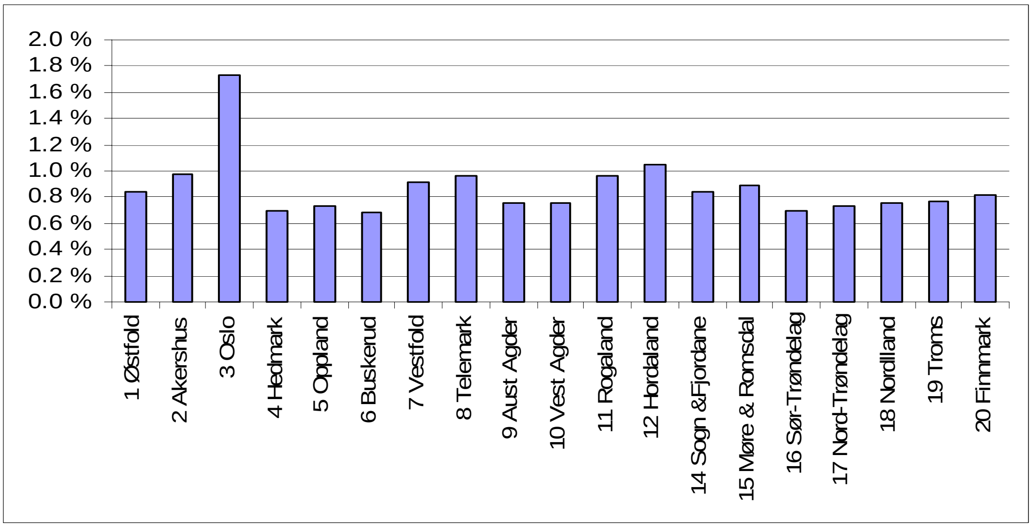

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Figure 4.1. Change in total production by county.

[7] It is noted that transport costs from other countries to Norway are constant in PINGO.

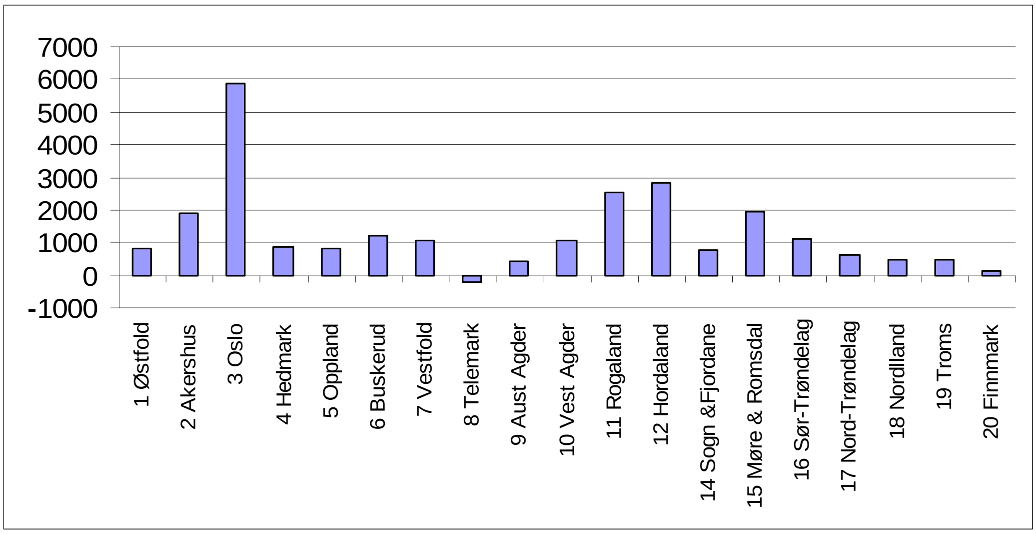

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Figure 4.2. Changes in transportation flows that originate in the counties (1000 NOK).

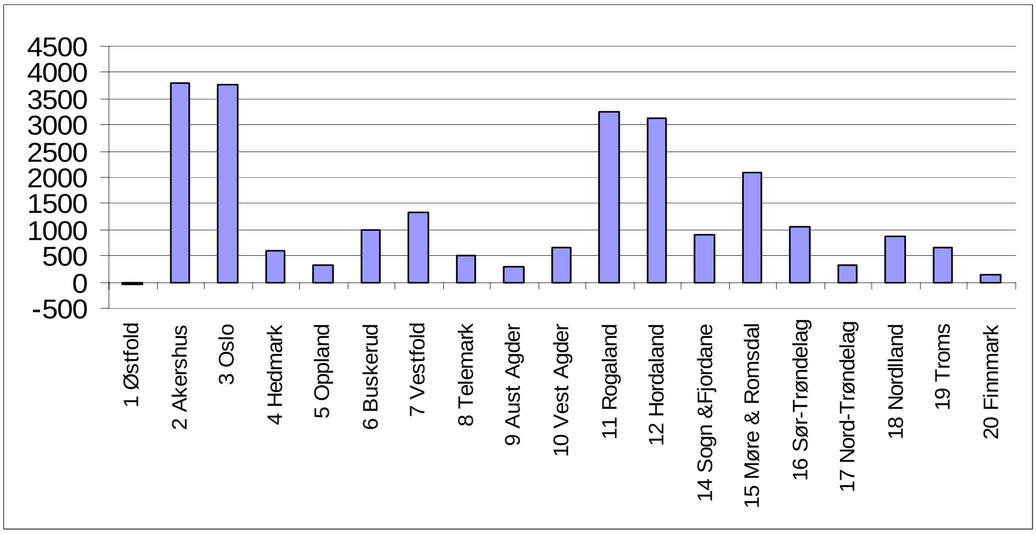

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Figure 4.3. Changes in transportation flows that terminate in the counties (1000 NOK).

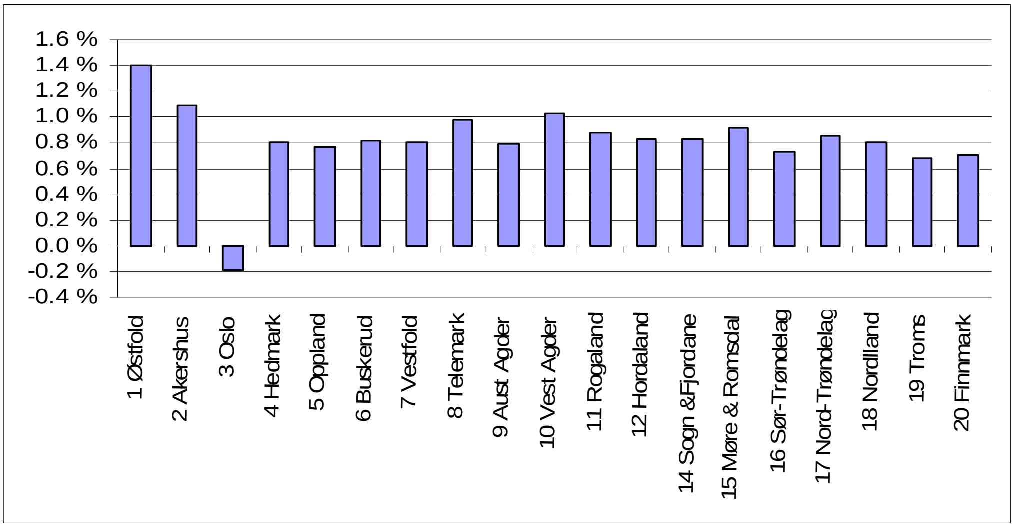

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Figure 4.4. Percentage change in total consumption by county.

