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Institute of Transport Economics
Norwegian Centre for Transport Research

PINGO – A model for prediction of regional and interregional freight transport in Norway

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Summary:
The PINGO model takes into account how geographic variations in population growth and industrial development affect future freight flows. The second version of PINGO has an improved model structure coherent with the rest of the national model system for freight transport. This report describes the second version of PINGO, and how the model is calibrated and applied in connection with forecasts for the period 2003 to 2040.

Tittel: PINGO - En fremskrivingsmodell for regionale godstransporter i Norge

Forfatter(e) *Arild Vold; Viggo Jean-Hansen*

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Sammendrag:
Fremskrivningsmodellen for regionale godstransporter i Norge (PINGO) er utviklet for å ta hensyn til hvordan geografiske variasjoner i befolkningsvekst og industriell utvikling påvirker fremtidige godsstrømmer. Andre versjon av PINGO har en forbedret modellstruktur og er utviklet for konsistens med det nasjonale modellsystemet for godstransport forøvrig. Denne rapporten beskriver andre versjon av PINGO, og hvordan modellen er kalibrert og anvendt i forbindelse med utarbeidelse av prognoser for perioden 2003 til 2040 til bruk i analyser for Nasjonal transportplan 2010 - 2019.

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Preface

Population growth and industrial activity vary considerably throughout the Norwegian geography. With the objective of taking spatial diversity into account, a first version of *PINGO – A model for prediction of regional and interregional freight transport* was developed by Ivanova, Vold and Jean-Hansen (2002) with financial support from the Program for Overall Transport research (POT) directed by the Ministry of Transport and Communications.

The Ministry of Transport and Communications also provided the financial support for development of the second version of PINGO. The second version is consistent with the year 2003 base case matrices and the newly developed logistic model for freight transport in Norway. The second version of PINGO was also improved and was prepared and used to forecast future regional and interregional freight flows for the period 2003 to 2040.

This report describes the work carried out to complete the second version. The main project workers were dr scient Arild Vold and cand oecon Viggo Jean-Hansen. Arild Vold was project manager. He developed and implemented the new model structure. Viggo Jean-Hansen was responsible for acquiring and preprocessing national accounts data. Chief Research Economist Inger Beate Hovi also contributed and was responsible for quality assurance. Laila Aastorp Andersen provided secretary aid and was responsible for editing the final version of the report.

Oslo, September 2007
Institute of Transport Economics

Lasse Fridstrøm	*Kjell Werner Johansen*
Managing director	Head of Department

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Innledning

Det nasjonale modellsystemet for godstransport i Norge kan deles inn i en etterspørsels- og en tilbudsside. Etterspørselssiden er representert ved et sett av basismatriser for godsstrømmer mellom kommuner i Norge og kommuner i Norge og utlandet, og PINGO, en modell for fremskriving av basismatriser for analyse av fremtidig etterspørsel etter godstransport i Norge. Tilbudssiden er representert ved en nettverksmodell og en logistisk delmodell, der transportløsning velges slik at bedriftenes logistiske kostnader blir minimert basert bl a på grunnlag av informasjon om transportdistanse og -tid (LoS-data) fra nettverksmodellen. Nettverksmodellen kan dessuten benyttes til å nettutlegge transportmiddelfordelte godsstrømmer i kartplott.

PINGO er en SCGE model ("Spatial Computable General Equilibrium"). Modellen representerer hele den norske økonomien, men er spesielt utviklet for å predikere godsstrømmer innen og mellom regioner i Norge. Fordi modellen favner hele økonomien, er den også egnet til å analysere ringvirkninger av tiltak i transportsektoren.

Vare-sektorregnskap

Modellen representere økonomien ved et vare-sektorregnskap. Det er en sone for hvert fylke, en sone for ekstrafylket (Kontinentalsokkelen/Svalbard/Jan Mayen/noe aktivitet utenlands) og en sone for utlandet. I siste versjon er det gitt en mer detaljert beskrivelse av varer og sektorer. Representasjon av handel og transport er forbedret. Datagrunnlaget er oppdatert til basisår for 2003. For hver sone er det representert vare- og tjenesteproduserende sektorer for produksjon av 32 varegrupper, 6 servicegrupper og 6 investeringsarter, samt sektorer for privat og offentlig konsum. Det er også sektorer for import, eksport og en sektor for innkreving av skatter/avgifter og overføring og subsidier. Egne sektorer for handel og transporttjenester er spesielt utviklet for å representere de geografiske godsstrømmene innen og mellom sonene. Det er mulig å aggregere både soner, sektorer og varegrupper, der en aggregert sektor kan produsere mer enn én varegruppe. Vare-sektorregnskapet blir en matrise der kolonnene representerer sektorregnskapene og radene representerer markeder for varene. I matrisen fremgår også varestrømmene i verdi innen fylker og mellom alle par av fylker.

Metodegrunnlag

PINGO representerer sektorer og markeder ved CES/CET ("Constant Elasticity of Substitution/Transformation") funksjoner og konsumentene representeres ved CES nyttefunksjoner. Budsjettet til private og offentlige hushold kan endres eksogent. I "bottom-up" varianten vi har valgt for siste versjon av PINGO, er også eksportsektoren

representert som en konsument. Årsaken er at vi da kan gjøre eksogene endringer også i etterspørselen etter norske varer. Med fylkesvise vekstrater for befolkningsvekst fra Statistisk sentralbyrå fordeles nasjonale vekstrater fra modellen MSG6 til konsum per fylke.

Ved hjelp av en rutine som itererer for hvert år fremover i tid, gjør vi årvisse eksogene endringer i henhold til vekstratene. Etter eksogene endringer kjøres PINGO slik at vi får ny Walras-likevekt. Nye eksogene endringer gjøres for året etter, PINGO kjøres på nytt osv gjennom prognoseperioden.

Kalibrering og anvendelse

Til analysearbeidet i forbindelse med Nasjonal transportplan anvendte vi nasjonale vekstrater fra Hovi et al. (2007) for kalibrering og anvendelse av PINGO for basis-prognoser av basismatriser for totale godstrømmer i Norge fra basisåret 2003 og frem mot 2040. Med PINGO kan man også simulere alternative prognoser der man legger inn alternative transportkostnader og/eller transportavgifter. Provenyet fra avgiftene kan øremerkes eller man kan anta at de følger offentlige overføringer for øvrig.

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Summary:

PINGO – A model for prediction of regional and interregional freight transport in Norway

Freight transport demand is strongly affected by economic growth, demographic changes and trade development.Transportplanning and infrastructure investments should account for the accessibility and environmental consequences of freight transport on the industries, on the population and on society in general. To assist the Norwegian government in long-term planning of interurban freight transport, the National real network model for freight transport within Norway and between Norway and other countries has been developed (Hovi and Jean-Hansen, 2006; Vold 2006;de Jong, Baak and Ben-Akiva, 2006;Vold et al., 2002; Madslien, Steinsland and Vingan 2006).

This paper briefly describes the sub model PINGO for prediction of freight flow forecasts within and between zones and side-effects of changes in transport taxes and infrastructure and technological developments. PINGO is a regional economic SCGE (Spatial Computable General Equilibrium) model of the Norwegian economy. A general equilibrium model represents sector-commodity accounts, and determines solutions for the sector accounts based on Walras equilibria. PINGO input data are collected from official statistics of national accounts by county, from transport statistics, and from forecasts of population growth and certain socio-economic quantities.

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1 Introduction

Logistic service providers, import/export companies, manufacturing industries and wholesalers/retailers do all demand satisfactory freight transport services for domestic transport as well as import and export. Reduced monetary and time costs of transportation gives a competitive advantage and enable firms to sell their products more cheaply, which in turn stimulates greater demand, gives rise to economic growth. The freight flows have environmental implications for the society that depends on magnitude, location and mode of the freight flows.

Forecasts for how the Norwegian economy[1] 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 Norwegian public authorities develop transport plans that take into account both the business and the society requires methods to assess how freight flows are expected to change and grow with expected economic growth, specific infrastructure investments, technological developments and alternative levels of transport charges. The planning is facilitated by research, development and application of the real network model for freight transport within Norway and between Norway and other countries.

Currently the national freight transport model is subdivided in: (1) a set of base matrices for freight flows between municipalities in Norway and between municipalities in Norway and foreign countries, (2) A Logistic sub model that assign the base matrices in a real transport network representation and assess transport work, transport costs by commodity group and mode, and (3) PINGO - a model for forecasting the base matrices to future years for analysis the demand for future freight transport.

