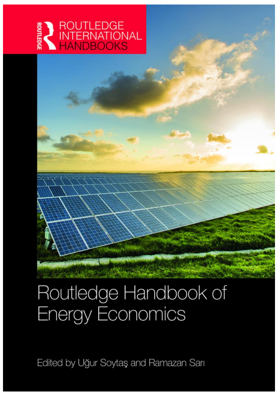

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A methodological framework for assessing macroeconomic impacts of energy security improvements in Asia

Deepak Sharma, Suwin Sandu, and Muyi Yang

1 Introduction

The Asian countries have experienced significant economic growth since the late 20th century, and these trends are expected to continue in the years to come (OECD 2018). This growth will however bring with it an unprecedented demand for energy. According to the International Energy Agency (IEA), energy demand in the Asia-Pacific region is projected to increase by 1.8% per year over the period 2016–2040 – faster than the projected world average annual growth rate of 1.4% over the period. This will make the Asia-Pacific region the world's largest energy consumer by 2040, accounting for approximately 60% of total energy consumption (IEA 2017).

Such rapid growth in energy demand could lead to a tightening of energy markets, growing import dependence, and rising price volatility, thus threatening the security of energy supply and socioeconomic prosperity of the region. The intensity of this threat could be further exacerbated by the impending threat of climate change, caused by ever-increasing rates of greenhouse gases (GHG) emissions from excessive use of fossil fuels. Search is therefore on for ways to redress the energy security challenge in the region. Among various policy options under consideration to redress the challenge, a broad consensus seems to have emerged on two options, namely, diversification of fuel-mix, with reduced reliance on fossil fuels and their replacement with low-emission sources (such as, wind, solar and nuclear); and energy efficiency improvements.

Several studies have been conducted to analyse the impacts of these policy options. Most of these studies have however tended to be micro-assessments, focusing on the immediate impact of specific policy measures on energy security. For example, some studies analyze measures (such as feed-in tariffs, tax exemptions, and public grants) to promote renewable energy and its impacts on fossil fuel consumption, energy prices, and emissions (Kumar 2016; Kumar, Shrestha & Abdul Salam 2013; Mofijur et al. 2015; Tongsopit et al. 2016). Other studies estimate the potential for energy savings and emission reduction from higher energy efficiency standards in households (Lu 2006; Mahlia, Masjuki & Amalina 2004; Shi 2015), transport (Karali & Gopal 2017), and industrial processes (Worrell et al. 2009).

While useful, such foci do not provide insights into the broader macroeconomic, and hence policy-significant, impacts of policy measures to improve energy security. For example, promotion of biofuels may be an attractive option to reduce fossil fuel dependence, but it may be less attractive from a broader macroeconomic perspective, due to the potential impacts of biofuel production on land use, water supply, and food prices, which may in turn affect economic growth, employment, and social welfare.

Against this backdrop, the primary objective of this (and the following) chapter is to examine the macroeconomic impacts of energy security improvements, especially identifying the trade-offs that policy makers may like to consider while designing policies to redress the energy security challenge in the region. This chapter outlines the methodological framework to analyse the macroeconomic impacts of energy security improvements. The next chapter analyses the macroeconomic impacts of energy security improvements for seven major Asian countries (China, India, Indonesia, Japan, Korea, Malaysia, and Thailand), for the period 2015–2050. These countries collectively account for 44% of the world population, 30% of economic output, 35% of primary energy consumption, and 41% of GHG emissions in 2015 (World Bank 2018).

2 Methodological framework

The methodological framework for analyzing macroeconomic impacts of alternative energy security improvements scenarios is shown in Figure 31.1. This framework comprises five key elements: identification of attributes in terms of which the socioeconomic and energy security outcomes of alternative scenarios are assessed (Section 2.1); procedures for integrating socioeconomic and energy security domains into a single platform (Section 2.2); development of alternative future scenarios and underlying policy drivers and assumptions for each scenario (Section