Test case 2 differs from the previous test case in that we increase labor endowment by 5% not only in Oslo but also in all other counties. The results show that the overall increase in labor endowments leads to increased production in all the counties (Figure 4.5) and corresponding changes in transportation flows originating from and terminating in the counties (Figure 4.6 and 4.7). Most of the increase is located in Akershus, Oslo, Rogaland and Hordaland. We may conclude that the model correctly predicts that these counties are the most economically important, and the ones that are associated with the largest transportation flows.

The changes in the absorption of transportation flows are a bit different from those of Test case 1, which can be due to the fact that the distribution of the population over the country does not correspond to the distribution of production activities.

Consumption in the counties is positively affected as demonstrated in Figures 4.8. An exception is Oslo, where the total consumption has been reduced. The explanation for the negative change in household incomes and consumption in Oslo is probably the same as for Test case 1, and that other counties produce more of their needs themselves when their available labour endowments increases and that Oslo is more negatively affected since its wages constitute a greater share of the household income.

The reason for a reduction of the proxy for the average transport distance $\Sigma_{case2} = 279.029$ NOK, can be that nearby counties produce a greater part of the commodities, which gives less need for long-distance transportation.

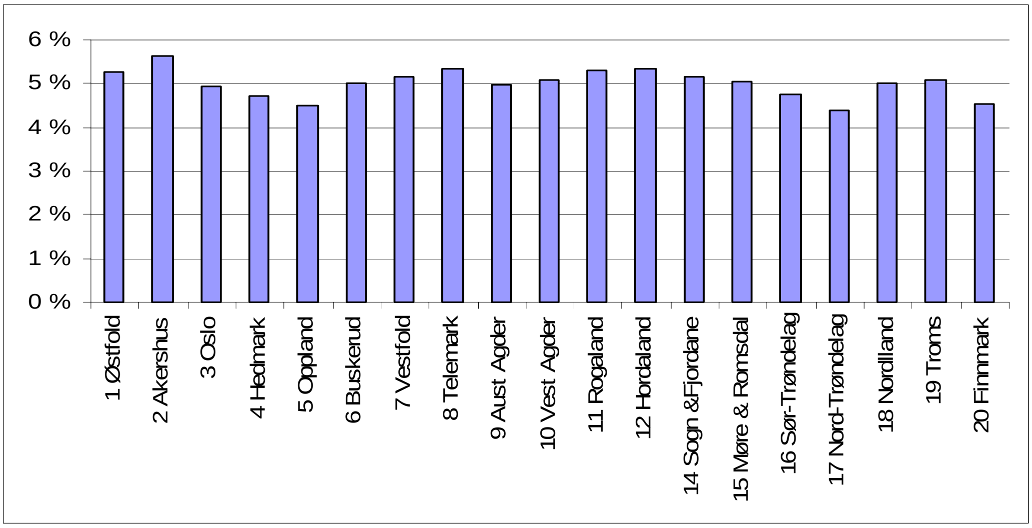

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Figure 4.5. Change in total production by county.

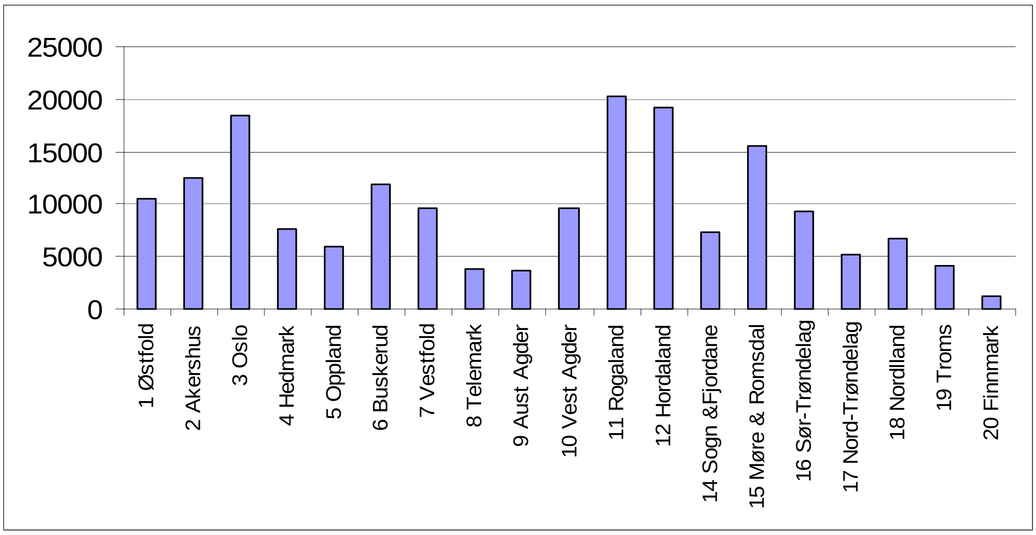

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Figure 4.6. Changes in transportation flows that originate in the counties (1000 NOK).

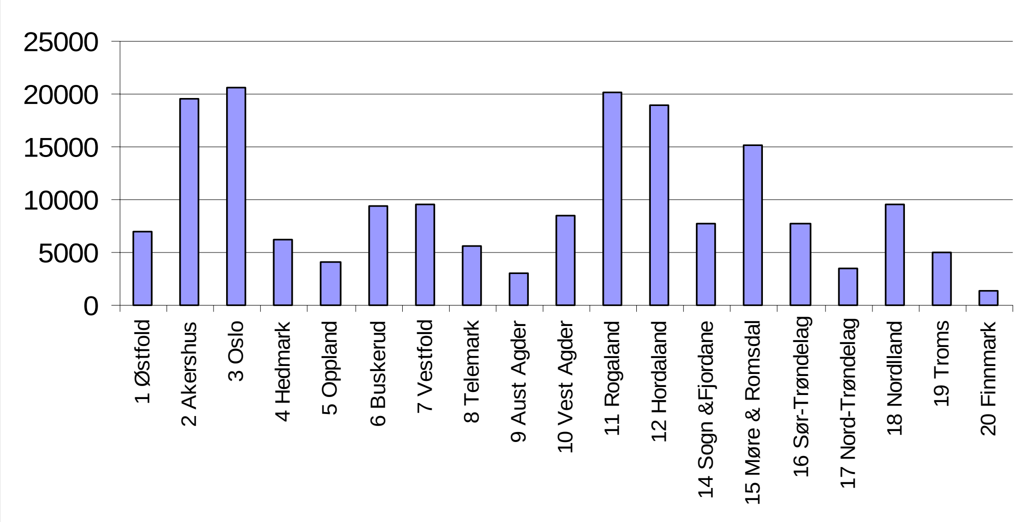

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Figure 4.7. Changes in transportation flows that terminate in the counties (1000 NOK).