A first version of the Logistic model has been developed together with corresponding base freight flow matrices for base year 2003 (de Jong, Baak and Ben-Akiva, 2006;Hovi and Jean-Hansen, 2006;Vold 2006;Madslien, Steinsland and Vingan 2006). A first version of PINGO was developed by Ivanova, Vold and Jean-Hansen (2002). This report describes the new version of PINGO. The work is financed by the Ministry of Transport and Communication in order to make an upgrade to improve the structure of PINGO and to make PINGO consistent with the base year matrices for 2003 plus finalise work required to use PINGO for carrying out forecast of the national freight flow matrices.

Chapter 2 contains a brief overview of the PINGO model. This is followed by a description, the theoretical foundation and the model structure. Chapter 3 describes how the new version of PINGO represents the national sector-commodity account. This

[1] The Norwegian economy is relatively small and open. The population is 4.6 million people and export+import comprise 55% of GDP. Important industries are oil, fish, forestry, exploitation and processing of minerals. The unemployment is only about 4%. The production sector employs 17% and the service sector employs 83%.Oil-boosted budget surpluses is invested in a Government petroleum fund (valued more than $150 billion). Domestic freight transport amounts to 453 million tonnes, where 22 are oil from the continental shelf to the main land by ship and 86 is oil and gas in pipeline between the continental shelf and refineries at main land. Import amounts to 33 million tonnes and export amounts to 42 million tonnes + 196 million tonnes of oil and gas exported directly from the Norwegian continental shelf in 2004 (60% ship, 40% pipe). The domestic mode shares in 2004 were 48% seaborn, 5% rail and 47% road. Overall freight tonne-kilometres in Norway increased by 6% in 2004 (Rideng, 2005).

includes subsections about production sectors, the freight transport sector and the trade sector, export/import, the government sector and the private- and public households. Chapter 4 is about how we chose and obtained forecasts for exogenous model variables. Section 4 also includes a section about how model calibration was performed for the base case scenario assumption for forecasts of the freight flow matrices over the period 2003 – 2040. Output of socio-economic quantities from PINGO predictions with base case scenario assumptions are briefly presented as well as a reference to an in-depth analysis of the structure of future intra- and interregional freight flows based on the PINGO predictions and assessments of corresponding transport indicators with the Logistic model of the National freight model.

2 Model description

To predict future freight flows we need to take into account the mechanisms in the economy that induces changes of the production and consumption at the regional level. Some areas grow more than others in terms of population growth and industrial activity, which affects the freight flows. PINGO is developed to regionalise national growth in production and import as predicted with the national growth model MSG (Multi Sectoral Growth Model)[2] and to determine the growth in transport within and between pairs of counties. Forecasts of freight transport within and between counties can subsequently be used to forecast freight OD-matrices between municipalities, which can be assigned in the National real network model for freight transport. The network model can be used to determine figures for tonne kilometres; environmental costs etc. at different levels of aggregation (see Figure 1).

PINGO is a SCGE (Spatial Computable General Equilibrium) model of the Norwegian economy. A general equilibrium model represents and determines equilibrium solutions for the sector-commodity accounts based on Walras-equilibrium. PINGO represents the national accounts by counties and employs data from national accounts statistics and other sources. The input is organised in terms of social account matrix (SAM) representation of the sector-commodity account by county (base year 2002/2003) for the Norwegian economy and includes import and export activity. PINGO emphasises 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. It is a based on the same principles as the SCGE model developed by Bröcker (1998). This includes the so-called pooling concept in interregional trade which was introduced by Moses and Chenery. The major difference is that the Bröcker's model does not include an explicit transport sector. 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. This is not the case in PINGO, where the transport sector is represented by CES production functions. Also, PINGO has a public sector and subdivides final demand into consumption, investment etc., whereas the Bröcker model has not. PINGO is implemented in the MPSGE software, which is a non-algebraic interface to the GAMS software and the PATH solver for solution of Mixed Complementary Problems (MCP) – problems as implemented in GAMS (Rutherford, 1995).

[2] Johansen (1960)

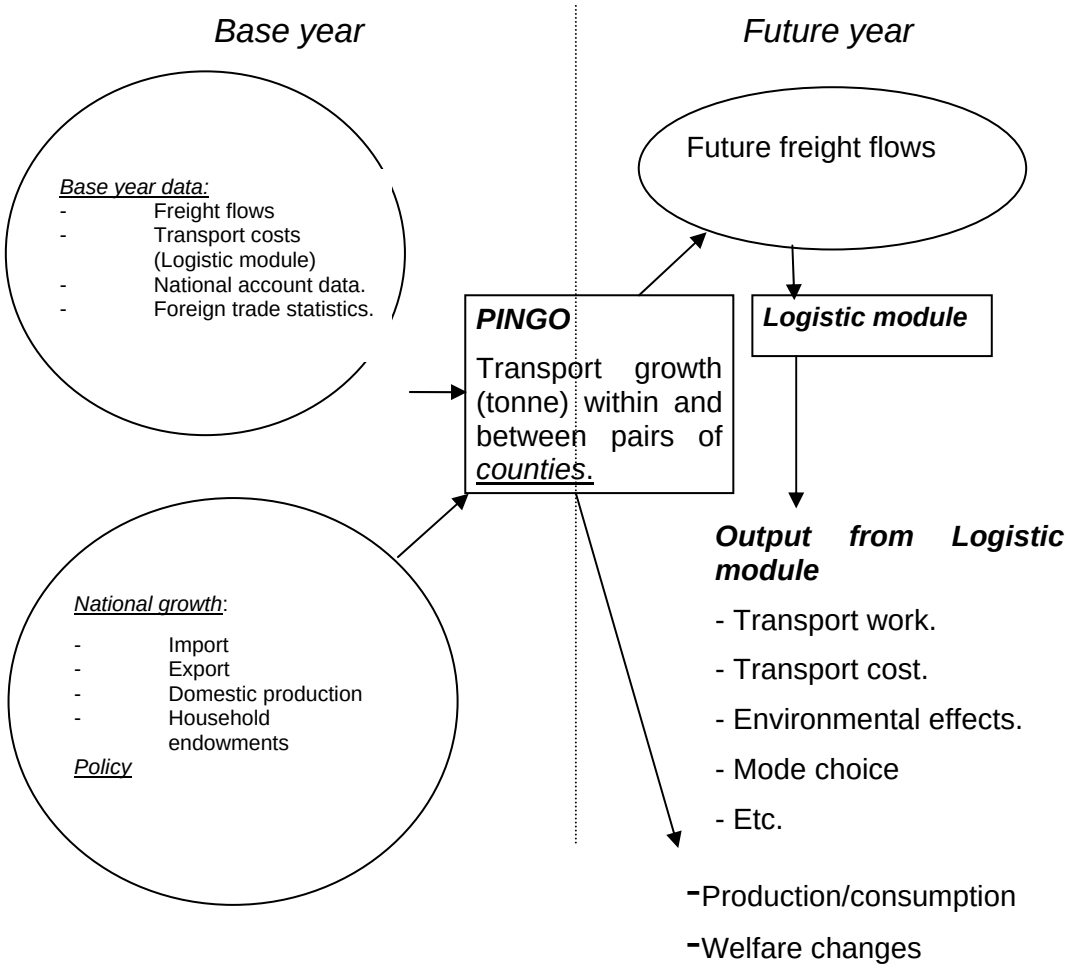

Figure 1. Schematic view of components of the national model system for freight transport in Norway with PINGO emphasised.

2.1 Theoretical foundation and model structure

The theoretical basis for PINGO is the Walras equilibrium that can be represented in the GAMS/MPSGE modelling system (Rutherford, 1995). It is based on the assumption that all economic agents 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. Prices on any good or labour can be fixed or endogenously determined.

The Walras equilibrium is characterised in that:

- Commodities in excess demand are free
- Sectors earn zero profit. And any activity earning negative profit is not operated
- Supply of any commodity balances or exceeds the demand of the consumers
- In effect all commodity markets are in balance

We may specify two types of sectors in MPSGE models: Producers and Consumers. Producers use input (commodities and services) and production factors (capital and

labour) in order to produce output. Consumers harbour endowments in terms of income from labour and transfers from the government. The endowments are allocated between alternative goods in order to maximise consumer utility.

2.2 Dimensions

Dimensions of the model comprise (1) the spatial resolution, (2) economic agents[3] and (3) markets for commodity groups and services. Elements in the dimensions can be merged to any level of aggregation. High resolution increases the detail at which the model can be applied but increases also the required resolution of data and computational demand.

