

ECONOMY-ENERGY-ENVIRONMENT: THE 3E COMPASS MODEL

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Summary

The 3E COMPASS (COMprehensive Model for Policy ASSessment) is an econometric simulation model designed to capture the interaction among the 3E spheres encompassing economy, energy, and environment. COMPASS is designed for simulation experiments up to the year 2020. This time horizon is not particularly long in modeling exercises: In fact, there are models, particularly of the CGE (computable general equilibrium) type, projecting up to the year 2100. The COMPASS model in contrast is characterized by regional and structural details based on econometrically obtained parameters, which enable the model to trace the actual time path of the global

economy. The model achieves international linkage for 60 regions, covering 99.5% of the world's GDP (gross domestic product). The country models are based on time series of a 36-sector input-output framework, the System of National Accounts (SNA), and financial accounts. They are linked to each other through time series of 25-commodity trade matrices, which explicitly describe annual trade flows among world regions, achieving global coverage. The model also generates data on energy balances and CO₂ emissions for individual countries. Thus, COMPASS provides multisector, multicountry information on production, trade, balance of payments, saving and investment flows, energy demand and supply, and environmental impact. It is capable of generating consistent output and price series, together with interest rates, exchange rates, and energy prices. Empirically based econometric methods are employed throughout, enabling users to trace a dynamic time path of policy measures, such as increased energy price through introduction of tradable permits. The model framework we employ may be termed input-output + econometric model (IOE), following West. Modeling of this magnitude became possible by adopting an object-oriented database approach, which consists of consistent naming conventions, accounting rules, and logical structure. The graphic user interface facilitates access to the database, operation of the model, and policy simulation experimentation.

1. Purpose

Introduced here is a COmprehensive Model for Policy ASSESSment (COMPASS) which is an econometric simulation model designed to capture the interaction among the 3E spheres encompassing economy, energy, and environment. COMPASS is designed for simulation experiments up to the year 2020. This time horizon is not particularly long for modeling exercises: in fact, there are models, particularly of the CGE (computable general equilibrium) type, projecting up to the year 2100. COMPASS in contrast is characterized by regional and structural details based on econometrically obtained parameters, which enable the model to trace the actual time path of the global economy. The model achieves international linkage for 60 regions, covering 99.5% of the world's GDP. The country models are based on time series of a 36-sector input-output framework, the SNA, and financial accounts. They are linked to each other through time series of 25-commodity trade matrices, which explicitly describe annual trade flows among world regions, achieving global coverage. The model also generates energy balances and CO₂ emissions data for individual countries. Thus, COMPASS provides multisector, multicountry information on production, trade, balance of payments, saving and investment flows, energy demand and supply, and environmental impact. It is capable of generating consistent output and price series, together with interest rates, exchange rates, and energy prices. Empirically based econometric method is employed throughout, enabling the users to trace the dynamic time path of policy measures, such as increased energy price through the introduction of tradable permits. The model framework we employ may be termed input-output + econometric model (IOE) following West. Modeling of this magnitude became possible by adopting an object-oriented database approach, which consists of consistent naming conventions, accounting rules, and logical structure. The graphic user interface facilitates access to the database, operation of the model, and policy simulation experimentation.

The 1992 Earth Summit in Rio de Janeiro called for an integrated approach to achieving

long-term sustainable development and formulated *Agenda 21* as its action plan. The UN's System of Integrated Environmental and Economic Accounting, dubbed SEEA, the EU's National Accounting Matrix including Environmental Accounts, or NAMEA, and related statistical systems were devised during the preparations for the Earth Summit. Experience in empirical application and theoretical issues that came out of the Special Conference of the International Association for Research in Income and Wealth (IARIW) held in 1996 was described by Uno and Bartelmus. To facilitate exchange of views and further development, a group of experts formed a forum called the London Group, named after its first meeting in London. The fifth meeting took place in Fontevraud, France, in 1998. The development of environmental accounting so far, however, remains a single-country, static framework.