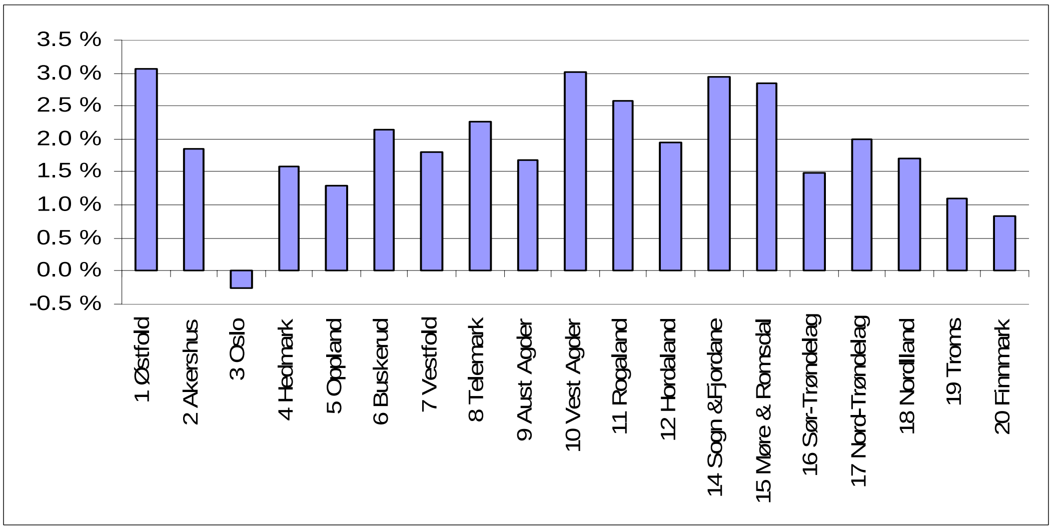

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Figure 4.8. Percentage change in total consumption by county.

Test case 3 was run in order to investigate the effect that a 5% increase in the price of imported goods will have on the transportation flows (e.g., added import tax). An overall effect is the reduction in imports going to all the counties relative to the benchmark situation (Figure 4.9). The greatest effects are found for Østfold, Akershus and Oslo respectively, which is reasonable, since these are the counties that are associated with the largest shares of the total imports. The percentage change in import for the counties is quite similar (about - 4.5 %), except for Troms that has and 8% reduction in imports (Figure 4.10). The increased price on imported goods reduces production and transportation flows, except for Østfold where production and originating and terminating transportation flows increases (Figure 4.11, 4.12 and 4.13). However, consumption is reduced in all counties (Figure 4.14). The average distance of transportation was reduced: 279.76 NOK.

The anomalous results for Østfold may be due to Østfold's role as a transit point for much import to other counties and that the model due to the lack of necessary data does not reflect this empirical fact. The anomalous import to Østfold gives a benchmark situation with incorrectly high consumption in the private households in Østfold, and the effect that private consumption includes an incorrectly high share of imported commodities. Higher import prices reduce demand for import and increase the demand for domestically produced commodities (administrated by the commodity agents). This have the consequence that a greater part of household's income in Østfold is used for domestically produced goods, whereas the artificially high government subsidies to households to finance the artificial import to Østfold (which is actually transit import to other counties) in the benchmark situation are reduced. The reduction in artificial subsidies reduces households income, which have the consequence that consumption goes down, but total production and total transportation within Østfold and between Østfold and other regions increases due to increased demand for domestically produced goods.

In conclusion then, a small correction must be made in order to make the model respond adequately to changes that affects import. One way of doing this would be to construct a SAM were imports are distributed directly to the county where it is consumed or used as input.

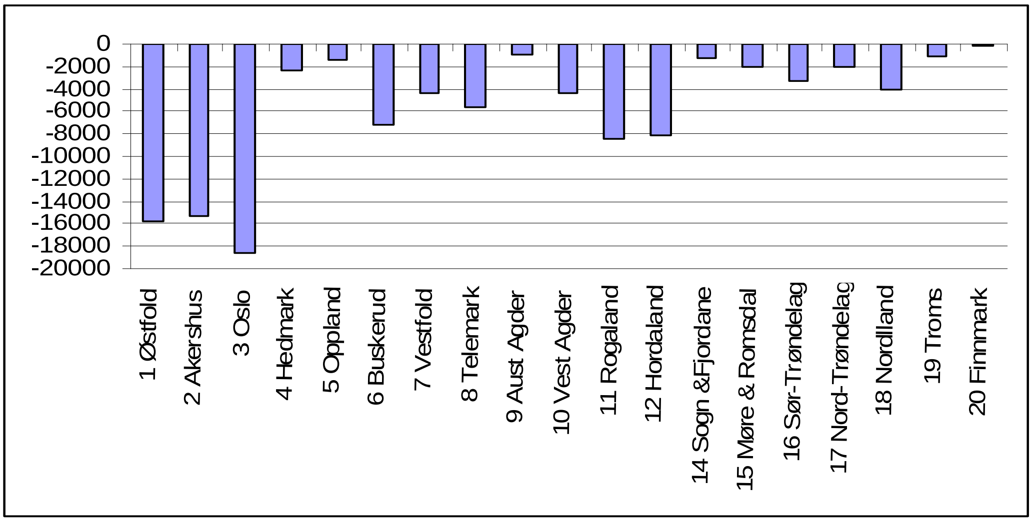

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Figure 4.9. Changes in imports to the counties (1000 NOK).

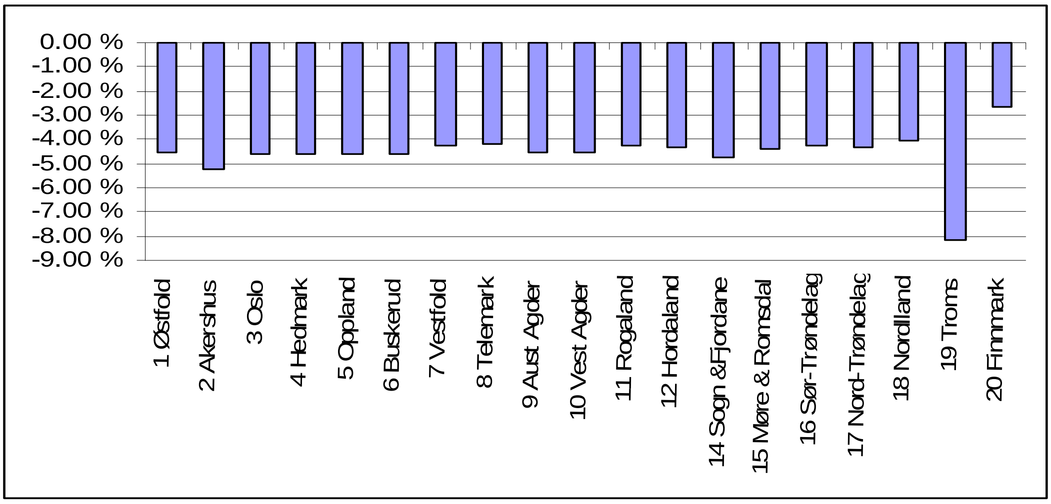

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Figure 4.10. Percentage changes in imports.