2.3 Model functions

Specifically for the production sectors we need to specify production functions and for the consumers we need to specify utility functions and endowments.

Production functions in MPSGE are represented by nested constant elasticity of substitution (NCES) functions. The production NCES functions can have two levels, whereas the utility CES functions have one level. The MPSGE CES production functions $y_n(I_n) = (\sum_m \alpha_{m,n} \cdot I_m^{\rho})^{1/\rho}$ are specified by the input, I_m, for commodities m in the benchmark situation and the elasticity of substitution between the input goods, $1/(1-\rho)$, where $\alpha_{m,n}$ are reference quantities for the share of inputs. The functions are merging two or more inputs into an intermediate product I_n when the intermediate and not each basic input factor are used to create the final product. 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. 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.

MPSGE represents the output structure of production sectors in terms of constant elasticity of transformation (CET) functions, $(\sum_m \chi_{m,n} \cdot O_{m,n}^{\upsilon})^{1/\upsilon} = y_n$, for production technology and utility, which are similar to CES functions. CET functions are fully described by the elasticities of transformation and reference coefficients $O_{m,n}^{\upsilon}$ for shares of output of each commodity and service. The CES/CET formulation of production functions implies constant return of scale.

Consumers demand is represented in terms CES functions plus a budget constraint:

$$\underset{C}{\text{Max}}\, U(C) = \left(\sum_m \mu_m \cdot C_m^{\rho} \right)^{1/\rho}$$

$$\text{s.t.} \quad \sum_m C_m(P_m) = M$$

[3] An economic agent can be a production sector, an investment sector, a service sector, a trade agent, a representative private or public household, a transport sector, an import sector, an export sector or the government.

In the standard MPSGE model, utility functions are quasi-homothetic and production functions exhibit constant returns to scale. The reference quantities, together with corresponding reference prices define the consumer preferences in the base case situation.

2.4 Elasticities of substitution

Substitution elasticities define the propensity to change the shares of inputs or expenditures on different goods if prices are changing. If we define the substitution elasticities in terms of Cobb-Douglas technology then the same budget shares for the input or expenditure commodities as in the base case are always used (i.e., if the price of a commodity goes up then the quantity goes down and some more money is used on other goods such that budget shares remain constant). With Leontief technology, the quantities are always the same irrespective of changes in prices. This means that changes in prices has no effect on consumer preferences and the overall consumption level is adjusted to fit the budget constraint. Elasticities are sometimes in-between or greater than one as well.

Whereas estimation of the reference coefficients is performed on the basis of the data for the base year, we have on the other hand that elasticities of substitution cannot solely be estimated on the basis of data from the base year. Most elasticities of substitution are simply set at 0 (Leontief), 1 (Cobb-Douglas), and a few at some other "qualified guess". The elasticities we use in the current version of PINGO are coarsely based on a general understanding of the economy. More formal estimation remains as a task for future research.

2.5 The Social Accounting Matrix for base year data

Representation of base year data for the sectors and markets in PINGO comprise inputs and outputs of each sector and the amount the consumers spend on different commodities, services and savings in the base year. Input data to PINGO for the base year is collected in a so-called Social Accounting Matrix (SAM), where the columns represents the sector accounts and the rows represents the markets of commodity groups and services. The SAM matrix includes data for the trade between all pairs of counties and the explicit costs of transport between all pairs of counties per commodity.

A complete SAM contains the data required for estimation of the representative share coefficients of the NCES and CET functions in the production functions and the CES utility functions of the MPSGE modelling system. Necessary requirements to make PINGO compatible with the logistic module of the National freight model, was to update the Social Accounting Matrix (SAM) for base year 2002. The data sources we used for this purpose comprise: (1) National Account statistics by county for year 2002 for representation of each sectors account, (2) foreign trade statistics for year 2002, (3) base case freight flow PWC matrices (Hovi and Jean-Hansen 2006; Vold 2006), (4) account data by from national transport statistics (Statistics Norway 2005) and (5) Transport costs within and between regions are based on assessments with the Logistic module of the National model for freight transport.

According to the principle of the sign - the economy may be divided into a part for *endowments* and *outputs* and a part for *demands and inputs*. The two parts are supplementing in the sense that the endowments 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. Production and endowments are represented by positive figures and input and consumption by negative figures.

The column of the SAM represent the sector account for a group of economic agent's, and the rows represents markets for goods and factors of production. Economic equilibrium implies that each row and column has zero sums. To balance the columns, we adjust operating surplus commodity - the factor that represent the net of taxes, profit and subsidies/loans and other elements not accounted for. Next the different value sets have the consequence that rows in the SAM matrix for the economy do not sum to zero[4]. The rows (markets) are balanced by adjusting the relative level of the prices of the goods produced in different commodities. The amount of exchange commodity that is finally needed to balance the government sector also balances the trade balance. All rows and columns of the SAM ultimately sum to zero, which is the consequence of a well-known property of matrices (Hardley, 1973).

2.6 Model simulation

PINGO is used to determine the effect of exogenous perturbations in endowments or certain changes in technology and taxes. We may specify variables as exogenous in MPSGE by formulating these variables as endowments. It is required that this is done in a way such that the systems of model equations are well defined and can be solved by the MPSGE built-in solution algorithms.

The base year SAM matrix is an equilibrium solution. If one or more exogenously specified variables or certain technology and taxes are perturbed then PINGO can be used to find new values of the endogenous variables such that a new equilibrium is obtained. PINGO has a recursive dynamics facility, where the model equations are solved for time series of exogenously specified perturbation in corresponding time steps forward in time.

The recursive dynamics facility can be used for forecasts of economic activity by county and the transport flows between pairs of counties. The basic forecasts can be compared to forecasts with alternative assumptions on prices, import/export, and consumption and production opportunities. 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.

[4] 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.

3 The national sector-commodity account representation in PINGO

Ivanova, Vold and Jean-Hansen (2002) give a comprehensive description of the first version of PINGO. The last version of PINGO is upgraded with:

- More disaggregated sectors and commodity groups
- Re-modelled transport and trade sectors in order to correct inadequate behaviour discovered in the first version
- A bottom-up formulation suited for simulation of forecasts based on data from the National MSG model
- Improved computer programs for processing of input data, and significantly improved coding of model equations
- Possibility to aggregate and disaggregate the model with respect to geographical zones, commodities and sectors
- Explicit representation of the Continental shelf
- Collected and processed data for establishment of the SAM matrix for base year 2003 and for provision of growth factors for the recursive dynamic facility for forecast simulations with PINGO.

3.1 Dimensions in the last version of PINGO

PINGO represents Norwegian economic activity by county (Figure 2), for the Continental shelf/Svalbard/Jan Mayen/Some other activity abroad (1 zone[5]) and trade with foreign countries (1 zone). Each region has explicit representation of production, consumption, transport- and trade sectors, representative households, import/export activity. On the national level there is a government sector that balances the economy and operates as agent for collection and distribution of taxes. Trade and transport within zones and between all pair of zones is represented for each commodity group.

The new commodity groups were defined by Hovi and Jean Hansen (2005), who used criteria such as for instance to obtain a distinction between freight for final consumption and for input to production[6]. This comprises distinction between high- and low value goods, i.e., the prices of the consumption subgroups are substantially higher than the input subgroups. If the consumer share is exceeding the average consumer share of 12 per cent, the commodity is classified as a consumer commodity; otherwise it is an input commodity. But some commodities are classified according to other aspects. The maximum number of commodity groups, services and investment types has increased to

[5] Includes data for the extra county. At the Continental shelf the yearly investments may vary a lot (we use 2002). For later version one should consider to use “capital deterioration” instead.

[6] The existing commodities are split in such a way that it is possible to aggregate from a new to the old NEMO classification.

32, 6 and 6, respectively, with corresponding production sectors, and also public and private consumption per county (see Tables 1-3). There are also sectors for import, export, transport and a government sector at national level. There is one production sector per commodity per commodity group, service and investment type. The service- and *investment sectors* produce physical capital for the county where it is located based on the same types of inputs as the production sectors.

