ECONOMY & ENVIRONMENT

GOOD PRACTICE NOTE 7

Modeling Macroeconomic Impacts and Global externalities

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ACRONYMS AND ABBREVIATIONS

CGE	computable general equilibrium (model)
CO2	carbon dioxide
CNY	Chinese yuan
DSGE	dynamic stochastic general equilibrium (model)
EIA	Energy Information Administration
ENVISAGE	Environmental Impact and Sustainability Applied General Equilibrium (model)
ESRAF	Energy Sector Reform Assessment Framework
EU	European Union
FGT	Foster-Greer-Thorbecke (a class of poverty measures)
GDP	gross domestic product
GHG	greenhouse gas
GIDD	Global Income Distribution Dynamics
GTAP	Global Trade Analysis Project
IDR	Indonesian rupiah
IFPRI	International Food Policy Research Institute
IO	input-output
OECD	Organisation for Economic Co-operation and Development
SAM	social accounting matrix
SEDLAC	Socio-Economic Database for Latin America and the Caribbean
SUBSIM	subsidy simulation Stata package
VAT	value added tax

1. INTRODUCTION

Energy subsidies represent an important cost for governments and taxpayers worldwide. Even in 2016, when the world oil price fell to the lowest level since 2003 in real terms, the International Energy Agency estimated that global fossil fuel subsidies amounted to US$260 billion, against US$140 billion for renewable energy (IEA 2017). There is widespread agreement that energy subsidies are an inefficient and inequitable strategy for supporting economic activity, household welfare, and environmental outcomes. Coady and others (2015) show that the richest 20% of households receive six times more subsidies than the poorest 20%. Energy subsidies persist, despite their well-understood deficiencies, because of entrenched interests—not only firms and households, but also fuel smugglers and fuel black marketers—who benefit from the subsidies even if society as a whole would be better off without them. Despite the general poor targeting of universal price subsidies, governments often find it difficult to eliminate these subsidies, because they are claimed to be necessary to enable the poor to purchase essential energy, especially when the targeting performance of other social protection measures is also weak. An important element of any energy subsidy reform package would be the inclusion of offsets for the losses suffered by the intended beneficiaries of the subsidies that are large enough to assure political viability, while small enough to preserve the overall gains.

Economy-wide models are among the best tools to assist in designing an overall reform package (including compensation) because economy-wide models

- Are sufficiently flexible and detailed to deal with the wide variety of energy subsidies that exist;

- Offer a comprehensive evaluation of the effects of reform, capturing direct and indirect (including second- and third-round) effects, as well as the cyclical impacts of reform initiatives;

- Offer a better estimate of the overall costs and benefits of reform than partial equilibrium approaches—possible outputs include

  - Impacts on government revenues via taxation, profitability of state-owned enterprises, and budgetary transfers to fund subsidies where relevant;

  - Identification of the industries and households that would be most adversely affected by reform, which forms a critical input to assist in designing a targeted compensation package;

  - Estimation of the short-term adjustment costs of implementation of policies as distinct from long-term effects; and

  - Estimation of environmental impacts of subsidy reform;

- Can be used to design mitigation strategies, having identified winners and losers and the fiscal implications of a reform package, including

  - Alternative approaches to dealing with any fiscal windfall: paying down debt, investing in public infrastructure, and offsetting harms on specific population groups or industries; and

- Design of macroeconomic policies to offset short-term, cyclical effects of reform (inflation, employment dislocation, and increases in the cost of living of the poor).

This note provides guidance on the different economy-wide modeling tools that can be utilized to quantify the economic effects of energy subsidy reform. ESRAF defines an energy subsidy as a deliberate policy action by the government that specifically targets electricity, fuels, or district heating and that has one or more of the following effects:

- It reduces the net cost of energy purchased.

- It reduces the cost of energy production or delivery.

- It increases the revenues retained by those engaged in energy production and delivery (energy suppliers).

Subsidies are provided through four primary mechanisms:

1 | Budgetary transfers of government funds

2 | Government-induced transfers between producers and consumers

3 | Forgone taxes and other government revenues

4 | Underpricing of goods and services

Examples include government control of energy prices that are kept artificially low (referred to as consumer price subsidies hereafter); budgetary transfers to energy suppliers or tax expenditures granted to energy suppliers to keep costs down to benefit consumers, producers, or both; underpricing of goods and services, such as fuels, land, and water used by energy producers; subsidized loans; and shifting of risk burdens, such as the assumption of risks created by energy supply or use through limits on commercial liability.