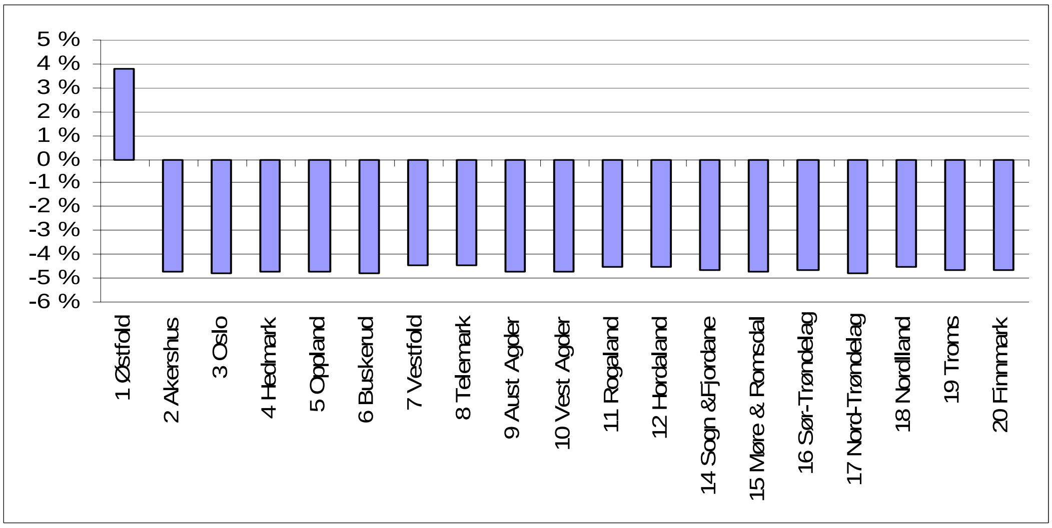

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Figure 4.11. Percentage change in production by county.

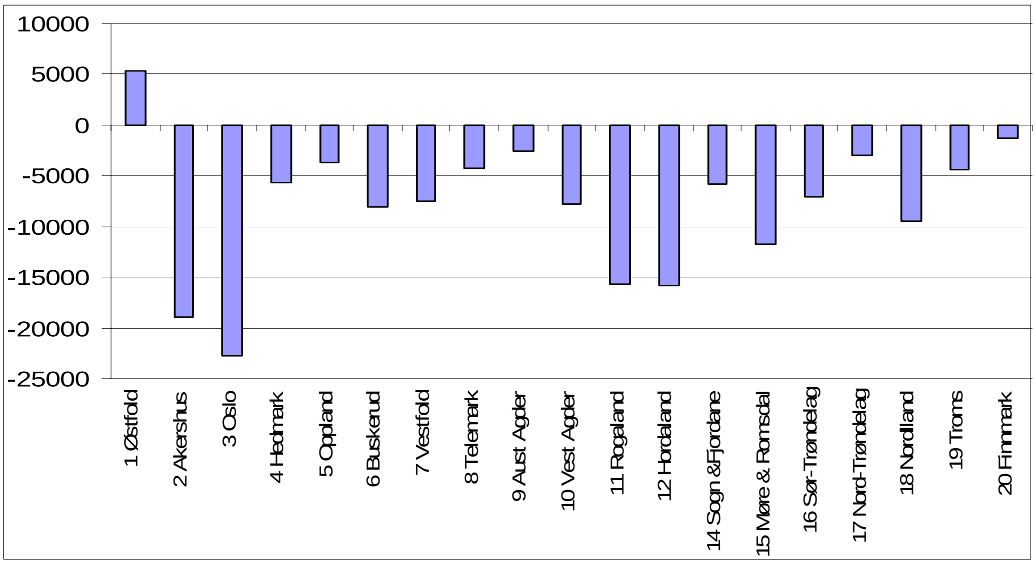

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Figure 4.12. Changes in the transportation flows (1000 tons) that terminate in the counties.

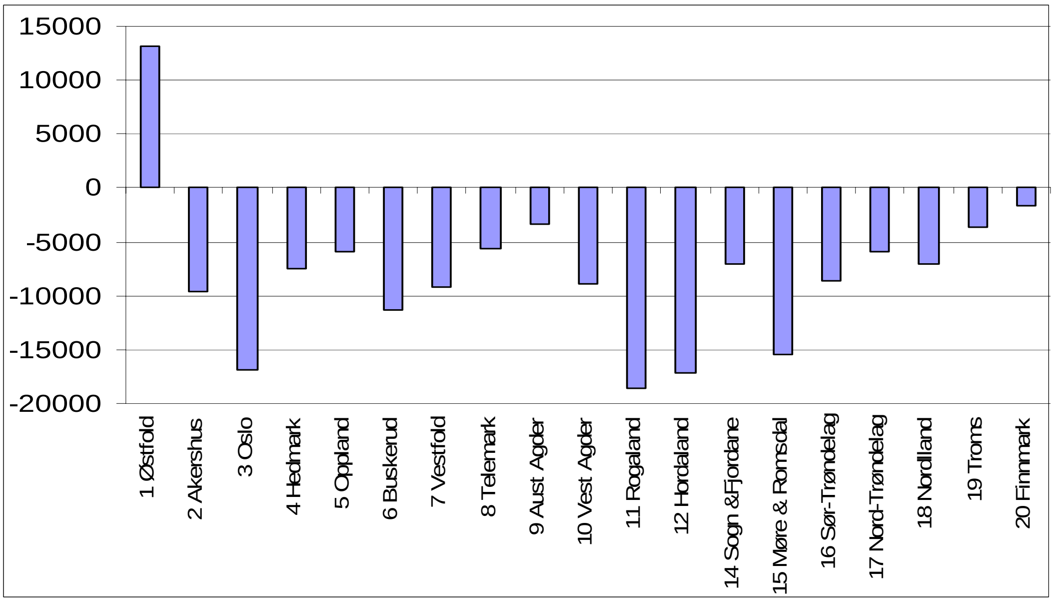

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Figure 4.13. Changes in the transportation flows (1000 tons) that originate in the counties.

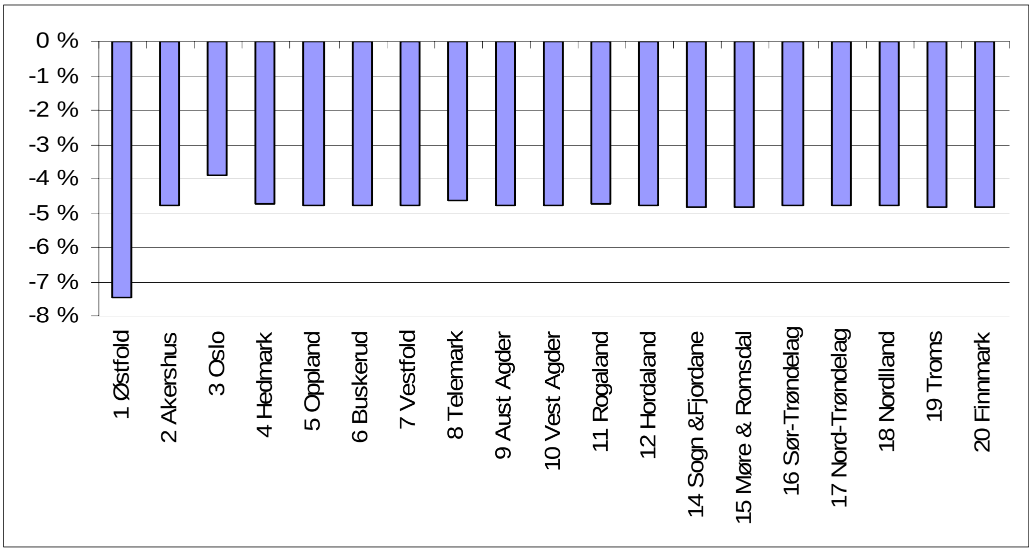

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Figure 4.14. Percentage change in consumption by county.

In *Test case 4* we investigate the effect of a 2% increase in the price of commodity group 10 (bulk commodities), which includes petrol and oil that are important inputs in the transportation sector. There is a reduction in production and originating and terminating transportation flows for all counties, except for Østfold, whereas consumption is reduced for all counties (Figures 4.15, 4.16, 4.17 and 4.18). These anomalies are due to the same problems that were outlined under the description of test case 3, i.e., increasing transport prices gives less demand for imported goods, this increases the demand for domestically produced commodities and so on. There is a small reduction in the proxy for average transportation distance: 280.323 NOK.