Markets for commodity and service outputs from the production sectors are represented in producer value. Markets for the same commodities after change of ownership between links in the transport and trade sector are also represented. Additionally, PINGO also represents markets for labour, specific freight transport services, operative surplus and foreign currency (or exchange). Labour in the production and service sectors comprise 17 and 83 percent of total employment, respectively. Production on the Continental Shelf requires input of labour from consumers that reside in the 19 counties. Because this labour is not explicitly represented in the data for the production sector on the Continental shelf, the labour input appears as a profit that is transferred to the Government which in turn distributes this as transfers corresponding to the income from labour on the Continential Shelf[7]. The specific freight transport services between each pair of zones that are produced by additional transport sectors. The specific operative surplus commodity is defined and used to represent savings/loans/transfers and financial deficits or surpluses in the sector accounts[8]. It is considered as output when it is positive (i.e., savings/profit or taxes) and as an input when it is negative. The value of the operating surplus commodity is used (produced) in fixed proportion to other inputs/outputs (i.e., Cobb-Douglas technology). The exchange commodity is traded between the import and export sectors and the government sector.

Table 1. Overview over the commodity groups in Nemo (From Hovi and Jean-Hansen, 2005).

No	Nemo com. No	Nemo commodity	No	Nemo com. No	Nemo commodity
1	11	Bulk food	17	62	Pulpwood
2	12	Consumption food	18	63	Pulp and chips
3	13	Beverages	19	64	Paper intermediates
4	21	Fresh fish	20	65	Wood products
5	22	Frozen fish	21	66	Paper products and printed matters
6	23	Other fish (conserved)	22	71	Mass commodity
7	31	Thermo input	23	72	Coal, ore and scrap
8	32	Thermo consumption	24	73	Cement, plaster and cretaceous
9	41	Machinery and equipments	25	74	Non-traded goods
10	42	Vehicles	26	81	Chemical products
11	51	Gen cargo, high value	27	82	Fertilizers
12	52	Gen cargo, living animals	28	91	Metals
13	53	Gen cargo, building materials	29	92	Aluminium
14	54	Gen cargo, inputs	30	101	Raw oil
15	55	Gen cargo, consumption	31	102	Petroleum gas
16	61	Sawlogs	32	103	Refined petroleum products

[7] 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.

[8] Whereas the MPSGE framework is based on theory for perfect competition and non-profit production (Walras equilibrium), we have that in reality production sectors can be subsidies or profitable. To represent profit (i.e., greater value of output than the value of input), we balance the sector by increasing the input of operative surplus commodity (i.e., representing the profit). If there is a deficit, then we increase output of the operating surplus commodity from the sector (representing subsidies).

Table 2. Overview of services represented in PINGO

990	Public social and privat services
991	Building and construction
992	Energy
993	Wholesale and retail
994	Hotel and restaurant
995	Transport and communication

Table 3. Overview of investment types represented in PINGO

801	NIA 1	Building
802	NIA 2	Construction
803	NIA 3	Ship
804	NIA 4	Aircrafts
805	NIA 5	Oil and gas
806	NIA 6	Used real capital

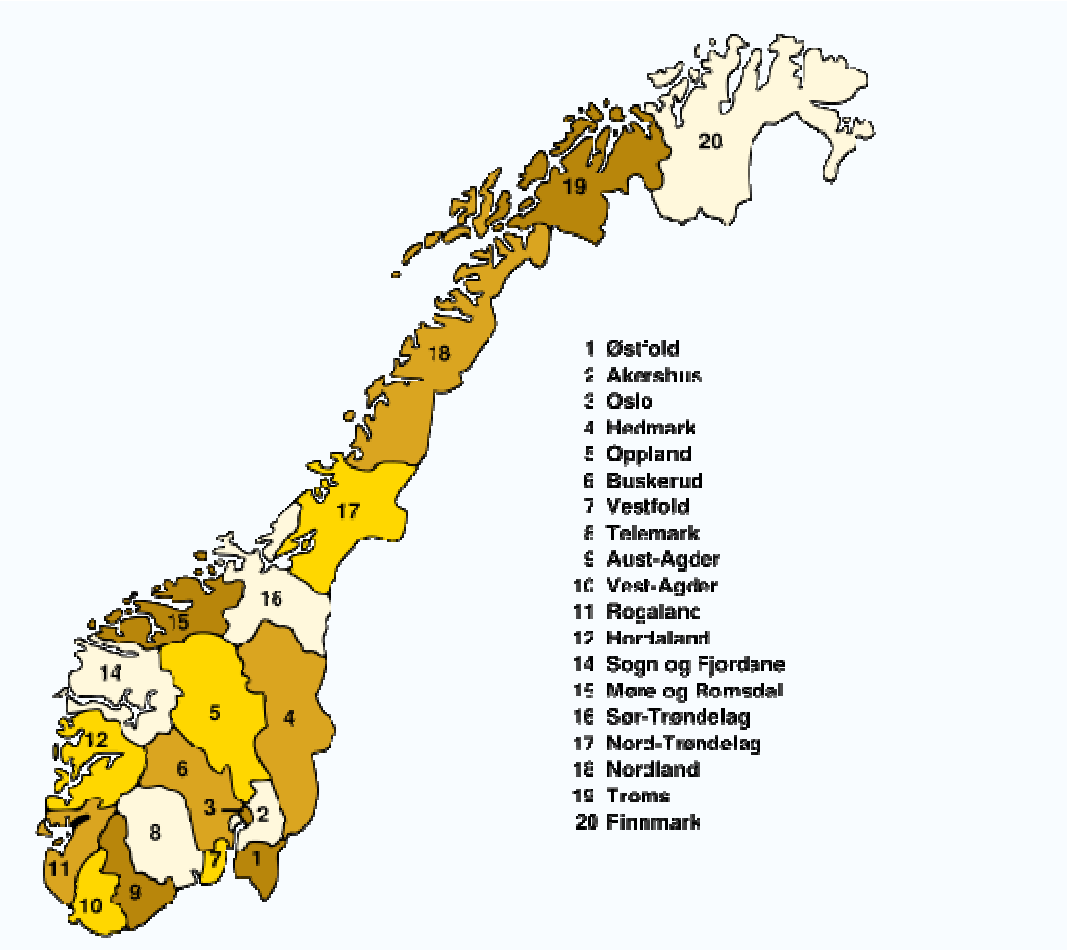

Figure 2. Counties in Norway. Svalbard is administratively under "Justisdepartementet" and doesn't belong to or constitute a county. County 13 diminsihed when Bergen was merged with Hordaland in 1972.

3.2 Production of commodities and services

Production sectors in PINGO are two-level with Cobb-Douglas technology in the lower nest for substitution between labour and physical capital. The upper nest has Cobb-Douglas technology for substitution between pool commodities and factors of production. It is further assumed that outputs from the production sectors are produced in fixed proportion (in value), i.e., if we aggregate sectors such that the aggregate sector produce several commodities then the elasticity of transformation between outputs is one.

We use National Account data for the year 2002 for representation of the input-output accounts for production of commodity groups, services and investments types in the base year 2003 SAM for PINGO[9].

PINGO sectors are aggregates of the 174 sectors National Account (NA) sectors with outputs classified in terms of CPA. Whereas most PINGO commodities are aggregates of many complete NA sectors, there are some PINGO commodities that include only shares of outputs from complete NA sector[10]. This means that NA sectors are sometimes split between PINGO sectors. In these cases, the output from the NA sectors have to be split according to factors, i.e., we solve the problem by splitting the NA sectors before they are aggregated to the PINGO sectors.

3.3 Transport

The service sector "995 Transport and communication" is one of the five service sectors in PINGO, which is based on the National Account statistics. This sector covers both passenger and freight transport, and unfortunately we do not have information that makes it possible to split the sector in separate sectors for passenger and freight transport. And although production sectors buy transport services from this sector, producers perform transport themselves as well. The transport they perform themselves is represented in terms of investments in vehicles, fuel etc. Hence, because the "995 Transport and communication"-sector covers both passenger and freight transport, and not the transport many producers carry out themselves, it isn't entirely representative for the production of freight transport services.

To correct this problem, we represent an additional sector per commodity and county specifically designed for production of freight transport services. We assume that the cost of transport undertaken are similar irrespective of whether they are organised by a specialised transport company or whether they are organised by the production sectors themselves.

The additional transport sectors represent the components of inputs required for performing transport services (labour, fuel, machinery, other commodities and services) [11]. A two level CES function represents the technology of the additional transport sector. Labour, pooled commodities and operative surplus commodity is input with zero elasticity of substitution. The elasticity of transformation for the transportation sector

[9] Data for input/output of production: "Produksjon_nemo.xls", "Produktinnsats fnr 2002.xls".

[10] There is a one-to-one relationship between SN ("standard for næringsgruppering"), CPA (commodities in the National Accounts), National Account sectors (except 20,4+20.5 in SN which is merged in the National Accounts).