Different forms of subsidies are catalogued with examples in table 2 of note 1. Many have little effect on energy prices. For example, tax expenditures may increase the profits retained by energy producers and result in large fiscal losses, but may have no impact on end-user prices if, for example, tax expenditures are granted to oil producers in a deregulated oil market. Because tax expenditures are seldom reported or subject to scrutiny by legislators, they frequently attract little or no attention from the public and policy makers. By contrast, those subsidies that lower prices paid by consumers—and the reform of which is likely to raise prices—are much more visible. As such, while this note is broadly applicable to all forms of subsidies, it focuses largely on modeling the impact of reforming subsidies that raise prices for energy paid by consumers.

Energy subsidies may lower prices through several mechanisms. The most common approach is to set price levels or price ceilings at any point along the supply chain for reasons unrelated to lack of adequate competition (the presence of a natural monopoly requires economic regulation and some measure of price control, but in a competitive market prices should be set by the balance between supply and demand). Examples include price controls for gasoline, kerosene, diesel, and liquefied petroleum gas. A less direct way in a competitive market is through trade restrictions. A very high export tariff, for example, would reduce domestic prices, as would quantitative export restrictions, and conversely import restrictions could raise domestic prices. Where economic regulation exists to address a lack of competition—which is the case for anything involving a network, including transmission and distribution of

electricity, natural gas, and district heating—apart from budgetary transfers to energy suppliers, the government may provide consumer price subsidies through limiting the return on investment in state-owned utilities, providing financial and fiscal concessions, providing subsidized inputs, and other means outlined in table 2 of note 1. While this note applies modeling tools to reform of consumer price subsidies in the energy sector, the guidance can easily be applied to other sources of permanent changes to energy prices, such as carbon taxes, emissions trading schemes, and supply-side shocks.

Among the economy-wide modeling tools, the main focus of this note is computable general equilibrium (CGE) models. Partial equilibrium models are discussed only briefly. The latter models, by carefully mapping the details of energy production technologies including substitution between fuel types and process and efficiency improvements (Bohringer and Rutherford 2008), can generate important insights to shape the design of a reform. However, they tend to have limited or no interaction between the market of interest and the rest of the economy. As a result, they are unable to measure the indirect and dynamic effects that a reform can generate, particularly with respect to energy-consuming sectors, the prices of goods and services that use energy as an intermediate input, and the impact of all of these changes on investment, industrial structure, and household welfare.

The rest of the note is organized as follows. It begins with a brief overview of the different types of modeling tools in section 2. Existing studies on estimating the effects of energy price subsidy reforms are outlined in annex A. The literature review shows that the bulk of studies use a CGE model for examining the effects of energy subsidy reform.

One deficiency of most CGE models is their inability to reliably track the short-term and cyclical impacts of policy reform. Macrostructural models do this much better and can be used to quickly quantify the likely macroeconomic impacts of a reform, and have the advantage of requiring relatively few data and being easier to work with than CGE models. A guide to using macrostructural models to estimate the short-term effects of energy subsidy reform is presented in section 3. The various macrostructural models that are available are included in annex B.

Section 4 presents a guide to using CGE models to estimate the long-term effects of reform. A more detailed discussion of CGE models is included in annex C. The feasibility of using any given model will depend heavily on the availability of data, requirements for which are discussed in section 5. After briefly touching on empirical studies on energy reform in section 6, section 7 concludes with some highlights and guidance on the issues to consider when choosing a model to carry out energy price subsidy reform.

2. MODELING TOOLS

This section provides an overview of the types of models that can be used to analyze energy subsidy reforms. While each model has different underlying assumptions, strengths, and weaknesses, they are all able to estimate the effect of reform on the following indicators:

- Economic growth

- Gross domestic product (GDP) by expenditure

- GDP by industry

- Balance of payments

- Government fiscal aggregates

- Labor markets: employment, wages, unemployment rate, and labor supply

- Financial markets: inflation, interest rates, and exchange rates

IO MODELS AND SAM MULTIPLIER MODELS

Input-output (IO) models and social accounting matrix (SAM)-multiplier models are fixed-coefficient, multi-industry models that take into account interactions between different sectors of the economy. Unlike partial equilibrium models, they track the use of energy and other goods as intermediate inputs in the production of goods and services throughout the economy. As a result, they provide insights into the indirect effects of subsidy reform on the cost structure of firms and expenditures of households. Unlike the other models discussed in this note, these models do not normally provide for feedback effects from the impacts of a reform on the behavior of individuals and

firms, such as declining demand for energy-intensive products and labor dislocation. For large-scale reforms, these effects can be significant, and they are often the source of political resistance to reform. Like IO models, SAM multipliers are fixed-price models that assume that the firms in the local economy are not operating at full capacity (not subject to supply-side constraints). An important difference between the two is that SAM multiplier models provide the possibility to capture the effects of economic shocks on the distribution of income across socioeconomic groups of households. However, the IO model linked to a microsimulation module could also be used for distributional analysis. The latest version of SUBSIM (subsidy simulation Stata package) developed at the World Bank by Araar and Verme (2012) is an example of an IO model combined with a microsimulation module.

MACROSTRUCTURAL MODELS

Macrostructural models use econometrically estimated relationships to explain the behavior of economic agents. Unlike purely data-driven approaches, such as vector autoregressions, the underlying long-term structure of these models is based on economic theory. In contrast to the IO and SAM-multiplier models, consumer, government, and firm behavior does react to changes in relative prices, allowing for substitution away from higher-cost products or sectors, as well as second- and third-order effects, such as changes in employment, unemployment, and inflation. Generally these models do not include the same level of sectoral or product detail as found in CGE or partial equilibrium models,

but they track more realistically the short-term disequilibrium behavior of the economy following the initial shock, and as markets adjust and the economy moves to its new equilibrium growth path.

CGE MODELS

CGE models are economy-wide models that focus on the long-term effects of policy changes. In the literature, they have been the tool of choice for analysis of the long-term effects of large-scale reforms, including subsidy reform, because they capture the many complex direct and indirect effects of these reforms on the structure of the economy. Like IO and SAM models, they rely on an IO table or SAM for data, and they tend to have greater sectoral detail. As a result, compared with macrostructural models, they provide a more precise mapping of the relationships between sectors and products. Firm and consumer behavior is fully flexible, with each reacting to changes in incentives in a manner consistent with economic theory. These assumptions are appropriate in the long term. In the short term, there may be frictions in the economy that prevent it from fully adjusting to the shock.

DSGE MODELS

Dynamic stochastic general equilibrium (DSGE) models are general equilibrium models where the current decisions made by economic agents are influenced by uncertain future outcomes. These intertemporal decisions are based on microeconomic foundations. Because of their careful mapping of expectations of future conditions, a DSGE model might be useful to understand how firms

and households might react in anticipation to future reforms. However, DSGE models tend to be much less detailed than CGE, IO, or SAM-multiplier models, and therefore are unlikely to be a good first choice for subsidy reform. Typically these models are used to analyze financial policy where expectations of future revenues are an essential feature of market behavior.

MODEL DEVELOPMENT COSTS

The feasibility of different modeling options will be driven by data availability, which is covered in section 5. Other considerations include time, budget, and long-term uses of the model.

Using an off-the-shelf macrostructural model would be a prudent choice when time is limited. Modifying an existing model to capture the effects of an energy subsidy reform would involve additional time and budget, but such costs and time requirements are modest relative to modifying other types of models.

IO models and SAM multipliers are easier to develop than CGE models. DSGE models tend to be the most time-consuming to develop and require a high level of technical proficiency to maintain and run.

While CGE models can be expensive to produce and are difficult to work with, they typically encompass much more than the energy sector, and can therefore serve dual purposes for a wide range of additional applications, such as medium-term budget planning, tax reform analysis and labor market policy analysis. Hence, consideration should be given to the potential long-term uses of the model.

3. CAPTURING SHORT-TERM CYCLICAL EFFECTS USING A MACROSTRUCTURAL MODEL

Energy subsidy reform could introduce short-term adjustment costs in the economy, such as unemployment. Understanding and mitigating these short-term costs would be an important component of ensuring the viability of the reform. These costs arise because it takes some time for households and firms to respond to the reform. Depending on the nature and the scale, an energy subsidy reform could entail a change in the structure of the economy, requiring factors of production, such as labor and capital, to move from contracting sectors to expanding sectors. This movement across sectors can take some time to take place, so in the short term there may be an increase in unemployment as workers are retrenched by contracting sectors. The size of these short-term costs depends on country-specific factors such as the state of the economic cycle. For example, the increase in unemployment is likely to persist if the economy's existing unemployment rate is high. Similarly, reforms of consumer price subsidies for energy typically, but not always, lead to an increase in prices.[1] If inflation expectations are well anchored, this will lead to a one-off increase in the price level. If inflation expectations are not well anchored, inflation rates may be affected.