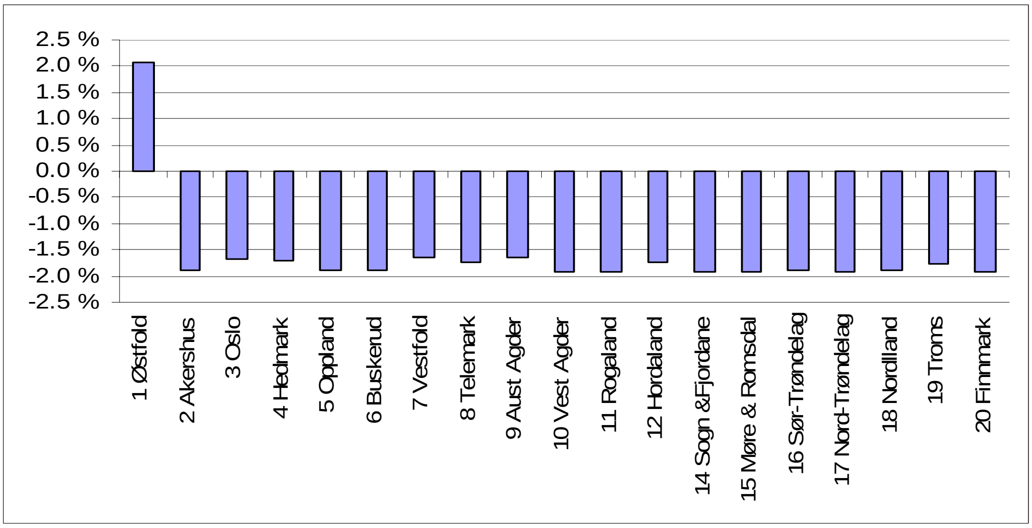

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Figure 4.15. Percentage increase in production by county.

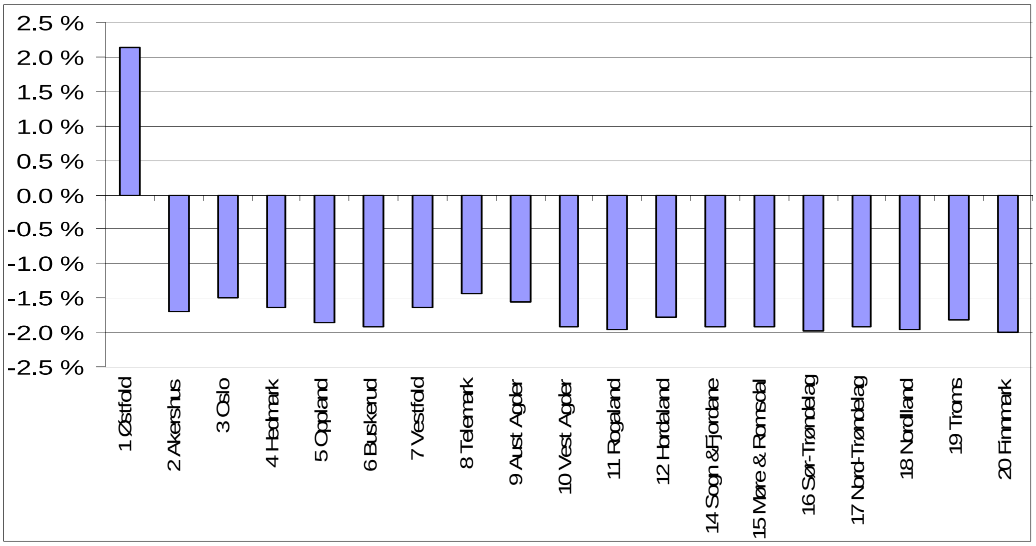

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Figure 4.16. Percentage changes in transportation flows (tons) to the counties.

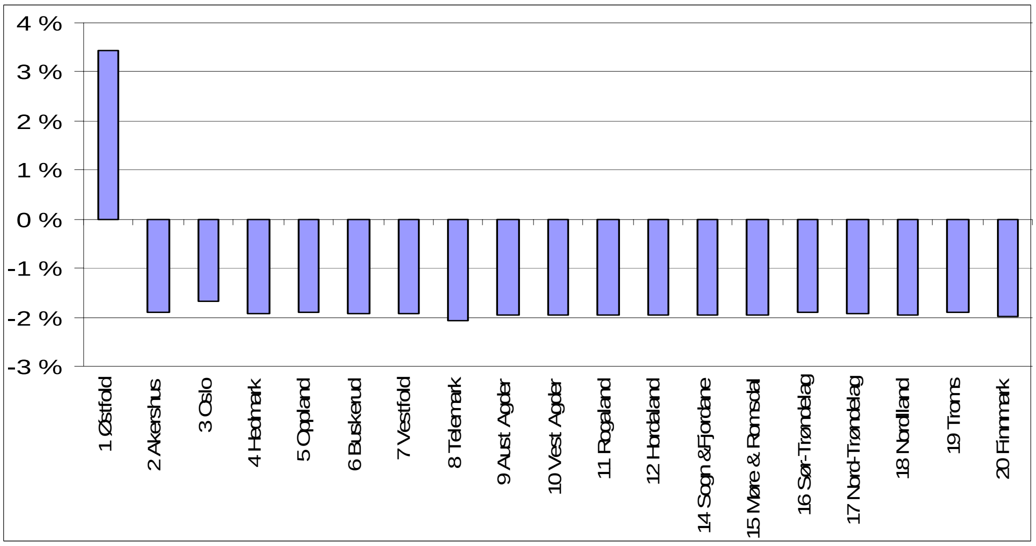

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Figure 4.17. Percentage changes in transportation flows (tons) originating in the counties.

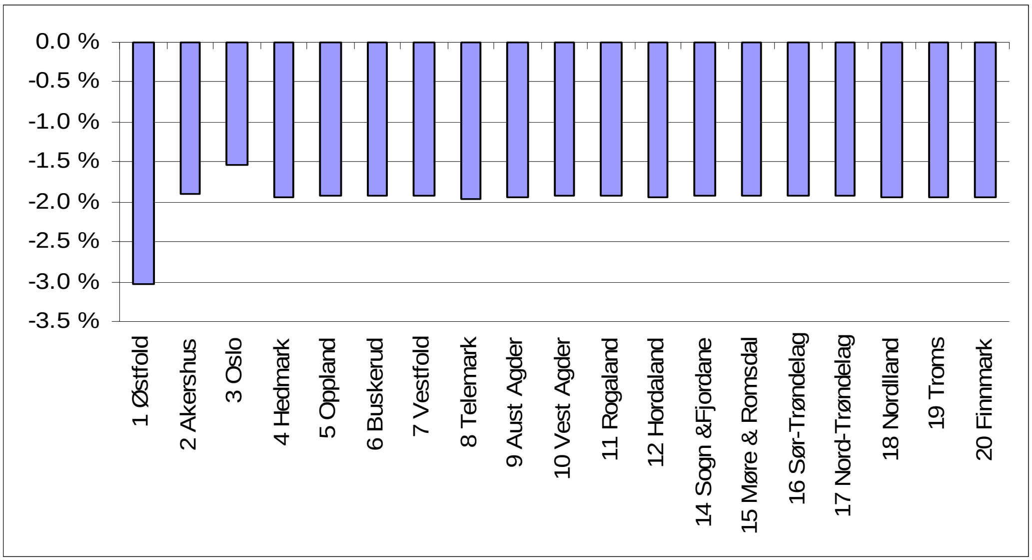

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Figure 4.18. Percentage changes in consumption by county.