[11] Some overlap of resources for transport purpose will be the effect of representing both the transport related part of the SUT and the added representation of freight transport costs. By balancing out the SAM matrix for the base case, this does not affect the model results except that we need to take into account that inputs used for transport is in part double counted and that there is somewhat less profit in the trade sector, where the difference between basis value (sellers price) and purchase price is balanced out. We have decided to keep the 995 sector as it is, as this sector not only delivers freight services, but also passenger transport, which is demanded and purchased by the households.

production function is set at a large value (5), so that production of one transportation service may be perfectly substituted for the other in situation when we have aggregated commodities and services and therefore also the corresponding additional transport sectors.

Representation of the additional transport sector was in part based on data from Statistics Norway (2005), the National Accounts and the Logistic module. Data from Statistics Norway (2005, p.93-94) includes account statistics for train, road and sea transport operators in terms of turnover[12], operating income[13], operating cost[14], production value[15], value added primary factors (personnel cost and investments) and inputs of commodities and services that are used as input to the national transport sector (i.e., costs that are not fuel or labour). For comparison against the data from the sector account of the National account, we find that we may use: Turnover, operating cost (includes depreciation but not the yearly investments), personal costs and investments, where Turnover – operating cost is considered profit.

To derive a complete input structure we subdivided "cost that are not fuel or labour" according to the shares of input and production factors of "995 Transport and communication", where we find that the commodity category refined products (32) and the services "Public and private services" (33) and transport (38) are of major importance (Figure 3)[16]. Transport operators often sub contract others operators to be able to carry out the complete transport chain for shipments which can explain why transport is and important import for production of transport services. The investment in machinery and equipment (41) and ships (41) are small compared to the cost of fuel.

[12] Turnover is operating income exclusive of VAT and without special taxes, subsidies and profits from the sales of fixed assets.

[13] Production value and subsidies together comprise the operating income.

[14] Operating costs are commodity costs, depreciation, devaluation, personal costs and other operative costs, i.e., for capital costs it looks like capital depreciation is used instead of yearly investments.

[15] The production value is defined as turnover, plus or minus the changes in stocks of finished products, work in progress and goods and services purchased for resale, minus the purchases of goods and services for resale, plus capitalised production, plus other operating income (excluding subsidies). Income and expenditure classified as financial or extra-ordinary in company accounts is excluded from production value. Included in purchases of goods and services for resale are the purchases of services purchased in order to be rendered to third parties in the same condition.

[16] Processed data for input to the transport sector in the National Accounts are found in InnsatsTransportsektorenFNR.xls.

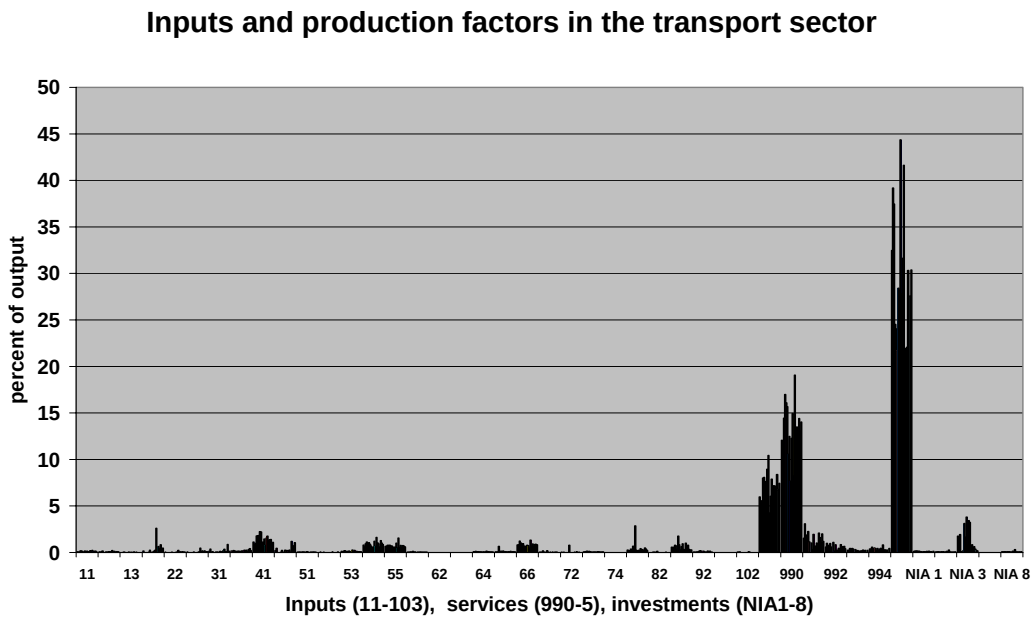

Figure 3. The shares of inputs to "995 Transport and communication" (Source: the National Accounts)

To get representative transport costs per commodity group, the input and output structure per mode was weighted by the base year shares of truck-, rail- and ship usage per commodity group (Table 6.6 and Table 6.10 in the Vold et al., 2002) and then merged. Within this merge, we also made adjustments to account for overall assumption of the relative price level of truck, rail and sea transport. Finally the input and output per transport sector is scaled by the transport costs for the total freight flows as calculated by the Logistic module in the base case situation[17].

Representation of transport charges and improved transport technology as part of the additional transport sector are described in Appendix II.

3.4 Trade

Representation of trade in the National Accounts (993 wholesale and retail) includes only its inputs in terms of e.g. wrapping paper, transport etc. PINGO also represents sectors for additional trade agent per county per commodity- and service group with additional data for the physical through-flow. The trade agents buy up commodities from production sectors in any county and from the import sectors and use transport services provided by the corresponding additional transport sectors to gather the goods into a pool. The pooled commodity is sold to producers and consumers in the same county with a profit margin. There are corresponding agents for services and investments, but these agents do only purchase services and investments from the county where they are located and do not make use transport services, i.e., Transport in connection with services is primarily short distance and is not included in this version of PINGO, and we have assumed that physical

[17] Final assessment of data to the transport sectors is found in KoblingNOS_FNR_TrSektoren.xls.

capital cannot move between counties (In reality there are trade between counties as well as between Norway and other countries).

Trade patterns of commodities in the base year 2003 are represented in terms of the base freight flow PWC matrices (Hovi and Jean-Hansen, 2006; Vold, 2006)[18]. PWC matrices exist in split versions with sub-matrices for flows between pairs of trade links. The flow via a trade link is sometimes only a monetary link, whereas the physical flows move directly from the producer to the final user of the goods. Hence the PW and WC links should to some extent be replaced by single PC links. In the current version of PINGO we didn't take this into account. Instead we located wholesaler activity in the same county as the actor that uses the commodity for input or final consumption. The PW and CW flows are scaled to fit with the production value of output from the production sectors. In a future version of PINGO this could be refined by more exactly representing both the physical PW and CW flows within and in connection with the additional trade sector.

The prices of pool commodities depend on the producer prices in the counties and the transportation costs. trade 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 transport agents tend to acquire more commodities 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 in the production functions of the trade agents (Figure 4).

The additional trade agent is represented by a three-level NCES function, where a lower nest contains inputs of goods from producers and the cost of transporting the good. To make it possible to change transport costs exogenously, we use Leontief technology to fix the share of goods and transport (see Appendix II for more about representation of taxes and technology changes). We have assumed an elasticity of substitution different from zero between the same types of goods produced in different counties (i.e., the Armington elasticity). The upper nest adds a profit margin to the price of the pooled goods, which is then sold as input or for final consumption. It is a Leontief elasticity in both the CES and CET function of the upper nest to avoid that change in the cost of transport services is compensated by a change in taxes or subsidies.