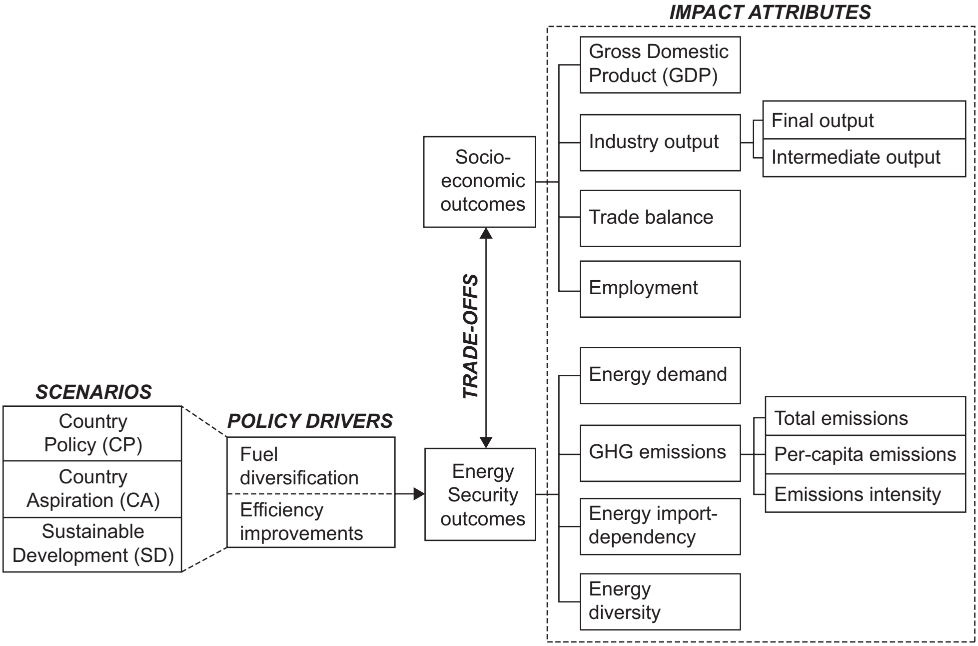

Figure 31.1 Methodological framework

2.3); development of an analytical model to determine the impact (in terms of selected attributes) of alternative scenarios (Section 2.4); and development of composite socioeconomic and energy security indices to enable analyses of policy trade-offs (Section 2.5).

2.1 Impact attributes

There are a range of attributes that can be used in order to assess the impact of policies. The selection of impact attributes used in this chapter is broadly based on the guidelines suggested by OECD (2011). The essence of these guidelines is that the attributes should appropriately reflect the country context; they should be analytically sound; they should be measurable; they should be temporally consistent and comparable across countries, regions, sectors; and, most importantly, they should be of policy significance.

Guided by these requirements, eight attributes are selected in this chapter; four for measuring socioeconomic outcomes and four for measuring energy security outcomes. The socioeconomic outcomes are measured in terms of economic growth (GDP), industry output (both final and intermediate demand), trade balance (including trade with different countries and trade-dependency of the country), and employment.

The measures of energy security outcomes are not straightforward. Energy security has traditionally been referred to as assured and affordable access to domestic energy resources such as oil, gas, and coal. This construct has however become less useful to policy makers as energy sector becomes increasingly globalized, both in terms of its integration with international markets and in terms of emerging global issues such as climate change (von Hippel et al. 2011). In this chapter, energy security is therefore measured in terms of energy demand, energy-related environmental emissions, energy import dependency, and energy diversity.

The energy demand attributes include both primary and final energy demand. The environmental attributes include: total and per-capita greenhouse-gas (GHG) emissions, and greenhouse-gas intensity of the economy. Energy import-dependency is expressed in terms of the ratio of net energy imports to total primary energy demand. Energy diversity measures the degree of diversification of primary and final energy sources in the economy. It is measured by Herfindahl index, with a low value of the index suggesting greater diversity.

2.2 Integration of socioeconomic and energy security domains

The socioeconomic and energy security domains are integrated in this chapter with the view to identify trade-offs between different policy objectives, for example, trade-offs between energy security and economic prosperity; energy security and country's trade balance; and environmental sustainability and job opportunities.