No one by now disputes the emergence of global environmental problems. When signatories to the Framework Convention on Climate Change met in Kyoto in December 1997 at the third Conference of Parties to the Convention (COP-3), the initial position was zero reduction for the US, 15% for the EU, and for Japan 5% globally but 2.5% at home. Agreement was reached that the US, the EU, and Japan should reduce their emission of global warming gases by 7%, 8%, and 6%, respectively, by the year 2010. The reduction targets take into account the portion achieved through technology transfer to developing countries. Reduction in developing economies was postponed to future discussion, although a proposal was made to ask their voluntary commitment to reduction targets. COP-4 convened in Buenos Aires in November 1988 and ended by adopting an action plan spelling out a future negotiation schedule, without going into substantial discussion on the tradable permits of global warming gases. It was agreed that concrete stipulation pertaining to emission trading be decided in the year 2000. There still remains the equity issue concerning the initial allocation of the permits, particularly for developing economies and economies in transition. Technology transfers to developing countries, compensation to oil-producing countries for possible economic losses, and the mechanism for joint implementation also are being disputed. Thus, we may say that there is a real danger that COP will degenerate into a political process. One way out of this will be an information system, which allows for various policy experiments.

Our purpose, therefore, is a construction of a simulation model with a dynamic framework. Individual countries have to be explicitly treated in the model as policy-implementing agents. After all, policy measures will have to be implemented by national governments. It is important to capture the repercussions across national boundaries.

There are already enough operational models estimating the cost of emission reduction. Repetto and Austin provide a list of focal points of the available models as follows.

1. The extent to which substitution among energy sources, energy technologies, products, and production methods is possible.
2. The extent to which market and policy distortions create opportunities for low-cost (or no-cost) improvements in energy efficiency.
3. The likely rate of technological innovation and the responsiveness of such change to price signals.

4. The availability and likely future cost of nonfossil, backstop energy sources.
5. The potential for international “joint implementation” of emissions reductions.
6. The possibility that carbon tax revenues would be recycled through the reduction of economically burdensome tax rates.

In addition, there are possible damages (or benefits) that can be avoided by the introduction of a carbon tax. They are:

7. The economic damages from climate change, and
8. The reduction of other air pollution damages associated with the burning of fossil fuels.

Of these, our model is capable of treating (1), (3), (5), (6), and (8) in whole or in part. Substitution between energy and other factors of production, particularly capital, has been discussed extensively in the literature. Substitution among energy sources also can be analyzed in a model depicting energy balances encompassing various sources of primary energy. The rate of technological innovation, or item (3) above, is described in our framework as the changes in input coefficients over time. This does not automatically mean that technological change can be endogenously explained in the model framework. Rather, scenarios may be developed based on technology inventories, which then can be interpreted as alternative input coefficients. Such technology inventories in environmental spheres are available from IPCC (International Panel for Climate Change), IEA (International Energy Agency), UNEP (United Nations Environmental Program), IIASA (International Institute for Applied Systems Analysis), in addition to various country sources. The assessment of joint implementation, which is item (5) above, is particularly suitable for the model framework at hand. In the arsenal of economic theory, technology is best described in an input-output framework in terms of input coefficients. An alternative technology described in input coefficients, whether they are the ones actually achieved in one country or the ones obtained by hypothetical scenarios, can be shifted to different countries to observe economy-wide repercussions. As for (6) above, one can incorporate a channel linking carbon tax revenues to, for example, reduction in social security contributions. It is also possible to deal with (8) in terms of changes in the imputed damages which is attributable to, for example, SO₂.

2. Data Sources and Object-Oriented Approach

The feasibility of a 3E model encompassing economic, energy, and environmental spheres is largely dependent on the availability and organization of empirical data.