Macrostructural models capture the economic cycle and are well suited to quantifying these short-term adjustment costs, and to tracking a likely adjustment path. They can also analyze policy responses to mitigate transition costs induced by the implementation of such reforms. For example, the central bank may implement tight monetary policy to control inflation. Alternatively, fiscal policy can be targeted to support the transition of retrenched workers.

More generally, macrostructural models are well suited to estimating the short- to medium-term adjustment path of the economy following a reform of consumer energy price subsidies. In the short term, households and industries are less responsive to the increase in energy prices following the pricing reform. It takes some time for households and industries to adjust to higher energy prices by substituting previously subsidized energy—now priced higher—with cheaper alternatives or investing in energy-efficient technologies. Since the short-term relationships within these models are based on data, they tend to track these short- to medium-term economic behaviors well, reflecting country-specific frictions often not captured by neoclassical economic models, such as CGE models.

The fiscal effects of energy subsidy reform are captured well in a macrostructural model. These models cover the effects of the reform on both different sources of government revenue and expenditure. Since these models are better able to capture the short-term adjustment costs of policy reform, their estimates of fiscal effects may be more realistic than those from a CGE model.

4. CAPTURING LONG-TERM EFFECTS USING A CGE MODEL

This section discusses the important issues to consider when building a CGE model to assess energy subsidies. A particular emphasis will be given to the following aspects where applicable:

- Definition of the type of reform and how to set up the simulation within a CGE model

- Specification of the production technology and energy demand

- Capturing the market structure of energy firms

- Determining how the economy achieves equilibrium and the different ways to use additional revenue made available to the government by energy subsidy reform, if any

- Specification of how energy subsidy reform can affect growth, including the pattern of energy efficiency

- Estimating the distributional effects of reform and how this can influence the overall impact of the reform

- Estimating environmental effects and how to capture externalities of energy subsidy reform

MODELING DIFFERENT TYPES OF ENERGY SUBSIDIES: HOW TO SET UP REFORM SIMULATIONS WITHIN A CGE MODEL

CGE models provide a highly flexible framework that allows simulations of a wide range of subsidies. The mechanism by which the subsidy is provided drives the impact of reforms on the economy, and the type of subsidy reform considered will determine the specification of the CGE model used to assess its impact. Giving its multisector, multi-activity nature, as well as its ability to integrate various categories of households and factors, a CGE model can identify or simulate subsidies based on production (effects B and C in the definition of an energy subsidy in this note), factors (B and C), and consumers (A).

CGE models are not well suited for analyzing subsidies provided through a firm's financing arrangements. CGE models do not have a financial sector, since they are models of the real economy. Hence, it can capture how financial subsidies lower a firm's cost of capital, but it does not fully allow for the distortions this may create in the financial sector.

Table 1 reproduces the main forms of subsidies from note 1 and gives examples of how that can be simulated within a CGE model.

TABLE 1: Major Mechanisms Used to Model Energy Subsidy Reform in CGE Modeling

Category	Examples	Simulation setup in CGE modeling	Examples from the literature
Direct transfer of government funds			
Direct transfers of funds to energy producers (whether on- or off-budget transfers).	Budgetary support to compensate producers for price controls. Budgetary support to fund applied research and development, demonstration projects in commercial development of an energy technology, and other types of support for energy or firms engaged in energy trade and transformation.	This is straightforward and consist of taking the change in the level of subsidies observed in the SAM either for consumers or producers.	Not available.
Cash transfers to consumers, where transfers are directly linked to energy consumption.	Cash transfers to the poor intended to increase affordability of a specific form of energy and linked to its consumption.	The cash transfer will be simulated by explicitly incorporating the targeted household categories into the model. If the cash transfer is linked to energy consumption, the simulation of a reform can be modeled as an equivalent change in ad valorem tax. That tax (either negative or positive) would be applied to the prices of specific forms of energy consumed by the targeted household categories.	Not available.
Government-induced transfers between producers and consumers			
Government control of energy prices			
Prices or price limits set by government. Direct regulation of prices, price ceilings, or price floors at any point along the supply chain to reduce costs to producers or consumers, or to increase prices paid to producers.	Price regulation in a market where competition is possible (absence of high market concentration and of natural monopoly). High guaranteed prices to attract investment, such as feed-in tariffs. Excludes economic regulation based on prices corresponding to benchmark sector performance prompted by concerns over market concentration.	Use the results of the price gap calculations described in sections 3 (fuels) and 4 (electricity) of note 1 to simulate changes in price regulation. The regulated price is integrated into the CGE model as sum of the reference price (price in a competitive market adjusted for quality and location, or its equivalent) and the estimated price gap reflecting the level of regulation.	Lin and Jiang (2011) analyze the effect of removing energy subsidies in China by modifying the final consumer prices.