[18] *PWC matrices stand for Production-Wholesale-Consumption. They account for the possible detour some commodity flows are subject to as they are shipped via the wholesale link before they are consumed or used as input.The Production-Consumption (PC) matrices do not. Hence both the total transport costs and the total tonnes and tonnekm become too small with PC matrices.*

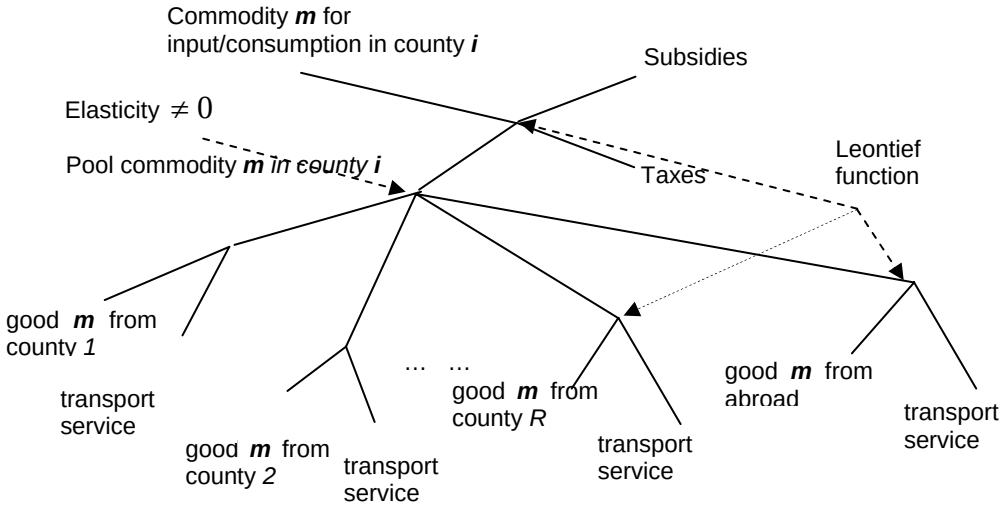

Figure 4. Schematic view of input/output and technology of the additional trade agent.

3.5 Export/Import

There is one export sector per county that buys commodities directly from the producers in the county. The commodities are exported FOB to foreign countries in exchange of foreign currency, which has a positive impact on the trade balance. The export demand for Norwegian commodities is not explicitly modelled in PINGO. The export sectors per county are specified as consumers in MPSGE, where the export of goods is specified as demand and the exchange commodity earned exogenously is specified as endowments.

The import sectors per county are formulated as a production sector in PINGO, which use the exchange commodity for input and produce import commodities that are bought by the additional trade agent. CET functions with non-zero elasticities are used to represent the import of various commodity groups. If prices of imported goods become relatively cheaper as compared with domestically produced goods, then the trade agents tend to acquire a greater share of import goods to serve their market.

The price of the exchange 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.

We use data from the foreign trade statistic (Statistics Norway) to represents import and export flows. Data are based on change in ownership when the commodity is sent out of Norway (delivered ”free on board” – fob), whereas data 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). This gives a slight inconsistency in the additional trade agent sector, where we add transport costs to import goods. This is compensated in the calibration process, however.

3.6 Government sector

The government is represented as a MPSGE production sector at national level. It is represented as and has the following functions: (1) it is a tax agent that levy taxes on the production- and transport sectors, (2) it balances operating surplus (i.e., transaction of

surplus from profit, taxes and charges as subsidies, transfers and social security) and (3) it is related to the import and export sectors because it both sell and buy the exchange commodity.

Taxes/charges/profit are considered as output while subsidies/transfers are considered as input. If the net of the government account of operating surplus is negative (i.e., the government distributes more operating surplus than it acquire), it means in turn that the government is selling more exchange commodity to the import sector than it get as input from the export sector. On the other hand we have that the more goods are imported from abroad the greater is the demand for the exchange commodity, which is either balanced out by increased export activity and/or more transfers and subsidies.

The net of government input and output of the exchange commodity gives the overall trade balance.

Transfers can be pure financial transactions, which are huge in macro economic value. Especially banks and financial institutions are involved in this, but all actors are more or less involved. It would be possible to extract and represent these transactions in a separate finance/banking sector in a possible future version of PINGO.

3.7 Representative households

PINGO represents two types of households – one private and one public. Data for private and public consumption were obtained from the National Accounts for base year 2002[19].

3.7.1 Private households

Households' endowments comprise income from labour, loans, social security transfers, profits earned from ownership in the production sectors (the enterprises profit is net of capital cost). It is assumed that households use all endowments per year for consumption of commodities and services (i.e., all costs of living including the housing rent[20]). For consistency with the statistical sources, we need to assume that commodities like cars, furniture, electrical units and clothes are consumed in the year they are bought.

Consumption is only represented for the Norwegian counties – not for the extra county or for consumption by Norwegians abroad. Household consumption by Norwegians and foreigners in Norway are merged in the same sector**.** It is noticed that the National Account by County includes the correction elements "5076[21], Consumption by foreign tourists in Norway" and "5077, Other foreigners in Norway (households)". We could possibly use the former correction coefficient to approximately extract and move consumption by foreign tourists in Norway to the export sector. However, we didn't as this is tricky with regard to the transport costs. Consumption by Norwegian tourists abroad can be considered as import of services from foreign countries tourist sectors. This is not included in the National Accounts by County, however.

The difference between expenditure on private consumption and endowment from labour[22] is balanced in terms of a factor representing either transfers or savings. We do

[19] Consumption is found in the spreadsheet Konsum_nemo_2002.xls

[20] National Accounts represents housing costs by a housing rent that is paid to "990 Offentlig social og privat tjenesteyting", who in turn buy premises and residences from "991 Bygge og anleggstjenester".

21 Product codes in "oppdatert nemo_nr.xls" are National Account (NA) codes. They are very detailed and only the last digits are included.

22 Income from labour is based on the data found in the spreadsheet "Lønnskostnader 2002.xls" and "Fordelingsavh lønnskostnader fylke.xls". The first spreadsheet contain labour for commodity production (in 100 000 kroner) and the second spreadsheet include labour for

not have data for labour in the extra county. It is noticed, however, that much labour is used for production of oil and gas in some other counties, which is probably the labour required at the Continental shelf. This gives a deficit in the oil producing sector in the respective counties and a corresponding extra surplus in the production sectors at the Continential shelf (this is merely a matter of transaction, however, we just need to be aware of it).

Representative household's preferences for different commodities and services are specified by their CES utility function, which is fully described by representative consumption bundles (see section 2.1.2). We use a zero elasticity of substitution in order to fix consumption bundles according to exogenously given preference structure.

In later versions of PINGO, it could be possible to segment the households according to income or labour groups and thus different consumption patterns would make it possible to analyse distributional effects.

3.7.2 Public households

Public consumption and consumption by unincorporated non-profit associations are merged into one sector representing public consumption. The endowments of the public household are represented in terms of the operative surplus commodity (i.e., transfers from the government and charges from private sector). In essence the public consumption per commodity group is considered as net of what public sector doesn't finance by charging private actors (e.g., if for instance a public management company achieves 5 million kroner in basic funds and pay back 2 million to the government from charges paid by private actors, then the public consumption amount is 3 million).

The endowments in public consumption represent payments from the governments and charges levied upon producers and consumers, i.e., represented as transfers ("operating surplus commodity"). A major part of demand in the public consumption sector is "990 Public social and private services".

service production (in 1000 000 kroner). The data is copied to "lønnskostnader fra annet ark.xls" where the data are scaled to unit of 100 000. There is production of some other production sectors in the extra county but none of them include labour. For Vest-Agder and Aust-Agder the spreadsheets included figures for labour in Agder as a whole. We split the total for labour in Agder into 2/3 for Vest-Agder and 1/3 for Aust-Agder. We do not have labour for production of the investment categories.

4. Specification of exogenous variables in PINGO

Sectors in MPSGE are either represented as producers or consumers. The producers are fully endogenously determined, whereas it is required that the consumer's endowments available for consumption as specified in real prices is exogenously specified.

Real world producers and -consumers are usually specified as producers and consumers in MPSGE, respectively. There are exceptions, however. In principle we may alternatively specify a real producer in terms of a consumer in MPSGE. In that case the inputs are represented as demand and the output as a number of endowments. A real consumer can alternatively be specified in terms of a producer. If a real consumer is specified in terms of a producer in MPSGE then the endowments are specified as output and the demand as the input.

Specification of real producers in terms of MPSGE consumers makes it possible to run PINGO top-down with exogenously specified production volumes. This can be a possible option if we have data for production by county and have the objective of focusing on how exogenously specified production volumes will affect the freight flows. A bottom-up specification where real producers and consumers are respective MPSGE producers and consumers is used if it is required to endogenously determine production by county.

The current version of PINGO can be run with a distributed top-down approach and a distributed bottom-up approach.

A recursive dynamics algorithm is used for both approaches, which read values of exogenous variables and applies PINGO to endogenously calculate the corresponding new equilibrium. In each step of the recursive forecasting algorithm, we update the reference quantities. The Leontief elasticities in the consumer utility function assures that consumer preferences are kept in accordance with the exogenous assumptions derived from National growth forecasts. New values for exogenous variables are read in the next time step and PINGO is applied and so forth throughout the prediction interval.