The core platform to integrate these domains is a Multi-Country Input-Output (MCIO) table, developed specifically for this purpose. The IO table for a country portrays its economy as a system of interrelated goods and services, at disaggregated levels. The Global Trade Analysis Project (GTAP) databases are used as the bases to develop national IO tables as they are available in consistent (industry-classification) formats (Aguiar, Narayanan & McDougall 2016). The bilateral trade data in GTAP databases are, however, not available at disaggregated levels; exports are presented as aggregate sectoral exports to the destination country (i.e. not to the consuming sectors), while imports are presented as sectoral total imports by the consuming sectors with no detail about the country of origin. The national IO tables developed from GTAP databases are accordingly extended in this chapter to represent trade (i.e. exports and imports) at disaggregated levels. For this purpose, the method proposed by Peters, Andrew & Lennox (2011) for developing MCIO tables from GTAP databases is followed; it distributes bilateral exports (in terms of the prices of the producing country) in the same proportion as sectoral consumption patterns of the importing country (in terms of the prices of the consuming country). The difference between the prices received by the exporters and prices paid by the importers are considered as trade margins, and are added to the value added component of the national IO tables in order to retain input-output balance across all sectors. Further, since the current GTAP databases are available for the 2011 base year, the MCIO tables are rebased to 2015, using the most recent macroeconomic indicators (such as, total household consumption, government expenditure, and total investment) available from the World Bank (World Bank 2018).

The MCIO tables are then extended by incorporating data from the International Energy Agency (IEA 2018), to provide a disaggregated representation of energy production and consumption by sector as well as electricity generation using different technologies. Further, greenhouse gas emission factors are used to develop environmental accounts associated with the MCIO tables. Such integration of multi-country economic accounts with energy and environmental accounts enables an assessment to be made of the macroeconomic impacts of energy policies, not only on the domestic economy but also on regional trade and the environment. Table 31.1 presents the list of countries/regions, sectors, commodities, primary production factors, final demand categories, and greenhouse gas emissions included for the analysis in this chapter.

2.3 Scenario descriptions and assumptions

This chapter develops three energy policy scenarios up to the year 2050, namely, Country Policy (CP), Country Aspiration (CA), and Sustainable Development (SD) scenarios.

These scenarios broadly align with the recent IEA's World Energy Outlook (2017), which considers three scenarios: Country Policy, New Policy, and Sustainable Development. The CP scenario in this chapter represent a continuation of existing energy plans and policies that have already been put in place in the form of legislation or national and global agreements. The CA scenario assumes a heightened emphasis on promoting energy security. In particular, it incorporates, in addition to policies and measures of the CP scenario, more ambitious targets for energy security improvement. The SD scenario goes even further; while assuming more aggressive energy policies, it sets achievement of the Paris Agreement and the UN's Sustainable Development Goals (SDGs), especially those related to energy sector, as its main goals. Specifically, it assumes universal access to modern energy by 2030, as well as energy efficiency targets and electricity supply options that will significantly reduce greenhouse gas emissions from the current levels.

The salient features of the three scenarios are summarized in Table 31.2. The scenarios differ from each other in terms of the depth of the two key energy policy drivers, namely, energy efficiency improvements and fuel diversification. Fuel diversification is further divided into three variables: (1) electricity supply options; (2) transportation fuel-use options; and (3) access to modern energy services (mainly electricity and cooking fuels).

The targets for energy efficiency improvements are derived from various sources, as informed by the assumptions about future growth rates of GDP per unit final energy ratios for various sectors of the economy (including industry, transport, commercial, agriculture, and households). For China and India, this ratio is estimated from IEA (2017) for all scenarios. For other countries (Japan, Korea, Indonesia, Malaysia, and Thailand), estimates are based on country reports in the case of CP and CA scenarios (ACE 2017; METI 2015; MTIE 2014). For the SD scenario, GDP per unit final demand for these five countries is assumed to follow the trends in IEA (2017).