Category	Examples	Simulation setup in CGE modeling	Examples from the literature
Domestic price effects of import or export measures. Import duties or quantitative restrictions that raise the domestic price received by producers and paid by consumers; export duties or quantitative restrictions that reduce the domestic price received by producers and paid by consumers.	Applicable largely to fuels. Excludes import or export duty reduction as part of trade liberalization that does not target a specific form of energy. Import bans or restrictions and high import duties benefit certain domestic producers; export bans or restrictions and high export duties benefit domestic consumers.	Quantitative restrictions can be simulated by imposing an ad valorem tax equivalent of the restriction. This is similar to imposing tariff equivalents of nontariff barriers in international trade.	Not available.
Special case of cross-subsidy. Policies that reduce energy costs to particular types of customers or regions by increasing charges to other customers or regions, or by requiring firms to use profits in one segment of the supply chain to reduce prices charged to consumers in another segment of the supply chain.	Lifeline rates for electricity and natural gas, whereby the first block of residential tariffs is priced low and cross-subsidized by higher blocks. Pan-territorial pricing irrespective of cost of delivery to different parts of the country. Underpricing of refined products using surplus profits in upstream oil. Underpricing of oil or natural gas on the domestic market by using export profits and mandating domestic supply obligation. Underpricing of LPG sold to households, compensated by higher unit prices charged to non-residential consumers.	Simulations of cross-subsidies require explicit incorporation in the SAM of the benefits to the cross-subsidized customers (sectors, regions, or household categories), as well as the costs to other customers paying for the subsidy policy. The modeling of the subsidy will depend on its nature.	Grainger and others (2015) analyze the impact of cross-subsidies in the electricity market in Belarus. The World Bank's LINKAGE incorporates this feature.
Purchase or supply mandate			
Purchase requirement. Required purchase of a particular form of energy, typically when other choices are more financially attractive.	Requiring every fuel wholesaler to purchase from the monopolistic domestic refinery (which cannot compete with imports). Dispatch order not based on increasing cost and instead favoring certain producers or sources of electricity.	Simulating this type of subsidy would require the calculation of the price gap between the subsidized energy and the more financially attractive substitute. The reform will be simulated by decreasing or increasing the price gap.	Not available.

Category	Examples	Simulation setup in CGE modeling	Examples from the literature
Domestic supply obligation. Required sale of a fuel on the domestic market, typically when domestic prices are kept artificially low compared to export markets or alternatives.	Domestic gas supply obligation with low domestic prices in exchange for a license to export gas. Requirement to blend a certain percentage of biofuel in gasoline or diesel.	The simulation of change in this subsidy will consist of incorporating an equivalent tax that allows the gap between the domestic price and reference market price (economic opportunity cost) to be increased or decreased.	
Foregone government revenue			
Tax expenditure. Corporate income tax, environmental tax, land tax, import duties, value added tax (VAT), excise tax, general consumption tax, and other taxes reduced or waived. Acceleration of allowable deductions. Additional deductions over and above what is generally allowed.	Reduction on corporate income tax targeting certain firms, such as a tax holidays for a new refinery and a new power generation plant. Differentiation in excise tax between gasoline and bioethanol, or between petroleum diesel and biodiesel. Environmental tax that is not based on environmental outcome, such as taxing gasoline more than diesel. Carbon tax that is not consistent with each fuel's carbon content. Carbon tax exemption for energy-intensive industries. Tax-exempt operating status for SOEs. VAT or import-duty exemption for LPG cylinders. Lower VAT for electricity, and VAT exemption for residential consumers.	The CGE models generally incorporate various categories of taxes applied to products and institutions (corporate, households). The simulation of subsidies reform would consist of increasing the taxation rate.	Not available.