2.1. Empirical Data

COMPASS is intended to be the basis for policy dialogue. It was therefore deemed important to adopt a transparent framework both theoretically and empirically. The model is based on open data published mostly by international organizations. Main data sets are introduced below.

2.1.1. Time series Input-Output Tables

Input-output tables are indispensable in the construction of multisector models in that they provide consistent structural data ranging from final demand, intermediate inputs (whereas input coefficients describe production technology), value added and income generation, and prices (potentially including a CO₂ tax or price hike reflecting emission trade). One should mention two important developments in this field. One is the publication of input-output tables for OECD member countries covering the period 1970 to 1990. Another is a series of bilateral and internationally linked tables for Asian countries by a Japanese source. The input-output and other pertinent data for China and Russia were provided by country experts.

Reflecting the original structure of the tables, the input-output tables for OECD countries have 36 industrial branches, whereas those for Asian countries have 25. Details are depicted in Table 1.

OECD IO Branches		APEC IO Branches		COMPASS	COMPASS	ISIC
				I-O Code	Trade Code	Definition
1	Agriculture, Forestry and Fishing			AFF	AFF	1
		1	Paddy	PAD		
		2	Other Agricultural Products	OAG		
		3	Livestock	LIV		
		4	Forestry	FOR		
		5	Fishery	FIS		
2	Mining and Quarrying			MAQ	MAQ	2
		6	Crude Petroleum and Natural Gas	CRP		
		7	Other Mining	OMQ		
3	Food, Beverages and Tobacco	8	Food, Beverages and Tobacco	FBT	FBT	31
4	Textiles, Apparel and Leather	9	Textile, Leather and Products	TAL	TAL	32
5	Wood Products and Furniture	10	Timber and Wood Products	WAF	WAF	33
6	Paper, Paper Products, and Printing	11	Pulp, Paper and Printing	PAR	PAP	34
		12	Chemical Products	CHE		
7	Industrial Chemicals			CHI	CHI	351+352+3522
8	Drugs and Medicines			CHD	CHD	3522
9	Petroleum and Coal Products	13	Petroleum and Petro Products	PCP	PCP	353+354
10	Rubber and	14	Rubber Products	RPP	RPP	355+356

	Plastic Products					
11	Non-metallic Mineral Products	15	Non-Metallic Mineral Products	NMP	NMP	36
		16	Metal Products	PMP		
12	Iron and Steel			IAS	IAS	371
13	Non-ferrous Metals			NFM	NFM	372
14	Metal Products			MEP	MEP	381
		17	Machinery	MAC		
15	Non-electrical Machinery			NEM	NEM	382-3825
16	Office and Computing Machinery			OAC	OAC	3825
17	Electrical Apparatus, nec			ELM	ELM	383-3832
18	Radio, TV and Communication Equipment			RTC	RTC	3832
		18	Transport Equipment	TET		
19	Shipbuilding and Repairing			TES	TES	3841
20	Other Transport			TEO	TEO	3842+3844+3849
21	Motor Vehicles			TEM	TEM	3843
22	Aircraft			TEA	TEA	3845
		19	Other Manufacturing Products	AOM		
23	Professional Goods			PRG	PRG	385
24	Other Manufacturing			OMA	OMA	39
25	Electricity, Gas and Water	20	Electricity, Gas and Water Supply	EGW		4
26	Construction	21	Construction	CON		5
		22	Trade and Transport	TRT		
27	Wholesale and Retail Trade			WRT		61+62
28	Restaurants and Hotels			RAH		63
29	Transport and Storage			TRA		71
		23	Services	OSE		
30	Communication			COM		72
31	Finance and Insurance			FAI		81+82
32	Real Estate and Business Services			RAB		83
33	Community, Social and			SPS		9

	Personal Services					
34	Producers of Government Services	24	Public Administration	GOV		
35	Other Producers	25	Unclassified	SDY		
36	Statistical Discrepancy					

Table 1. COMPASS Industrial Branches

The economic flow between generation of income and final demand is not explicitly described in the input-output tables. This gap is filled by the SNA data. This highly standardized data set is available for most countries in the world and is the basis for country models. Since input-output tables are available only for some time intervals, SNA data also are employed in estimating the economic structure in the interim years.

