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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.

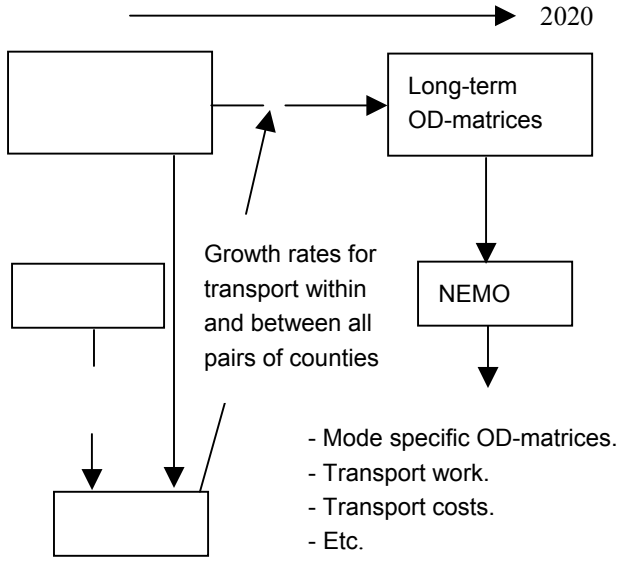

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Figure 1.1. Schematic view of the interplay between NEMO and PINGO.

[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.