Category	Examples	Simulation setup in CGE modeling	Examples from the literature
Other fiscal revenues. Bonuses for oil blocks, royalties, production share, and other non-tax fiscal payments reduced or waived in upstream oil and gas.	Differences in rates that cannot be traced to costs or profitability, seemingly favoring certain projects or firms, such as low royalties or production share for the government bilaterally negotiated with one company and not others in comparable oil fields.	Because the CGE model specifies, for each sector of the economy, the ownership of the factors of production (labor, land, capital, natural resources) for key institutions (households, enterprises, government, and the rest of the world), the simulation of changes in the production share for the government can be modeled. However, the determination of the magnitude of the simulation would require the calculation of the optimal level of government production share, which is generally not available.	Not available.
Government revenue from energy suppliers.	Reduction in government revenue as a result of state-owned energy suppliers—such as national oil companies providing subsidized fuels—deducting subsidies from dividends to be transferred to the government.	The flexibility of the CGE modeling framework allows explicit capture of the share of capital remuneration (payment to the government due to ownership of a share of capital, land, and natural resources used to produce energy) transferred to the government by energy firms. The simulation of energy reform in this case will consist of increasing that share. However, the number of companies explicitly represented in a CGE can be very limited, typically only one in a standard CGE model.	Not available.
Underpricing of other goods and services, including risk			
Subsidized inputs. Subsidies for large-volume inputs to energy suppliers, such as fuels and water.	A significant price discount for domestic crude oil sold to a domestic refinery. Subsidized or free diesel, fuel oil, or natural gas supplied to power utilities. Subsidies for water charges to biofuel feedstock growers or hydraulic fracturing for natural gas production. Subsidized rail freight for coal suppliers.	The reform is simulated through changes in prices of intermediate consumption of subsidized goods and services by energy suppliers. The reform would be simulated by increasing the prices of the intermediate goods and services.	Not available.

Category	Examples	Simulation setup in CGE modeling	Examples from the literature
Lending and credit. Loan guarantees, below-market provision of loans, and grants for energy production and supply.	Soft loans, typically for SOEs.	The subsidy delivery mechanism can be simulated by lowering the cost of capital of the targeted firms. The CGE model should explicitly integrate a variable for the subsidies related to lending and credit that would be changed to implement the shock.	Not available.
Goods and services provided by government. Underpricing of access to land and other goods and services.	Excludes goods and services provided to the broader economy, such as roads and rail used by many sectors.	The subsidy delivery mechanism can be simulated by lowering the cost of subsidized goods and services of the targeted firms. The flexibility of CGE models allows identification of the prices of intermediate goods consumed in each activity, as well as factors of production including land.	Not available.
Permits. Underpricing of permits and licenses.	Freezing of the permit fee for years or decades.	Not modeled.	Not available.
Shifting of risk burdens. Government assumption of price, safety, and other risks; consumer or resident assumption of risks through limits on commercial liability.	Assumption of risks must be specific to the energy supply chain. A superfund to clean up legacy projects (such as coal mines), paid for by taxpayers, would be an example. Government financing of a diesel price insurance in Chile in 2005–06 is another example. Benefiting energy producers and suppliers: Implicit government guarantee; state-owned energy suppliers enjoying ready access to state-owned banks.	Not modeled.	Not available.
Special treatment of SOEs. Undue risk-taking, soft budget constraints leading to contingent liabilities, debt cancellations.	Benefiting SOEs buying fuels from state-owned fuel suppliers: Late or no payment with no penalties or supply termination. Benefiting consumers: Not requiring SOEs to make reasonable profits in order to keep end-user prices low.	Not modeled.	Not available.

Source: Authors' construction based on table 1 in Good Practice Note 1.

SPECIFICATION OF THE PRODUCTION TECHNOLOGY AND ENERGY DEMAND

The specification of production function in many standard CGE models, relying on fixed-coefficients assumption for modeling the demand for intermediate goods, is not well suited for energy sector. A particularity of the energy sector is that consumption can be highly related to the level of investment in the economy and the improvement of technology. However, most CGE models rely on Leontief function (which assumes fixed coefficients) for modeling the demand for intermediate goods. As stressed in Jorgenson and others (2013), this assumption contradicts the empirical evidence of increasing energy efficiency in response, amongst others, to higher world energy prices.[2] To account for a potential link between energy consumption, investment, and technology, the energy sector should be incorporated as an additional value-added component (beyond labor and capital) with some level of substitutability with both capital and skilled labor.