Table 31.1 Coverage of socioeconomic and energy security domains

COUNTRIES	*SECTORS*	*COMMODITIES*	*PRIMARY FACTORS*
China	**Energy sectors**	**Energy commodities**	Capital
India	Coal mining	Coal	Unskilled labor
Indonesia	Crude oil exploration	Crude oil	Skilled labor
Japan	Natural gas production	Refined oil	Natural resources
Korea	Uranium mining	Natural gas	**FINAL DEMAND**
Malaysia	Combustible renewable energy	Uranium	Household consumption
Thailand	Non-combustible renewable energy	Bioenergy	Government expenditure
REGIONS	Petroleum refining	Heat	Investment
Rest of Asia	Heat production	Electricity	**TRADE**
Rest of the world	Electricity generation	**Non-energy commodities**	Exports
	Traditional coal-fired power	Paper products	Imports
	Advanced coal-fired power	Chemical products	**EMISSIONS**
	Traditional gas-fired power	Iron and steel	Carbon dioxide
	Advanced gas-fired power	Non-ferrous metals	Methane
	Oil-fired power	Non-metal minerals	Nitrogen dioxide
	Nuclear power	Other manufactured products	
	Hydropower	Mining products	
	Noncombustible renewable power	Agriculture products	
	Combustible renewable power	Commercial services	
	Non-energy sectors	Land transport	
	Industrial	Water transport	
	Paper manufacturing	Air transport	
	Chemical manufacturing		
	Iron and steel manufacturing		
	Non-ferrous metals manufacturing		
	Non-metallic minerals manufacturing		
	Non-intensive manufacturing		
	Non-energy mining		
	Agriculture		
	Commercial services		
	Transport services		
	Land		
	Water		
	Air		

The assumptions for electricity supply options, and access to modern energy services, are taken directly from IEA (2017) for China, India, and Japan. IEA (2017) has also published forecasts for the Southeast Asia region as a whole; this information is used to develop forecasts for Indonesia, Malaysia, and Thailand. For Korea, the values are estimated based on the assumptions for Japan, based on trends observed in the recent past.

The assumptions about transportation fuel-use options are based on WEC (2016), with CP, CA and SD scenarios broadly corresponding with the three WEC scenarios: Hard Rock, Modern Jazz, and Unfinished Symphony. Further, the three energy policy scenarios (CP, CA, and SD) are in accord with the medium population growth scenario of the United Nations, and the long-term historic trends in labor productivity growth (UN 2017).