The national accounts data are published by the UN. The model incorporates tables 1.1 and 1.2 (final demand in current prices and constant prices, respectively), 1.3 (cost components of GDP), 1.4 (general government current receipts and disbursements), 1.5 (corporate and quasi-corporate enterprises current income and outlays), 1.6 (households and nonprofit institutions current income and outlays), 3.13 (general government capital accumulation account), 3.23 (corporate and quasi-corporate enterprise capital accumulation account), and 1.7 (external transactions).

Needless to say, the SNA reveals the savings-investment balance for individual sectors. The external transactions account describes a country's linkage vis-à-vis rest of the world in terms of merchandise trade, service trade, factor income, and current transfers.

2.1.2. International Financial Statistics

Financial variables such as exchange rates and interest rates are obtained from the IMF's International Financial Statistics. The items relating to international transactions in this source provide further details on direct investment and portfolio investment, which have gained importance as the global linkage through financial flows becomes increasingly powerful. These and other financial variables included in the model framework help determine the financial solvency of a nation. Foreign direct investment is also a vehicle for technology transfer.

COMPASS distinguishes four institutional sectors, namely;

- the government sector (SEG),
- the corporate sector (SEC),
- the household sector (SHE), and
- the foreign sector (SEF).

The corporate sector SEC is split into financial and nonfinancial. The financial corporate sector (SECB) consists mainly of:

- the monetary authority (MOA),
- the deposit money banks (DMB), and
- the other banking institutions and nonbank financial institutions (SOB).

The sectors are covered by these statistical sources, providing a basis on which to construct a flow-of-funds account for individual countries. Thus COMPASS has as its statistical basis several accounting frameworks, a fact which provides a solid basis for consistency among variables. The cases in question include input-output tables, the SNA, flow of funds, trade matrices, and energy balances.

2.1.3. Time-series Trade Matrices

The country models are linked by time series of international trade statistics compiled by the UN. Trade matrices have been compiled from the most detailed trade data. The correspondence between production branch classification and trade classification is shown in Table 1. There are 24 distinct sectors as represented by the COMPASS world trade code plus one dummy sector representing statistical discrepancy.

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long-term models are of the CGE type. West in this paper takes up pros and cons of CGE (computable general equilibrium) versus static input-output, and, in particular, the dynamic framework of the input-output+econometric, models.]

Biographical Sketch

Kimio Uno is Dean of the Faculty of Policy Management, Keio University at SFC (Shonan Fujisawa Campus) since 1995. He obtained his Ph.D. in economics from the University of Illinois and was a visiting fellow at Yale University. He served as a consultant to the United Nations Conference on Environment and Development and the United Nations University on various occasions and worked as a research associate at the International Institute for Applied Systems Analysis (IIASA).

He has been a member of the London Group on Natural Resource and Environmental Accounting, an international group of experts consisting of national accountants and environmental specialists. He serves as chairman/member of several government groups in Japan related to environmental accounting under the Economic Planning Agency and Environmental Agency.

His major publications include: *Environmental Options: Accounting for Sustainability* (1985), Dordrecht: Kluwer Academic Publishers; *Japanese Industrial Performance* (1987), Amsterdam: North-Holland; *Measurement of Services in an Input-Output Framework* (1989), Amsterdam: North-Holland; *Technology, Investment, and Trade* (1991), New York: North-Holland; and edited volumes with Shishido, *Statistical Data Bank Systems* (1988), Amsterdam: North-Holland; and Bartelmus, *Environmental Accounting in Theory and Practice* (1988), Dordrecht: Kluwer Academic Publishers.