4.1 Top-down

For the top-down approach with PINGO we constraint the growth in domestic production by county and import and export to take values according to exogenously specified growth rates. We may adjust/calibrate elasticities of substitution in production function and expenditure functions in order to obtain a reasonable fit between the sum of consumption of goods groups over the counties as predicted by PINGO and corresponding national forecasts by MSG-6 (Heide, Holmøy, Lerskau, Solli, 2004). The top-down approach is deficient; however, as there are no viable ways of obtaining forecast data by county for the required exogenous variables.

4.2 Bottom-up

For the bottom-up approach of PINGO we specify private and public households' endowments exogenously. By also specifying the export sector as a consumer in MPSGE with exchange commodity per county as endowments and commodities for export as demand we obtain a well-defined system of equations. Initial values of exogenously specified endowments for private and public households per county, budget shares and export can be obtained from the SAM for the base year 2002. Changes in endowments of private households are set in proportion to population growth by county (from Statistics Norway[23]). Changes in total demand, consumption preferences and export can be obtained from the MSG model. MSG-6 forecasts are also used to overall adjust the income per capita, changes in consumer preferences and export of the goods groups as predicted by the MSG-6 model. The exogenous specification of export is required because PINGO is not representing how the development of international economy affects the demand for Norwegian goods. Export by county is based on prediction of export at national level from MSG as split by county in proportion to production levels by county.

Domestic production and import by county are endogenously determined with the bottom-up approach.

4.2.1 Exogenous predicting consumption demand per county

To exogenously predict endowments for consumption per county we need a methodology that consistently distributes the national growth as derived from the MSG-6 to the county level. We use the MSG-6 predictions of national consumption growth $G_{y,c}$ of commodity *c* to obtain the national consumption in year *y+1*

$$C_{y+1,c} = G_{y,c} \cdot C_{y,c}.$$

Further to this we simply make the assumption that consumption growths of commodity *c* in county *i* from year y to y+1 follows the national consumption according to the national MSG-6 predictions times the consumption shares by county *i*:

$$(1) \qquad C_{i,y+1,c} = S_{i,y+1,c} \cdot C_{y+1,c}$$

where the consumption share by county i in year y+1 is assessed by:

$$(2) \qquad S_{i,y+1,c} = \frac{G_{i,y,I} \cdot G_{i,y,P} \cdot C_{i,y,c}}{\sum_{j} G_{j,y,I} \cdot G_{j,y,P} \cdot C_{j,y,c}},$$

where $C_{i,y,c}$ denotes the consumption of commodity *c* in county *i* in year *y*, $G_{i,y,P}$ denotes the percentage population growth in county *i* and $G_{i,y,I}$ represents a percentage real income increase per capita for consumption (kr/year) that we currently set equal to 1.

By determining the consumption this way we implicitly assume that the national growth rates determine the level of the consumption, whereas the growth in population by county

[23] Statistics Norway provides national and regional predictions of the population growth (see Statistics Norway, 2004). Further to this we have data for consumption of commodity *c* in county *i* in year *y*, $C_{i,c,y}$, from base year data from the National Accouts by County (2002) from Statistics Norway, which are respresneted in the SAM matrix. The national consumption by commodity group, Gyc, is available in the base year and the growth rates are derived from by MSG-6 consumption group growth as explained earlier.

and the growth in income per capita determine the distribution of national consumption to the counties. Budget shares by county are determined by

$$B_{i,y+1,c} = C_{i,y+1,c} / \sum_c C_{i,y+1,c} .$$

The budget is based on income from labour and transfers. We predict the growth of household income from labour in year *y+1* by the population growth times the growth in household's real income,

$$L_{i,y+1} = G_{i,y,I} \cdot G_{i,y,P} \cdot L_{i,y} .$$

Transfers are assessed by

$$\sum_c C_{i,y+1,c} - L_{i,y+1}$$

(i.e., the difference between the sum of expenditures minus income from labour). We assume a positive difference is compensated in terms of transfers from the government and net capital income, whereas a negative difference is considered as savings. Net subsidies are assigned on the demand side and net savings are assigned on the income side.

Hence for counties where there is a positive difference between expenditures and income from labour, the demand side constitutes the expenditures on commodities and services and the endowments constitute income from labour and transfers and capital income. For counties where there is a negative difference, the demand sides constitute expenditures plus saving and the endowments are income from labour.

We may use MPSGE output to assess the increase in consumption that relate to the relative increase in real prices on labour.

4.2.2 Exogenously predicting future public consumption budget shares and endowments

We may determine public consumption budget shares similarly to how we determined budget shares for households. We need to consider, however, how we should assess the consumption shares by county (see equation 2 for corresponding quantity for households).

A possible equation could be:

$$S'_{i,y+1,c} = \frac{(\alpha \cdot G_{i,y,P} + (1-\alpha) \cdot G_{i,y,Prod}) \cdot C'_{i,y,c}}{\sum_j (\alpha \cdot G_{j,y,P} + (1-\alpha) \cdot G_{i,y,Prod}) \cdot C'_{j,y,c}},$$

where $G_{i,y,Prod}$ is the overall growth of production of commodities and service and $0 \le \alpha \le 1$. Currently, however, we use $\alpha = 1$. Budget shares are derived analogously to budget shares for household consumption. Endowments for public consumption are derived from the consumption shares, i.e., by $\sum_c C'_{i,y,c}$.

4.2.3 Exogenously predicting future export

Future export growth by county is determined by simply applying the national growth rates at the county level (beware, however, that this could cause complications in a top-

down approach where production by county is also exogenously specified, i.e., if the export growth becomes considerably greater than the growth in production). The export commodities are represented as demand and the exchange capital commodity as endowments which are balanced to equilibrium in each PINGO run.

There is one sector for each export commodity per county, which means that we may use the growth factor for the export commodity as a growth factor for the exchange commodity which represents endowment in the export sectors.

4.3 Forecasts for exogenous growth for calibration and application of the distributed bottom-up approach

In support of the analytical work carried out for the National transport plan Hovi et al. (2007) derived forecasts of national growth for base case scenario assumptions from MSG-6 in real prices for the exogenously specified variables (i.e., "low emission" alternative):

- Domestic production of 32 commodities, 6 services and 6 investment types[1].
- Import of 32 commodities[1].
- Export of 32 commodities[2].
- Private consumption of 32 commodities, 6 services and 6 investment types[2].
- Public consumption of 32 commodities, 6 services and 6 investment types[2].

[1]for calibration.

[2]for calibration and exogenous variables.

From MSG-6 we have growth rates for aggregates of National Account sectors (19 MSG-6 commodity producing sectors and 22 service sectors plus consumption groups)[24]. The growth rates predicted by MSG-6 can be used to project the base year PWC matrices to future years in a static way by simply multiplying with a factor. However, by applying PINGO, we may in a distributed way take into account the changes in population growth and changes in consumption and export. Thus, we used the MSG-6 forecasts to calibrate and apply PINGO with bottom-up approach with the purpose of assessing forecast for freight flow PWC matrices for the years 2006, 2010, 2014, 2020, 2030 and 2040.

4.3.1 Growth rates for production, input and consumption

Hovi et al. (2007) established tables for the relationship between National Account (NA) sectors and the CPA commodities *produced*, *used for input* or *consumed*. Then they used the NA-CPA structure to converted growth rates from MSG-6 for production to growth

[24] MSG-6 sectors are composites of National Account (NA) sectors and sectors represented in the NA produce one or more CPA commodities, and some of the NA sectors produce a group of CPA commodities that are not all part of one of the 32 commodity groups of the national freight model. Hence Statistics Norway had to make a split of some of the NA sector in order to make the production sectors for PINGO. MSG-6 growth rates are in terms of value in real prices. Applied to tonnes of commodity groups this implies that we assume the relative value per tonne of each commodity in the commodity group is constant (i.e., the unit values don't change during the forecast period).

rates for production of CPA commodities and thereby growth rates for production of PINGO commodities and services. MSG-6 growth rates for export were derived similarly.

4.3.2 Growth rates of export and import of commodities

Most of the import is used for input or consumed. We did not take into account that a share is directly re-exported. It is a minor share, however (pers.comm Knut Sørensen, Statistics Norway).

Each import growth rate from MSG-6 represents a composite of CPA commodities. Hence, it was possible to transform the MSG-6 composite growth rates to import growth rates for CPA commodities and based on the relative magnitude of CPA commodities per PINGO commodity for input and consumption, we found growth rates for the corresponding commodities that are represented in PINGO. A few exceptions to the above description are explained by Hovi et al. (2007).