Table 31.2 Scenario assumptions

		CHINA			*JAPAN*			*KOREA*			*INDIA*			*INDONESIA*			*MALAYSIA*			*THAILAND*		
SOCIOECONOMIC DRIVERS																						
Population growth (% pa)		–0.1			–0.5			0.0			0.7			0.6			0.9			–0.1		
Labor productivity growth (% pa)		1.4			1.0			1.3			1.6			1.4			1.3			1.6		
ENERGY POLICY DRIVERS		**CP**	**CA**	**SD**	**CP**	**CA**	**SD**	**CP**	**CA**	**SD**	**CP**	**CA**	**SD**	**CP**	**CA**	**SD**	**CP**	**CA**	**SD**	**CP**	**CA**	**SD**
Energy efficiency	**Energy productivity growth (% per year)**																					
	Industry	3.1	4.1	6.9	0.1	0.9	1.5	1.9	2.8	2.6	3.2	5.4	8.1	1.3	2.8	4.0	2.9	2.9	4.1	2.0	2.9	3.6
	Transport services	0.6	2.7	4.9	0.1	0.8	1.6	1.4	3.3	2.6	1.1	3.8	6.7	1.1	3.9	6.0	2.6	4.0	6.1	2.1	3.0	5.4
	Commercial services	1.9	3.2	4.6	0.1	0.8	1.6	0.3	0.3	2.6	4.8	6.8	8.3	1.7	4.5	5.9	2.6	4.6	6.0	0.6	1.1	5.4
	Agriculture	1.5	2.1	3.6	0.1	0.8	1.6	0.1	2.0	2.6	4.8	8.8	9.2	1.7	4.6	4.6	2.6	9.9	10.4	3.4	4.2	4.9
	Residential	1.0	3.3	4.7	0.1	0.8	1.6	1.3	1.4	3.1	4.8	8.9	9.7	1.7	4.5	5.9	2.6	4.6	6.0	2.4	3.5	5.4
Fuel diversification	**Electricity generation mix (% 2050)**																					
	Coal	75.0	39.2	12.6	32.7	21.9	2.1	42.7	31.5	0.4	71.2	47.2	9.8	46.5	85.7	11.2	32.4	52.3	13.0	20.4	24.4	3.9
	Gas	2.3	8.1	10.1	36.7	28.1	9.4	20.1	17.6	6.7	9.1	8.3	17.3	23.0	21.8	16.9	59.0	32.4	48.0	71.6	50.5	48.0
	Oil	0.1	0.0	0.0	1.3	1.0	0.3	2.9	0.2	0.1	2.5	0.5	0.5	18.0	2.2	1.3	1.0	0.2	0.3	1.6	0.1	0.1
	Nuclear	2.4	10.8	16.9	20.7	21.6	32.3	32.9	46.5	79.3	2.6	6.2	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	16.8	14.8	18.2	4.4	9.6	16.1	0.6	0.9	1.7	10.9	8.3	11.0	7.4	9.9	12.8	7.4	12.6	31.1	3.7	3.7	5.8
	Non-combustible Renewable	0.9	3.0	4.1	2.5	4.5	6.9	0.3	0.5	0.9	1.4	2.8	4.5	0.1	2.1	2.5	0.4	1.8	3.9	2.4	15.7	22.4
	Combustible Renewable	2.5	24.1	38.2	1.6	13.4	33.0	0.4	2.8	7.9	2.2	26.7	46.0	5.0	19.4	55.4	0.1	0.7	3.6	0.4	5.6	19.7
	Transport fuel-mix (% 2050)																					
	Oil	65.9	50.4	42.0	89.1	81.6	78.0	85.8	82.6	77.6	88.4	83.4	80.1	91.5	73.0	71.9	87.0	71.3	60.0	51.1	51.1	51.1
	Gas	9.3	8.2	6.9	0.5	0.4	0.4	4.5	4.0	3.3	3.0	2.6	2.2	0.1	0.1	0.1	1.6	1.4	1.2	11.6	10.2	8.6
	Biofuels	2.8	3.5	5.4	0.0	0.0	0.0	7.1	9.1	13.8	2.0	2.5	3.8	8.4	10.6	16.1	11.1	14.2	21.4	37.2	21.1	15.7
	Electricity	22.0	37.9	45.8	10.4	17.9	21.7	2.5	4.4	5.3	6.7	11.4	13.8	0.0	16.3	12.0	0.3	13.1	17.5	0.1	17.6	24.6
	Access to modern energy services (100% by year)																					
	Electricity	F.A.	F.A.	F.A.	F.A.	F.A.	F.A.	F.A.	F.A.	F.A.	2043	2043	2030	2020	2020	2020	F.A.	F.A.	F.A.	F.A.	F.A.	F.A.
	Cooking fuels	2060	2050	2030	F.A.	F.A.	F.A.	2025	2025	2025	2060	2050	2030	2060	2050	2030	2030	2030	2030	2060	2030	2030

Notes: Data in this table is developed based on information contained in ACE (2017), IEA (2017), METI (2015), MTIE (2014), UN (2017) and WEC (2016).
CP – Country Policy scenario; CA – Country Aspiration scenario; SD – Sustainable Development scenario.
F.A. – Full access to modern energy services.

2.4 Modeling approach

The two key modeling approaches that can be used to assess macroeconomic impacts of policies are computable general equilibrium (CGE) and input-output (IO).

The CGE modeling represents the economy as a system of interrelated elements, where the balancing between demand and supply is achieved through competitive-market-clearing principles. While it is a useful representation of an economy, its value for analysing the policy impacts is questionable on the following grounds: its underlying assumption of perfectly competitive markets; existence of a perpetual balance between demand and supply; role of prices in ensuring demand-supply balances; applicability for markets typified by varying degrees of regulated control and countries at various stages of economic development; and assessment of sub-macro level trade-offs, which are useful for engendering policy support. Moreover, the computational approach embedded in CGE models is less transparent for modeling the policy impacts of alternative scenarios.

While the IO model also portrays the national economy as a system of interrelated goods and services as does the CGE, its underlying analytics allows significant flexibility in terms of representing the structure and dynamics of an economy at disaggregated levels. It also provides a sound basis to represent market and non-market elements of the economy in a balanced manner. Additionally, it enables market-based clearance for those segments of the economy where price mechanisms work (by introducing flexible production functions instead of traditional fixed-coefficient Leontief function). Moreover, it is relatively more transparent in terms of both assumptions and computation approaches.