The analyst should choose a CGE modeling framework that specifically accounts for the link between technological improvement and energy efficiency. Among the examples are the World Bank's LINKAGE model and the ENV-LINKAGE model of the Organisation for Economic Co-operation and Development (OECD), both of which use putty-clay production specification for the energy sector to capture this link. Under this specification, the intermediate consumption of energy is modeled as a complement to capital in the short term, but a substitute to capital in the long term as technology improves. Typically, this approach requires a model that incorporates vintage capital (which assumes that capital deployed in different years has different productivity), and assumes that greater substitution between energy and capital in the long term (that is, with *new* capital) than in the short term (with old or installed capital).[3]

SPECIFICATION OF THE MARKET STRUCTURE AND PRICE PASS-THROUGH IN THE ENERGY SECTOR

The specification of the market structure is critical for determining the price pass-through by energy firms in response to price subsidy reforms. The pass-through of higher energy prices by firms operating in a competitive market is likely to be different compared to firms with monopoly power. A standard assumption in most models is perfect competition in product and factor markets. However, energy companies in a number of developing countries operate as a monopoly or an oligopoly without contestability.

One way to account for this is by assuming that the energy sector is operating under imperfect competition with increasing returns to scale using fixed production costs. This assumption is developed in some CGE models (LINKAGE and ENV-LINKAGE), where the fixed production costs are represented by some fixed combination of capital and labor. These models incorporate the markup effect that captures the difference between the marginal cost and consumer price. However, the implementation of this approach is particularly demanding in terms of data, since the modeler would need to determine the level of markup as well as the level of fixed costs.

MACROECONOMIC CLOSURE RULES AND POLICY OPTIONS TO USE ADDITIONAL REVENUE MADE AVAILABLE BY THE REFORM

Not all subsidies generate more government revenue. Some subsidies, such as high export tariffs to keep domestic prices low, generate government revenue, which will fall if the subsidies are removed. Others, such as budgetary transfers used to subsidize energy consumers or producers, will free up government spending when the subsidies are ended, but do not generate additional revenue, at least not in the short term. Ending tax expenditures will generate more revenue in the short term, even if tax revenue gradually declines over the long term as energy firms adjust to higher tax rates by reducing investment in the country.

Where subsidy reforms make more government revenue available for expenditures other than energy subsidies, modeling the impact of subsidy reform has to assume a macroeconomic closure. A critical closure is the fiscal closure rule—whether the government implements the reform policy in a way that (a) is fiscally neutral (spending any windfall revenues or reducing taxes by the amount of the fiscal shortfall), (b) reduces the debt, or (c) finances targeted spending. The macroeconomic closures provide important insights into the real-world options that are associated with alternative macroeconomic adjustment patterns (Lofgren, Harris, and Robinson 2002). These assumptions also reflect the constraints facing the economy. A careful subsidy reform analysis needs sensitivity analysis to explore how results change depending on what the government does. Assumptions regarding how the economy achieves equilibrium and how the additional revenue is utilized are a key driver of the economic effects of subsidy reform. In many cases, these assumptions determine whether the reforms boost GDP and household welfare. Table 2 provides examples of fiscal closure and policy options.

TABLE 2: Examples of Fiscal Closure and Policy Options

Government accounts	Closure 1: Revenues used to reduce deficit	Closure 2: Revenue used to cut taxes	Closure 3: Revenue funds public investment	Closure rule 4: Revenues used to increase current expenditures (such as transfers)
Current expenditures	Fixed	Fixed	Fixed	Endogenous
Capital expenditures	Fixed	Fixed	Endogenous	Fixed
Tax rate	Fixed	Endogenous	Fixed	Fixed
Government balance	Endogenous	Fixed	Fixed	Fixed

Source: World Bank staff.

GROWTH EFFECTS AND THE TREATMENT OF ENERGY EFFICIENCY GAINS

Dynamic CGE models adopt the neo-classical growth framework (Solow growth model). This means that the long-term growth rate of the economy is determined by three main factors: capital accumulation, labor supply growth, and increases in productivity. The first factor is endogenous, while the remaining two factors are determined outside the model.

