Supply chain disruption modelling framework

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1 . What is a general equilibrium model?

General equilibrium models are based on neoclassic economic theory and solve for the set of prices that achieves equilibrium in all markets in the economy. Key elements of a general equilibrium model include: (1) firms that maximise profits, (2) consumers that maximise utility, and (3) markets determine prices so that supply equals demand for all goods and primary inputs (e.g., capital and labour). See Winchester and White (2022, Section S1) for a mathematical formulation of a general equilibrium model.

2. What is a computable general equilibrium (CGE) model?

Computable models provide a numerical solution to the equations of a general equilibrium model by solving for the set of prices that achieves equilibrium in all markets. CGE models are calibrated to observed socioeconomic data, which are organized in a social accounting matrix (SAM). SAMs represent data on all economic transactions that take place within an economy. Observations in a SAM include data on input-output linkages (e.g., steel inputs used by the construction industry), consumer expenditure, and imports and exports.

3. A global economy-wide model for supply chain disruption analysis

A bespoke global economy-wide/CGE model was constructed to evaluate the supply chain disruptions. The model represents multiple regions and multiple sectors and captures: (1) how changes in one sector will impact other sectors (e.g., how an increase in the price of oil will impact airtransport), (2) how disruptions in one country impact other countries, and (3) how substitution among products/inputs can mitigate supply chain disruptions. The model represents 33 sectors, which are listed in Table 1. The model includes seven sectors in agriculture, forestry & fishing; six energy extraction, production & distribution sectors; four transport sectors; 12 manufacturing sectors; and four sectors related to construction and services. Key features of the model are described below.

3.1 Production

Production for each sector is represented using a series of nested constant elasticity of substitution (CES) functions. Input substitution possibilities for each sector are determined by the nesting structure used for that sector, assigned elasticity parameters, and input cost shares in the benchmark data. A unique production function is calibrated for each sector, but some sectors share a common nesting structure.

Table 1. Sectors represented in the CGE model.

Agriculture, forestry, and fishing		**Manufacturing**	
rmk	Dairy farming	crp	Chemical, rubber, & plastic products
b_s	Beef and sheep farming	nmm	Cement manufacturing
oap	Other animal products	nfm	Non-ferrous metals (e.g., aluminum)
v_f	Vegetables, fruit & nuts	i_s	Iron & steel
hor	Other horticulture	fmp	Fabricated metal products
frs	Forestry	mil	Dairy products
fsh	Fishing	mtp	Meat products
		ofd	Other food products
Energy extraction, production & distribution		w_p	Wood and paper products
col	Coal mining	tcf	Textiles, clothing & footwear
cru	Crude oil extraction	mvh	Motor vehicles & parts
oil	Refined oil products	omf	Other manufacturing
gas	Natural gas extraction & distribution		
oxt	Other mining	**Construction and services**	
ely	Electricity generation & distribution	cns	Construction
		afs	Accommodation and food services
Transport		bus	Business services
rtp	Road transport	ser	Other services
wtp	Water transport		
atp	Air transport		
hht	Household transport		

The nesting structure used for most sectors is illustrated in Figure 1. In the top-level nest, an energy capital-labour aggregate is combined with other intermediate inputs in fixed proportions (i.e., the elasticity of substitution between the aggregates is zero). In the energy-capital-labour nest, there are substitution possibilities between energy inputs and between energy inputs and capital and labour, which are governed by elasticity of substitution parameters (denoted by σ).