5 Forecasts

Growth rates are needed in order to project OD matrices from NEMO for freight flow (tonnes) from the base year 1999 to target years in the future.

In order to apply PINGO to produce such growth rates, we have to decide "to what degree" we want to use PINGO as a bottom-up or top-down model.

A bottom-up approach would be to apply exogenously given forecasts for labour endowments in PINGO and then use the resulting production and consumption in the counties as forecasts. In lack of forecasts for labour endowments in the counties, we may make the assumption that the relative change in the available labour in the counties is proportional with a weighted sum of the share of available labour in the benchmark situation in the counties $\frac{n_r^0}{\sum_r n_r^0}$ and the share of population growth in the counties $\frac{\Delta g_r}{\sum \Delta g_r}$. Thus, if the total change in labour endowments is Δn, then the change in labour endowments in the counties can be expressed by

$$\Delta n_r = \left(\alpha \cdot \frac{n_r^0}{\sum_r n_r^0} + \beta \cdot \frac{\Delta g_r}{\sum_r \Delta g_r} \right) \cdot \Delta n .$$

With a bottom-up approach we run the risk, however, that there can be considerable deviations between the national production and consumption obtained from national models and corresponding figures from PINGO.

A pure top-down approach would assure that the sum of production and consumption from PINGO equals corresponding figures from national models like MSG and MODAG. Adjusting labour endowments for each county such that there is coherence between the total production and consumption of each commodity group in a national model and PINGO can do this.

It is not obvious, however, how to do the adjustment. A less ambitious task would be to assure coherence for the rate of increase of total production only, which could be characterised as something in-between bottom-up and top-down.

We may assume that the production of commodities in each county is increasing according to the growth rates received from the MSG model. We would then like to find county specific labour endowments, which correspond to these growth rates. To perform the task we change the unknown variables in the formulation of PINGO (see section 2.4), so that labour endowments play the role of the unknowns while activity levels of the sector are known and derived from the forecasted growth rates. In order to be able to use MPSGE to solve PINGO in the new formulation it is necessary to interpret production sectors as the consumers with fixed endowments of produced goods and households as firms, which produce labour endowments using consumption goods.

The projected matrices are used as input to NEMO, where the OD matrices for the total transport volumes are distributed to OD matrices for different transport modes.

6 Future perspectives

This report describes the first version of the SCGE model PINGO and a simple verification of this model. This first version can be developed further in many respects to improve reliability:

- Estimation of elasticities
- Improve import
- Mobility of physical capital and labour
- Segmentation of household groups
- Economies of scale
- Better forecasts

One possible way to further develop the model would be to improve the elasticities of substitution either by literature studies and surveys or by econometric techniques with available time series data to estimate the elasticities of substitution between inputs and outputs for the production functions and the elasticities of substitution between demands for the utility functions of all economic agents in the model. Of major interest in this respect is the elasticities that govern the change in the shares of commodities that are delivered from other counties, where we would have to consider how transport cost reduction would changes the logistic systems of the firms.

A small correction would make the model respond more adequately to changes that affects import. In order to do this one should construct the SAM were import is distributed directly to the county where it is consumed or used as input. The problem here is the availability of necessary data.

In the first version of PINGO, we have assumed that physical capital labour cannot move between counties. In reality there is a migration between counties as well as immigration to Norway from other countries, where the households may either move or commute to new work places. It would be worthwhile to construct a new sub model in PINGO for allocation of physical capital and labour in the counties according to the Nash equilibrium (Varian, 1992).

Segmentation of the households according to income or labour groups and thus different consumption patterns would make it possible to analyse distributional effects.

Producers in the present version of PINGO exhibit constant returns to scale and there is a perfect competition in the economy. Returns to scale and market power influence the level of production and prices; hence they are essential for determining goods flows between counties. Inclusion of more realistic mechanisms in this respect would probably improve the reliability of PINGO.

Transport infrastructure is the scare economic resource provided mainly by the government and it has a certain capacity. However capacity constraints are not present in PINGO. A possible way to include capacity constraints would be to model congestion through the decreasing returns to scale production technology of the transport sector, so that after some level of output transport services become more and more expensive to produce. Another solution is to integrate transport network and Wardrobian equilibrium into the general equilibrium framework. It is possible since both general equilibrium and Wardrobian equilibrium may be formulated as a mixed complementarity problem and solved simultaneously.

None of the proposed methods in chapter 5 for how to use PINGO to project OD matrices from a base year to a future benchmark year were true top-down approaches. For a true top-down approach, a more advanced method is needed, which would include assurance of coherence not only for production and consumption, but also for export/import and the use of commodities and services as input to production. An in-depth study of methods for how to use PINGO with top-down approaches is needed to improving the suggested methods to set up a future benchmark year with PINGO.

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Appendices

Appendix 1: CES functions

A.1.1 CES production functions

CES ("constant elasticity of substitution") is a class of functions that are suited for modeling of general equilibrium. The CES functions that are used in PINGO describe constant return to scale. The CES functions includes constant elasticities of substitution that govern to what degree the shares of the inputs are changed with respect to price changes. We formulate a general CES-function by

$$X_{ir} = f(\mathbf{H}) = \gamma_{ir}\left(\sum_{j \neq i} \alpha_{jr} H_{jr}^{\rho}\right)^{\frac{1}{\rho}},$$

where γ_{ir} is a scale parameter, α_{jr} is a reference coefficient for the share of input where $\alpha_{jr} > 0$ and $\sum_{j \neq i} \alpha_{jr} = 1$. It can be shown that $\rho = \frac{\sigma - 1}{\sigma}$, where σ is an elasticity of substitution, which again imply that $\sigma = \frac{1}{1-\rho}$. The CES functions are linear homogenous (of degree 1). One can therefore calibrate the CES function by letting the expression $\left(\sum_{j \neq i} \alpha_{jr} H_{jr}^{\rho}\right)^{\frac{1}{\rho}}$ express the production of a single unit of the commodity group *i*. From this, we may let the initially (observed) production volume, X_{ir}, be represented by the scale parameter γ_{ir}.

If the elasticity of substitution is set at zero then we get the Leontief function

$$X_{ir} = f(\mathbf{H}) = \min_{j}\left[\frac{H_{jir}}{\alpha_{jr}}\right],$$

which gives a inelastic use of input factors if we assume cost efficient production. With Leontief, we get a system that is non-sensitive to price changes with fixed shares of input factors.

If we use elasticities of substitution equal to one, we get the Cobb-Douglas function

$$X_{ir} = f(\mathbf{H}) = \gamma \cdot \prod_{k} H_{kir}^{\alpha_k}$$

which gives that fixed shares of the budget is used for each input factor in optimum, i.e., there is a fixed share of the budget that is used to cover the cost of each input factor.

A.1.2 Profit maximization and utility maximization with CES functions

Consumption is determined by maximising a CES utility function with respect to quantities of each commodity consumed under the budget constraint:

$$\max_{C_{1r}^1,\dots,C_I^I} U^r(C_{1r},\dots,C_{Ir})$$

such that $\sum_{i=1}^{I} C_{ir}(P_{ir}) = L_r(P_{labour})$,

where U^r is a CES function representing the consumers utility function in county r with respect to county specific pool commodities, and L_r denotes labour endowment (all income) for representative household in county r. As a result of utility maximization at given prices of county specific pool commodities $\tilde{P}_{ir}$, we get the household's demand functions $d_r^i(L_r(P_{labour}), \tilde{P}_{1r},\dots,\tilde{P}_{Ir})$.