In view of the above noted advantages of the IO model, particularly its appropriateness for capturing features that are specific to the Asian countries (e.g. mixed market/non-market, and rapidly urbanizing and industrializing, economies), the core framework employed in this chapter centers on the application of energy-oriented MCIO platform. The base MCIO table (Section 2.3) can be transformed into MCIO coefficient matrices that underpin the model. In this base MCIO coefficient structure, the technology structure of a particular sector j in country r is presented under columns of the matrix, which comprises technical coefficients of an input from domestic sector i (a_{ij}^{rr}), coefficients showing imports of outputs from sector i in a foreign country s (a_{ij}^{sr}), and coefficients of primary factor v (c_{vj}). These coefficients represent the proportions of inputs required (from domestic sector, foreign country, and primary factors of production, respectively) for each unit of production of a particular sector. The MCIO coefficient structure also contains final demand sector k as a column in the matrix, which comprises output coefficients from both domestic and foreign sectors i. These output coefficients represent proportions of output required from sector i (from both domestic and foreign sectors) to fulfill final demand k (b_{ik}). An outline of the modeling structure is shown in Figure 31.2.

The modeling begins by asking the question, how will a technological change in one sector affect the rest of the economy? To introduce this in the model, the MCIO coefficients are exogenously changed, according to the assumptions underpinning alternative energy policy scenarios (Table 31.2). For example, energy efficiency improvements in a particular economic sector imply a relative reduction in the use of energy input to produce the same amount of output from that sector. The technical coefficients, representing energy inputs, are therefore assumed to be exogenously reduced over the time frame.

Another example: a switch from conventional, relatively inefficient, fossil-fuel power generation plants to renewable-based power generation plants will entail adjustments in the values of technical coefficients in the MCIO matrix; the technical coefficients representing electricity generation from fossil-fuel power plants are reduced, while those of renewable-based power plants

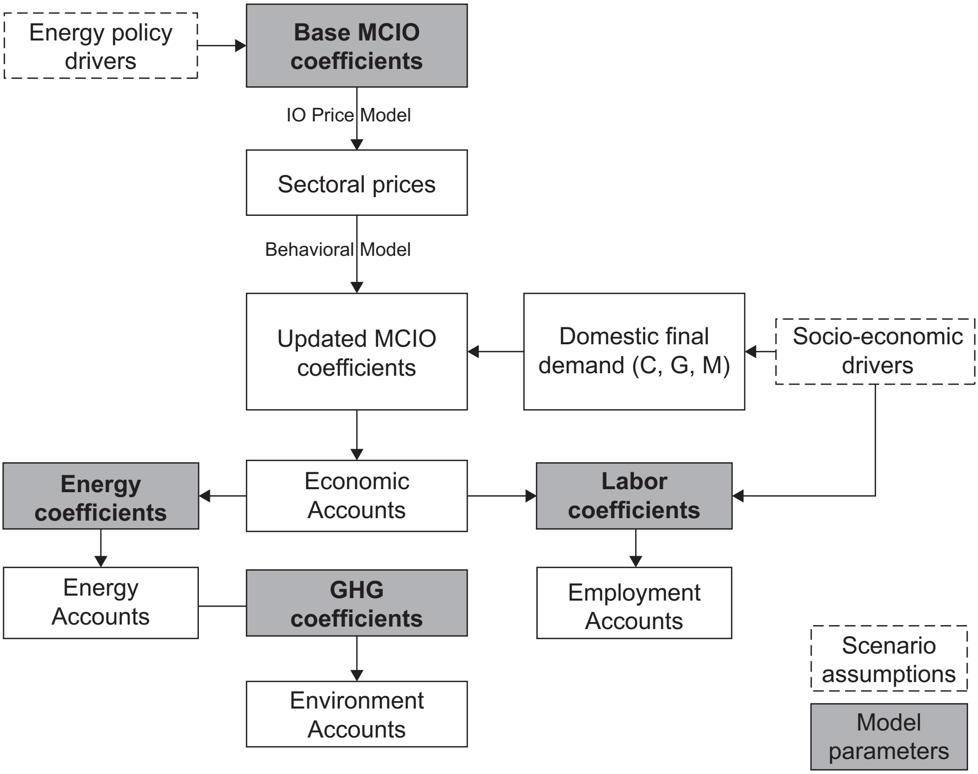

Figure 31.2 Model structure

are increased in the same proportion. This technique of adjusting technical coefficients is well established, and has long been used to examine the impacts of changes in energy technologies in the IO framework (see e.g. Faber, Idenburg & Wilting 2007; Gowdy & Miller 1968; Just 1974). The CGE modeling also applies the same principles for introducing technology shocks (see e.g. Burfisher 2011; Fatai, Oxley & Scrimgeour 2003).