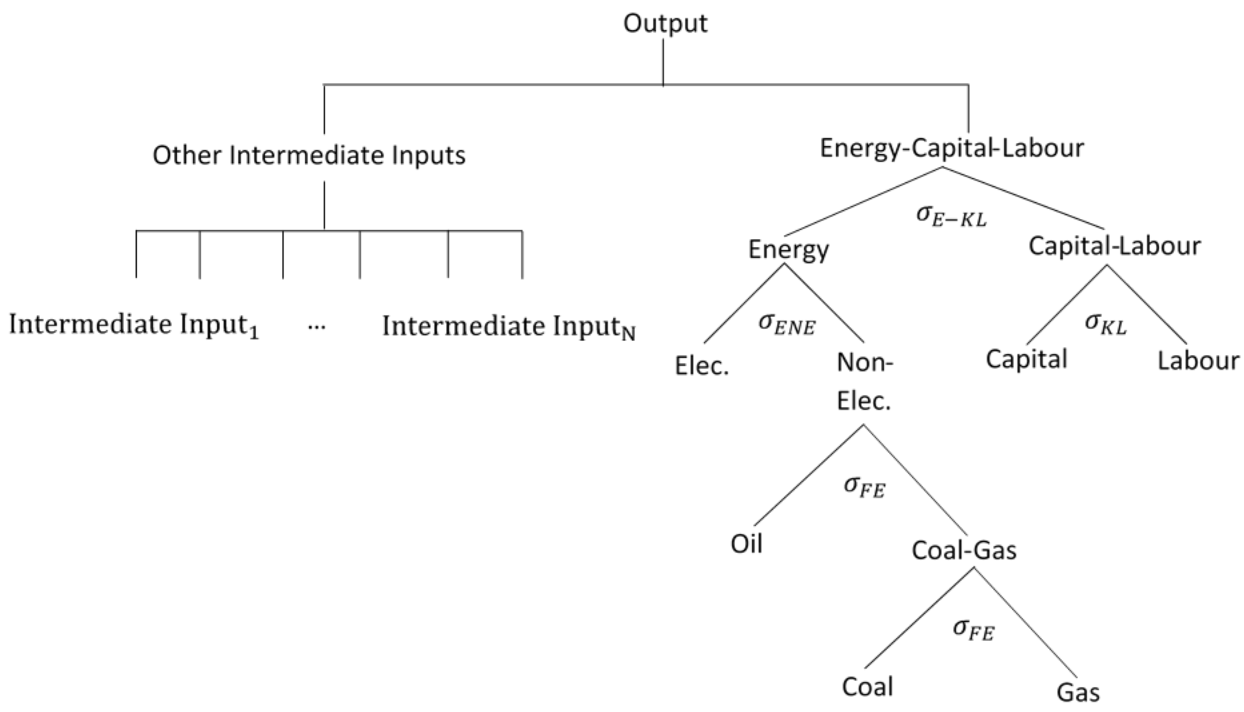

Figure 1. Production nest for most sectors.

Note: Vertical lines in the input nest signify a Leontief or fixed coefficient production structure where the elasticity of substitution is zero.

The production nest for agriculture and forestry sectors is outlined in Figure 2. Land is a key production factor for these sectors and the nesting structure allows for endogenous yield improvements through two channels. First, if $\sigma_{IL} > 0$, farmers can use more intermediate inputs, such as fertilizer, to increase output from a given amount of land. Second, if $\sigma_{AGR} > 0$, more labour, capital, and energy can be used to increase output from a fixed amount of land.