We assume that the profit-maximizing producer is constrained by the production possibilities

$$\underset{X_{ir},\mathbf{H}}{Max}\left[P_{ir}\cdot X_{ir} - \sum_l P_{lr}\cdot H_{lir}\right]$$

Profit maximization is found by solving the equation obtained by setting the derivative equal to zero (Gravelle & Rees, 1993, s.231). First order conditions becomes:

$$P_{kr} + P_{ir}\cdot\frac{\partial f_{ir}}{\partial z_k} = 0 \quad \forall k$$

If the product function is of the Cobb-Douglas type, then we get

$$P_{kr} + P_{ir}\cdot\left[\gamma\cdot\alpha_{kir}\cdot H_{kir}^{(\alpha_{kir}-1)}\cdot\prod_l H_{lkr}^{\alpha_{lir}}\right] = 0 \quad \forall k$$

If we set $P_{ir} = C_{ir}(\mathbf{P})$, we get

$$H_{kir} = \frac{X_{ir}}{\gamma}\cdot\frac{C_{ir}(\mathbf{P})\cdot\gamma\cdot\alpha_{kir}}{P_{ki}},$$

where the cost function C_{ir} is determined by solving the cost minimization problem:

$$\underset{\mathbf{H}}{Min}\sum_l P_{li}\cdot H_{lir}$$

s.t

$$X_{ir} = f_{ir}(\mathbf{H}) = \gamma\cdot\prod_k H_{kir}^{\alpha_{kir}}$$

A solution to this problem is given by (Varian, 1992, p.54)

$$C(P_{ir}) = \frac{1}{\gamma} \cdot \prod_{l} \left(\frac{P_{lr}}{\alpha_{lir}} \right)^{\alpha_{lir}}$$

where the scale factor γ express observed production in a the base case situation $\hat{X}_{ir}$. While we use the estimates

$$\hat{C}_{ir} = \sum_{l} \hat{P}_{lr} \cdot \hat{H}_{lir}$$

and

$$\hat{\alpha}_{kir} = \theta_{kir} = \frac{\hat{P}_{kr} \cdot \hat{H}_{kir}}{\sum_{l} \hat{P}_{lr} \cdot \hat{H}_{lir}},$$

it is easily shown that the share of input factors can be expressed by

$$H_{kir} = \frac{X_{ir}}{\hat{X}_{ir}} \cdot \frac{C_{kir}}{\hat{C}_{kir}} \cdot \frac{\hat{P}_{kir}}{P_{kir}} \cdot \hat{H}_{kir}$$

and that the unit cost for production of a commodity can be expressed as

$$C_{kir} = \frac{\hat{C}_{kir}}{\hat{X}_{ir}} \cdot \prod_{l} \left[\frac{P_{lir}}{\hat{P}_{lir}} \right]^{\hat{\alpha}_{lir}}.$$

If there are no limiting use of input factors, then the production are described as ”constant return to scale”. Some inputs or factors can be exogenously given, however, for instance labor. If a factor is exogenously given, then the price of the factor is given as the derivative of production functions with regard to the use of the factor $\frac{\partial f_{ir}}{\partial H_{kir}} = P_{kr}$. For a Cobb-Douglas function, the price of a constant amount of labor H_{kir} for production of a given commodity becomes:

$$P_{kr} = \gamma \cdot \frac{1}{H_{kir}} \cdot \alpha_{kr} \cdot \prod_{l} H_{lir}^{\alpha_l}$$

If there are limits in the use of input or factors, then the production has increasing return to scale. When the producer reach the capacity limit for one or several inputs or factors, then he may only use the other inputs or factors to increase the production which have the consequence the price of the limited factors increases exponentially.

A.1.3 Nested CES functions

Application of nested CES functions in order to assess production output with respect to inputs can be represented in terms of three structures (Figure A.1). If the input factors are outputs from other production processes, then we get a three structure with several levels (Figure A.2). Outputs from intermediate production are sometimes from independent factories, but can also belong to the company that delivers a product higher in the three structures. If the intermediate product in a production tree is the final product from some factory, then we may split such threes in several smaller threes (Figure A.3). Even if we get rid of some nests in this way, there is still need for nested CES functions in production trees with intermediate products. But in order to implement nested CES functions it is of some help to consider the intermediate product as a final product, which make it possible to split these trees as well.

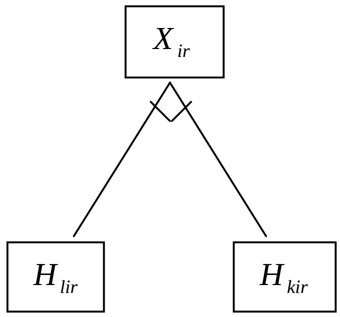

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Figure A.1. With a one level CES function, we may calculate the production X_{ir} as a function of two or more input factors H_{kir} and H_{lir} .

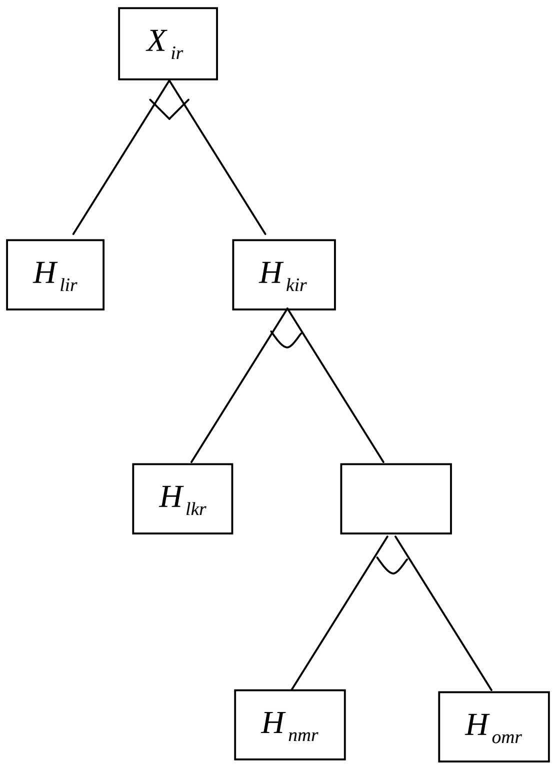

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Figure A.2 Nested CES functions makes it possible to calculate the production X_{ir} when there are intermediate products H_{kir} and H_{mkr} .