Alternatively, the MCIO coefficients can be endogenously determined within the model, by using price mechanisms. This is common in studies that examine the impact of carbon tax where the tax are assumed to be imposed on each sector *i*; this will translate into equivalent indirect taxes. The increased tax is then assumed to be fully transferred through energy and material prices (Creedy & Martin 2000), thus increasing the prices of factor inputs in proportion to sectors' carbon emissions. Such increases in relative prices of various sectors, where sectoral outputs are used by consuming sectors in the economy, will force a change in IO coefficients. This approach however becomes less attractive in the context of this chapter, as this chapter focuses on assessing the impacts of various energy technology options. In such a technology-driven assessment, sectoral prices will be endogenously determined by the adoption of various technology options, which can be achieved by exogenously changing the technical coefficients, based on scenario assumptions. As a result, the former approach of exogenously changing the technical coefficients is employed in this chapter.

A change in technology will induce changes in the input-mix of various production sectors. As a result, the prices of sectoral outputs would change. In the case of energy efficiency improvements in a particular economic sector, for example, this would imply a change in output price of that sector relative to other sectors. Similarly, a switch from conventional technology to advanced technology in a particular sector would result in increased output prices of that sector, compared with output prices of other sectors. These price effects are estimated using the standard *Leontief* IO price model, as shown in Equation 31.1:

$$\mathrm{P}_i = [\mathrm{I}-\mathrm{A}']^{-1}\, C'_j \tag{31.1}$$

where

P_i: vector of sectoral price index;
A: matrix of IO technical coefficients, adjusted for new energy technology; and
C_j: vector of total primary factor coefficients for each sector j.

It should be noted that the sectoral prices calculated from equation 1 will be in terms of an index change (i.e. a deviation from the base price of 'one'). This is because of normalization of prices in this approach. The base IO table presents value (price × quantity) flows. The use of price normalization approach translates value data into price and quantity data, by normalizing the initial (base) prices in the model into 'one'. If the base IO coefficient matrix is used to calculate sectoral prices from Equation 31.1 (instead of using an updated IO coefficient matrix with changed technology), the result will be equal to 'one' for all sectors. The coefficients for each column in the IO model are thus interpreted as the quantity of input per $1 of produced output, instead of value of input. This is the same approach that is also applied in CGE models, as it considerably reduces the information required to develop model database, without reducing the capability of the model to generate meaningful results (Burfisher 2011). Thus the estimated prices from Equation 31.1 are presented in terms of index of changes in sectoral prices.

Such changes in relative sectoral prices will induce substitution among sectoral factor inputs. However, factor substitution effects cannot be estimated using standard IO quantity model, because of the underlying assumption of fixed proportionality of factor inputs (i.e. no substitution) – *Leontief* production function. This limitation is overcome by introducing flexible neo-classical production functions in the IO model (Rose 1984). In essence, the Leontief IO coefficients (Equation 31.2) are replaced with the IO variables (Equation 31.3):

$$a_{ij}^{Leontief} = \frac{z_{ij}}{X_j} \tag{31.2}$$

$$a_{ij}^{CES} = \gamma^{\sigma-1}\, a_{ij}^{Leontief}\left(\frac{P_j}{P_i}\right)^{\sigma} \tag{31.3}$$

where

z_{ij}: output of sector i used in sector j;
X_j: total output of sector j;
γ: scale parameter; and
σ: substitution elasticity.

In the behavioral Equation (31.3), the input-output relationships will not stay fixed, but will change in response to changes in relative sectoral prices. The updated final demand coefficients

(b_{ik}^{CES}) are also determined in the same way. This equation is derived from CES (constant elasticity of substitution) input demand function. In this way, the substitution possibilities can be accounted for within the IO framework.