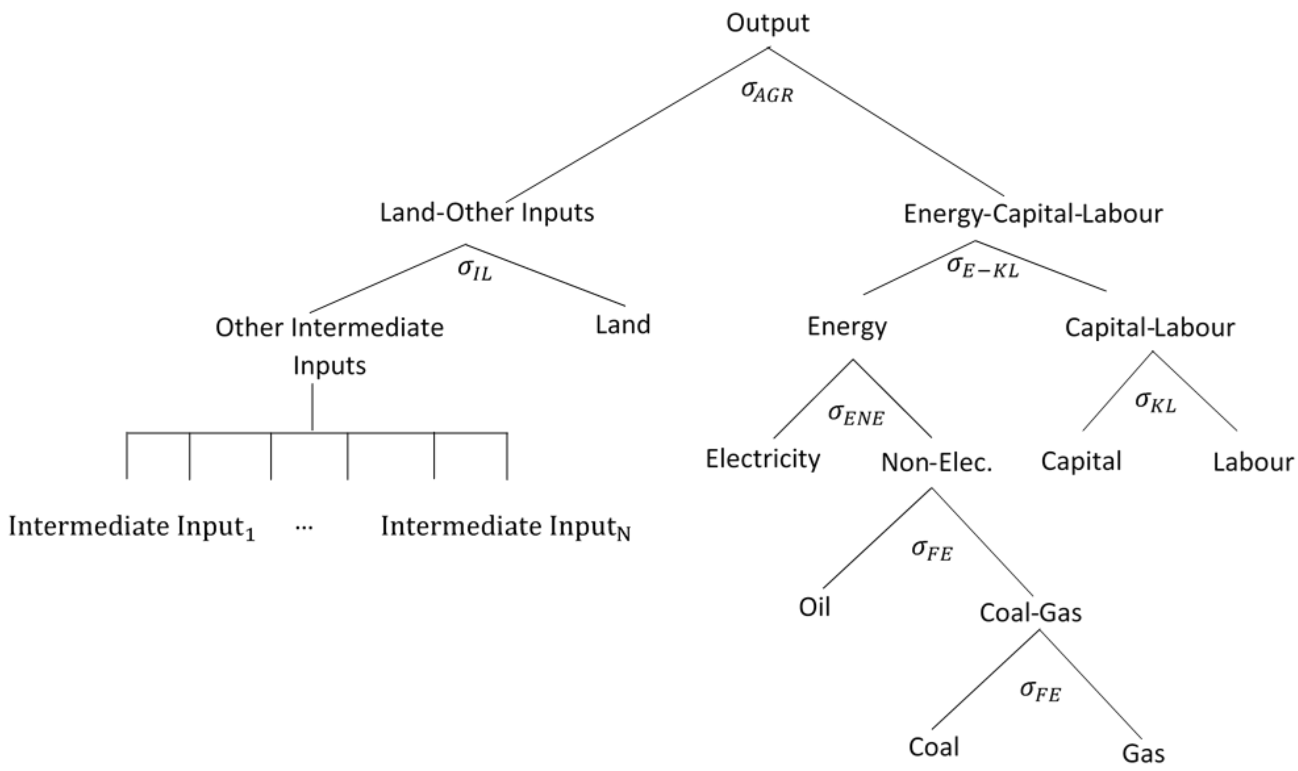

Figure 2. Production nest for agriculture and forestry sectors.

Note: See notes for Figure 1.

3.2 Final expenditure

Expenditure on final goods and services in each region is determined by a representative consumer who allocates expenditure in a utility-maximising fashion across investment, government consumption, and private/household consumption. Government consumption and investment expenditures are each represented by a single-level CES functions of commodities. Private consumption is represented by a series of nested CES functions that allow substitution among commodities. A key feature of household consumption is substitution possibilities in the consumption of transport services. In the transport nest, consumers can choose between commercial transport (e.g., taxis, buses, and airplanes) and household transport (travel in privately-owned motor vehicles).

3.3 International trade

The model represents bilateral trade in each commodity. In each region, imports are differentiated from domestic commodities and by region of origin according to the Armington assumption (Armington 1969). That is, for each good, imports from different regions are gathered in a constant elasticity of substitution (CES) nest to create an import composite. The import composite is combined in a further CES nest with the domestically produced variety to generate a composite that is purchased by firms, the government, and the private household (i.e., each good purchased in each country is a combination of domestically produced and imported varieties). International trade in the model also includes transportation costs. See Winchester and White (2022, Section S2) for a detailed description of international trade in the model.

3.4 Model closures

As in all CGE models, several relationships must be specified to 'close' the model. In the base specification of the model, labour is perfectly mobile across sectors, the supply of labour is fixed and the economy-wide wage adjusts to clear the labour market (i.e., there is full employment). In some simulations, unemployment is considered in the model using a multi-step process: (1) The shock is simulated under the full employment assumption; (2) Changes in sectoral employment are examined and in each sector with declining employment the number of displaced workers is estimated; (3) a fraction of displaced workers (e.g., 50%) is subtracted from the total workforce and the shock is simulated again.

In other closures, the supplies of sector specific and mobile capital are exogenous and capital rental rates are endogenous. The supplies of each land type (land used for forestry, dairy farming, beef and sheep farming, other agriculture, vegetables and fruits, and horticulture) are also exogenous and land rental rates are endogenous. The current account balance is fixed at the value in the benchmark year. Government spending and net tax revenue are endogenous with government surpluses or deficits passed on to consumers as (implicit) lump sum transfers. Investment is a fixed proportion of GDP and is equal to domestic savings minus the current account balance.

4. Model calibration and simulations

The model is calibrated using version 10 of the Global Trade Analysis Project (GTAP) Database (Aguiar et al., 2019). This database provides a snapshot of the global economy in 2014. The model estimates the impact of supply chain disruption shocks in 2025 using a forward-calibration routine, which follows that used by Paltsev et al. (2018, Chapter 6). This procedure is implemented in two phases. In Phase 1, the model is simulated to capture key changes that have occurred (or are likely to occur) between 2014 and 2025 that are not part of the supply-chain disruption of interest. This simulation is known as the baseline scenario. In Phase 2, the supply-chain disruption of interest is simulated on top of the changes in Phase 1. The impact of the supply-chain disruption is then estimated by comparing the results from Phase 2 to those from Phase 1.

Key drivers in the baseline scenario, which are informed by the Climate Change Commission's 2022 update to the Climate PoLicy ANalysis (C-PLAN) model, include: (1) growth in GDP and labour productivity, (2) land use for agricultural and forestry sectors, and (3) production constraints for selected sectors (fishing; crude oil extraction; gas extraction and distribution; iron and steel, cement manufacturing; chemical, rubber and plastic products; non-ferrous metals; other mining; water transport; and oil refining).

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