PINGO does not represent export and import of services. Thus it was not necessary to consider how to determine growth rates for import and export of services. However, the significance and possible expansion of PINGO in this regard should be considered in future model updates.

4.3.3 Growth rates of investments

Investment types can be treated similarly to services, i.e., we have MSG-6 growth rates for sectors that produce investments; there is a NA – CPA structure for production of investments. Similarly to services PINGO do not represent export and import of investments. However the significance of this should be investigated in later upgrade of PINGO.

4.3.4 Growth rates of public and private consumption

We have growth rates of MSG-6 consumption groups. By using the NA – CPA structure it is possible to map the MSG-6 consumption group growth rates to consumption of CPA and thereby PINGO commodities and services. Similarly to private consumption we use MSG-6 growth rates for the commodities and services demanded for public consumption.

4.4 Calibration of the distributed bottom-up approach

The exogenous specification of growth in the bottom-up approach accounts for the requirements of consistency with national forecasts of public- and private consumption and export. Growth rates of domestic production of commodities and a service and import goods are determined endogenously. Calibration is required; however, to ensure that growth rates endogenously predicted by PINGO for production and import are relatively close to the corresponding MSG-6 predictions at national level.

Because of slight inconsistencies between the sources of data for establishment of the SAM, it was necessary to merge commodity groups 71 and 74 and commodity groups 101 and 102. For the same reason, it was also necessary to aggregate the 21 zones to a total of 12 zones. The calibration was done on a 4 – zone version of PINGO to reduce the run time. The calibration was performed by running the PINGO recursive dynamics algorithm iteratively with the exogenously specified data. After each run, we adjusted the input shares of goods types based on inspection of the difference between MSG-6 and PINGO. Ultimately we stopped while by subjective consideration we didn't find ways to

further reduce the discrepancy (Table 4). The discrepancy is considered acceptable in light of the general uncertainty of predictions and the fact that MSG-6 and PINGO are different models and different level of aggregation.

With the current version of PINGO it isn't possible to constrain the share of import versus domestic production. As a result, we experienced that it was impossible to obtain a small discrepancy for both import and domestic production. Thus, we did individual trade-offs per commodity group with more weight on the biggest of domestic production and import.

When we used the calibrated shares for 12 zone version of PINGO, we found that the predicted quantities were very close to corresponding growth rates predicted with the 4-zone version. But the relative change in the real prices was different. We adjusted this consistently by a common factor, however, which in effect changed the numeraire.

According to PINGO the relative change in the real price on refined products (103) was about twice as high as for other products. When we compare growth in the quantity of commodity 103 as predicted by MSG-6 and PINGO, we need to take this into account by reducing predicted growth by MSG-6 by 50%. Or vice versa to compare by value we need to double quantitative growth predicted by PINGO for this commodity group.

Table 4. Deviation between PINGO and MSG-6 per commodity for production+import in year 2040 in year 2002 real prices in the final step of calibration. Numbers are positive when MSG predicts greater growth than PINGO and vice versa

	Commodity group	Commodity group description	%-age deviation between MSG and PINGO
1	11	Food bulk	11 %
2	12	Food consumption	-11 %
3	13	Beverages	9 %
4	21	Fresh fish	1 %
5	22	Frozen fish	0 %
6	23	Processed fish	-2 %
7	31	Thermo input	-3 %
8	32	Termo consumption	0 %
9	41	Mashines and equipment	-13 %
10	42	Vehicles	-3 %
11	51	High value products	-6 %
12	52	Alive animals	0 %
13	53	Construction materials	-2 %
14	54	general cargo for input	-32 %
15	55	general cargo for consumption	-8 %
16	61	Saw logs	-6 %
17	62	Pulpwood	-6 %
18	63	Pulp and chips	-8 %
19	64	Paper intermediate	-6 %
20	65	Board and woodwork	-3 %
21	66	Paper products and printed matters	-8 %
22	72	Coal, ore and scrap	-29 %
23	73	Cement, plaster and cretaceous	0 %
24	71/74	Mass commodity/Non-traded goods	-7 %
25	81	Chemical products	-7 %
26	82	Fertilizer	-12 %
27	91	Metals	-11 %
28	92	Aluminium	-5 %
29	101/102	Raw oil/Petroleum gas	21 %
30	103	Refined petroleum products	-10 %

5 Socio-economic results

Export and consumption demand are exogenously specified variables in PINGO with distributed bottom-up approach. Although the export of most Norwegian commodities increases during the period (2003 to 2040), we have a substantial reduction of oil and gas that overall reduces the real value of total Norwegian export from NOK 366 billion to NOK 271 billion, whereas the real value of consumption by private households increases from NOK 1330 to NOK 2763 billion (i.e., by 107%), whereas the population grow from 4.6 to 5.7 million individuals (i.e., by 24%).

PINGO endogenously determines that the overall domestic production of commodities and services increases from NOK 2547 to NOK 3891 billion and that overall import increases from NOK 412 to NOK 880 billion from 2003 to 2040.

In 2003, the trade sector buys NOK 2182 billion of domestically produced commodities and all of the 412 that goes to import. NOK 366 billion of the domestically produced freight goes directly to export. The trade sector sell goods worth NOK 2856 billion, where NOK 1152 is used for input in production of goods and transport services, and NOK 1330 are used for final private consumption. In 2003 the trade sector buys services worth 11 billion from the additional transport sector, which illustrate that the cost of transport is only a small part of the total cost of production of commodities and services.

In 2040, the trade sector buys NOK 3619 billion of domestically produced commodities and all of the NOK 880 that goes to import. NOK 272 billion of the domestically produced freight goes directly to export. The trade sector sell goods worth NOK 5088 billion, where NOK 1957 billion is used for input in production of goods and transport services, and NOK 2763 billion are used for final private consumption. In 2040 the trade sector buys services worth NOK 20 billion from the additional transport sector.

Table 5 summarises the results. The model reflects the situation that Norway becomes more dependent on import goods, and that the export goes down. The current version of PINGO does not include import of services, which is why the numbers are for import are lower than the 55% GDP share envisioned in the first footnote in this report.

Assessment of the future structure of intra- and interregional freight flows based on the PINGO predictions and assessments of corresponding transport indicators (e.g., changes freight transport work and the average transport distance) with the Logistic model of the National freight model are presented in Hovi (2007).

Table 5. Model output from base case scenario runs of socio-economic quantities in year 2003 and 2040 (billion year 2002 NOK)

	2003	**2040**	**%-change**
Domestic production of commodities and services	2547	3891	53
Import	412	880	114
Trade sector input from domestic production	2182	3619	66
Trade sector input from import	412	880	114
Export	366	272	-26
Trade sector output to input in production	1152	1957	70
Trade sector output for final consumption	1330	2763	108
Purchase of freight transport service	11	20	82

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Appendix I:

Representation of changes in transport charges and technological improvements

An important application area of PINGO is its basic ability of generating forecasts of the base freight PWC matrices. To make realistic PINGO runs we also need to take into account that transport costs and technology are subject to change over time. In this section we describe how an assessment of the isolated effects of changes in transport charges, infrastructure- and technological improvements is modelled in PINGO.

Altered assumptions about infrastructure improvements that affect transport costs can be represented in the logistic model, whereat the logistic model is run and new average transport costs within and between pairs of zones are determined and the SAM adjusted accordingly (i.e., the reference quantities, identified by the Q: notation in MPSGE). This gives imbalance in the PINGO sector-commodity accounts. Because Leontief technology is used for the trade sector input shares of transport versus goods, we find a new equilibrium solution by application of PINGO to the adjusted SAM. If the cost per tonnekm is reduced because of technological improvement or vice versa because of extra charges, then we need to represent this by the built-in MPSGE functionality for specifying and adjusting benchmark reference prices (P: notation) of different inputs or outputs in the production sectors.

For the current version of PINGO, we have explicitly specified taxes on transport services and how it is distributed buy using the construct such that a tax is levied on the input of transport services. Tax-rates can be specified on the inputs to the production sectors. This means that we need to set the tax rate and then the new reference price on the input in accordance with the change in the total cost of the input component due to altered tax rate. The governments sector is used as a tax agent who retrieves the taxes. From the government, the taxes are subject to endogenously redistribution in accordance with the model specifications. Redistribution may be merged with and follow the flow of other transfers or more strictly by earmarking the revenue for a specific actor.

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