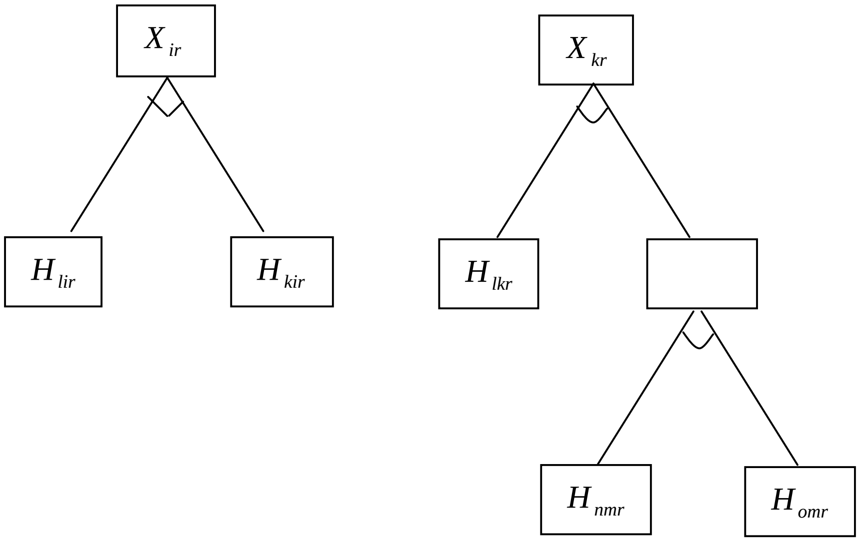

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Figure A.3. The whole or parts of the final product X_{kr} from a production three is used as an input factor H_{kir} in a different production three.

Appendix 2: An example

To investigate the nature of CGE modeling, we programmed a very stylistic CGE model in both the C programming language and the MPSGE software, with two production sectors (food and primary factors) (Figure A.2.1), and a sector for consumption of food and sale of labor to the production sectors. The producer of primary factors delivers commodities to the food producer. When there are two independent producers, then these may represent separate production threes (see Appendix 1). This simple example, allow us to represent production sectors with the usual non-nested CES functions (Figure A.2.2).

We used the SAM:

	Food	Primary factors	Consumption
Food	20		-20
Primary factors	-6	6	
Fuel		-1	1
Labor	-14	-5	19

We assumed that all unit costs are 1.0 in the benchmark situation, that the price of fuel is fixed and that the use of labor is constant, i.e., full employment with constant work force productivity.

We let X_1, X_2, X_3 and X_4 denote food, labor for production of food, primary factors, fuel and labor for production of primary products. The prices of these commodities are denoted P_1, P_2, P_3, P_4 and P_5. Consumption of food is set equal to the production of food whereas all other commodities only are used as input factors. Since the price of fuel is fixed and labor is constant, we have that $X_2 = X_{2,fixed}$, $X_5 = X_{5,fixed}$ and $P_4 = P_{4,fixed}$. If we use equations in Appendix 1 for Cobb-Douglas product functions on this case, with the price of fuel as a numeraire, then the model can be expressed in terms of the system of equations:

$$F_1 = C_1(X_1) - f(X_2, X_3) = 0$$

$$F_2 = X_2 - X_{2,fixed} = 0$$

$$F_3 = H_3 - f(X_4, X_5) = 0$$

$$F_4 = H_4 - X_4 = 0$$

$$F_5 = X_5 - X_{5,fixed} = 0$$

$$F_6 = \sum_k \left[P_k \cdot H_{k1}\right] - P_1 \cdot X_1 = 0$$

$$F_7 = P_2 - \gamma_1 \cdot \frac{1}{H_{2,1}} \cdot \alpha_{2,1} \cdot H_{2,1}^{\alpha_{2,1}} \cdot H_{3,1}^{\alpha_{3,1}} = 0$$

$$F_8 = \sum_k \left[P_k \cdot H_{k,3} \right] - P_3 \cdot X_3 = 0$$

$$F_9 = P_4 - P_{4,\,fixed} = 0$$

$$F_{10} = P_5 - \gamma_3 \cdot \frac{1}{H_{5,3}} \cdot \alpha_{5,3} \cdot H_{5,3}^{\alpha_{5,3}} \cdot H_{4,3}^{\alpha_{4,3}} = 0$$

We may formulate the system of equations as $\mathbf{F}(\mathbf{P},\mathbf{X}) = \mathbf{0}$. Since $\mathbf{F}$ is usually homogeneous of degree zero (for instance if we use CES production functions) in **P**, it is necessary to have an additional constraint in order to make it possible to determine the system of equations (Judd, s.188, 1998). According to Walras we have that sufficient conditions for equilibrium is $\mathbf{p} \cdot \mathbf{F}(\mathbf{p}) = \mathbf{0}$, and that $\mathbf{F}(\mathbf{p}) \leq 0$, $\mathbf{p} \geq 0$ (Lancaster, 1968). According to Judd (1998) the necessary extra constraint that follows from Walras law may be expressed by an extra equation $\sum_i P_i = 1$, from which we can see that prices are relative. With this extra equation, we get a system of equations where the number of equations and unknowns are the same.

Our system of equations becomes non-linear and can be solved with Newton's method. The method assesses production and prices in all iterations. This is done in two steps: First we have that cost functions are calculated for a given set of prices **P**, and thereafter we have that the elements in the right side of equation (4.16) for prices **P** and commodity volumes **X**. The left side is then determined such that the production of commodities in the county and import from other counties equals the right side. This way of adjusting the prices is referred to as Walras theory of tatonnement, and the solution we get is denoted as general equilibrium. If we alternatively allow profit, then we may ignore Walras law, but we must then assume decreasing return to scale of the production.

If we change the price of fuel to 1.4 times the fuel in the benchmark situation, then we get a decrease in production, where fuel is used as input (Table A.2.1).

The C program and the MPSGE program gave the same results.

Table A.2.1.Commodity volumes and prices for our stylistic equilibrium model in the benchmark situation and after a 40% increase in the fixed price of fuel

	Benchmark		**40 % increase in the fixed price of fuel**	
	Volume|	**Price**	**Volume**	**Price**
Food	20	1	19.496	1.0
Lab$_{mat}$	14	1	14.0	0.9748
Primary	6	1	5.1196	1.0613
Fuel	1	1	0.6005	1.4
Lab$_{prim}$	5	1	5.0	0.9185

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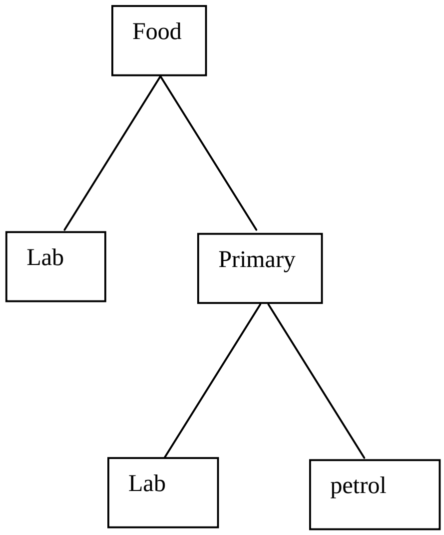

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Figure A.2.1. Stylistic production three for a food producer, where the commodities from a producer of primary factors are used as inputs.

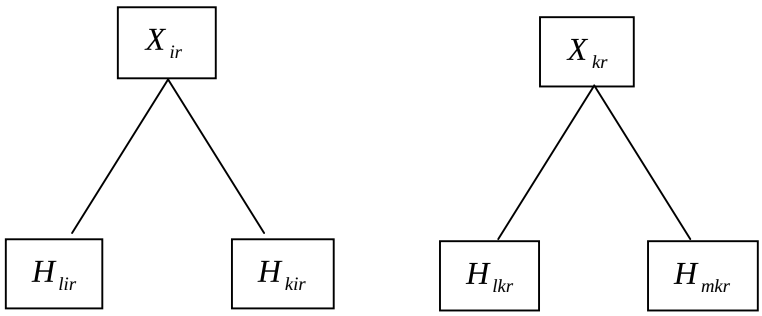

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Figure A.2.2. The same food producing sector as in Figure 5.1, where the commodities from a producer of primary factors are one input, but where the production three is split in one part for each production sector.