The updated MCIO coefficients form the basis to calculate economic accounts in the same way as the standard IO model. The main driver is population growth, which is used to determine domestic final demand for the future year t (F_k^t), where k includes total household consumption (C), total government expenditure (G), and total investment demand (M). Sectoral final demand is accordingly determined by:

$$F_i^t = \bar{B} F_k^t \tag{31.4}$$

where $\bar{B}$ is the coefficient matrix of individual elements b_{ik}^{CES}. The outcome of Equation (31.4) is then used to determine sectoral outputs for year t by using the following IO identity:

$$X_i^t = \left[I - \bar{A}^{rs}\right]^{-1} F_i^t \tag{31.5}$$

This equation forms the basis to estimate individual elements of the MCIO table, which form the economic accounts. In addition to these economic accounts, 'satellite' accounts (such as energy, emissions, and employment, expressed in physical units) are also developed in correspondence with the sectoral outputs in Equation (31.5) (see Miller & Blair 2009 for further details). In essence, the coefficient matrices of the satellite accounts are developed for the base year, where information on physical units of these accounts are divided by sectoral outputs. In the case of energy, for example, the matrix of energy coefficients are developed by dividing sectoral energy use (in toe) with sectoral output (in $). These 'satellite' coefficient matrices are then multiplied with Equation (31.5) to obtain values for satellite accounts.

To summarize, this model portrays economies as systems of interrelated goods and services, captures the interdependencies between different economies across regions through trade linkages, and can easily integrate other domains (energy, environment and social) within a single framework. It therefore constitutes an extremely useful analytical tool for examining the macroeconomic impacts of policies and strategies aimed at redressing energy security challenge.

2.5 Composite indices

To enable an assessment to be made of the trade-offs between energy security and socioeconomic outcomes, in terms of selected impact attributes (as shown in Figure 31.1), each of these outcomes (i.e. socioeconomic and energy security) is combined into a composite index. For example, composite socioeconomic index is calculated as a weighted mean of individual attributes, namely, GDP, industry output, trade balance, and employment. Similarly, composite energy security index represents a weighted mean of energy-import dependency, energy diversity, per-capita GHG emissions, and GHG intensity. The analysis in the following chapter employs an equal-weight index, where individual attributes are treated as equally important. Differential weight can however assign to different attributes if policy makers wish to give higher importance to specific attributes (employment, for example), relative to, for example, economic growth.

Given that all attributes are expressed in different units of measurement, they need to be first normalized into a dimensionless index, and then scaled from 0 to 100, where 100 represents most favorable outcome, and zero, least favorable. Attributes where a higher value indicates a more favorable outcome (such as, employment) are normalized as follows:

$$x_i = \frac{\left[x_i - \min\left(x_i\right)\right]}{\left[\max\left(x_i\right) - \min\left(x_i\right)\right]} \tag{31.6}$$

where $\min\left(x_i\right)$ and $\max\left(x_i\right)$ are the lowest and highest values for any given attribute *i*. For attributes where a high value indicates an unfavorable outcome (such as, energy-import dependency), the normalization function takes the form:

$$x_i = \frac{\left[\max\left(x_i\right) - x_i\right]}{\left[\max\left(x_i\right) - \min\left(x_i\right)\right]} \tag{31.7}$$

Once all attributes are normalized, they can be combined into a composite index to allow an examination of trade-offs between different composite indices.

3 Conclusions

This chapter outlines the methodological framework that can be used to examine the macroeconomic impacts of energy security improvements. It comprises five key elements: identification of attributes, in terms of which the socioeconomic and energy security outcomes of alternative scenarios are assessed; procedures for integrating socioeconomic and energy security domains into a single platform; development of alternative future scenarios and underlying policy drivers and assumptions for each scenario; development of the analytical model to delineate the impact (in terms of selected attributes) of alternative scenarios; and development of composite socioeconomic and energy security indices to enable the analyses of policy trade-offs. It is contended that this framework is suitable to examine the macroeconomic impacts of and strategies aimed at redressing energy security challenge as it portrays economies as systems of interrelated goods and services at disaggregated levels, captures the interdependencies between different economies across the region through trade linkages, can easily integrate other domains (energy, environment and social) within a single framework, and can combine different attributes into a composite index, to enable assessments of trade-offs between the outcomes of different domains. Chapter 8 will demonstrate the application of this framework for major Asian countries.

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