Energy subsidy reform can potentially affect the level of investment in the economy and hence the economy's growth rate. If a subsidy reform makes additional revenue available to the government for alternative uses, that extra revenue can be used, for example, for infrastructure investment. This growth channel is captured by these neoclassical models. However, they will underestimate the extent to which technology may evolve in response to higher energy prices, since they do not model the creation of these technologies. The dynamic module can be used to capture exogenously the impact of improved energy efficiency on productivity. Before running any policy simulations in a dynamic framework, it is often necessary to define the reference scenario. This requires assumptions about a broad range of dynamic variables, including population and labor supply growth rates, and the growth rate of factor and energy productivity. However, the specification of energy productivity is overlooked in most standard CGE setups, mainly because the appropriate data are generally available only to energy specialists. The LINKAGE model addresses energy productivity through the notion of "the autonomous energy efficiency improvement."

LONG-TERM VS. SHORT-TERM STRUCTURAL EFFECT

As discussed above, CGE models, unlike macrostructural models, are not particularly suited to capture the short-term effects of energy reforms. However, some short-term effects can be explored using a CGE model by assuming some level of rigidity on the movement of factors between sectors. Using the ORANI model, Cooper and McLaren (1983) determine the short-term effects of a policy by assuming that the capital in each industry is exogenous and unaffected in the short term. At the same time, rates of return are endogenous. Simulations conducted under this closure rule are thought to reveal effects that would emerge after about two years. If a long-term focus is required, the closure rule is reversed. It is assumed that deviations in rates of return would be temporary. Thus, in long-term simulations, rates of return are exogenous while capital stocks adjust endogenously to allow rates of return to be maintained at their initial levels.

DISTRIBUTIONAL EFFECTS

As discussed in notes 3 and 4, it is important to base distributional effects on what consumers actually pay, and not what they are supposed to pay. Price subsidies frequently create energy shortages, as a result of which subsidized energy is not available to meet demand fully. The supply-demand gap at the official prices can be considerable. In extreme cases, energy at subsidized prices is not available to the intended beneficiaries. Carrying out distributional analysis on the assumption that subsidies are implemented as intended could lead to inaccurate results and misguided policy conclusions. By contrast, budgetary transfers are typically based on official subsidized prices and at apparent consumption (inclusive of

subsidized fuels smuggled out of the country) and other concessions not necessarily captured by eligible recipients in practice. A model capturing effects on the government and on end-users may need to handle two sets of data, such as official prices facing the government and actual prices facing consumers. This presents challenges to linking the two models and analyses.

Subject to the above qualifier, there are several approaches to integrate distributional issues into economy-wide models. Most of them have been developed in relation to the CGE model, as discussed below.

The first approach, called the parametric approach, relies on exogenous functional forms of income distribution. This is the standard approach used in early CGE models focused on income distribution (see de Janvry, Sadoulet, and Fargeix 1991 or Annabi and others 2005). The implementation of these microsimulations consists of classifying households into "representative" groups and assuming exogenous functional forms for income distribution within each group to generate group-specific individual incomes. Examples of functional forms include log normal (see de Janvry, de Anda, and Sadoulet 1997) and beta flexible (Decaluwé, Martens, and Savard 2001). Once the income of each group is determined, the CGE model calculates the impact of subsidy reform on these incomes and computes standard distribution and poverty indicators (such as Gini and Foster-Greer-Thorbecke, or FGT). In general, the reliability of this approach depends on the type of distribution function considered (Reimer 2002; Boccanfuso, Decaluwé, and Savard 2008). Regardless of the functional form used, this approach assumes that the first moment is fixed and is not affected by the impact analyzed. Despite this limiting

assumption, this approach has the advantages that it can be easily implemented, since a household survey is not needed.

The second approach is to disaggregate, using household income and expenditures surveys, the representative household in the CGE model into different categories of households based on criteria of interest to the modeler.[4] The integration of various categories of households into the model also enables the analyst to consider different approaches to compensating losers from the reform. However, this approach requires the modeler to have the ability and time to disaggregate the SAM using a household survey. Further, this approach is limited by the categories of households incorporated in the SAM and would not allow the computation of poverty and inequality indicators.

A third approach, developed by Bourguignon, Robilliard, and Robinson (2003), is the sequential CGE microsimulation, which links the CGE model and the household survey in a sequential way. This approach can be implemented in two steps:[5]

- **STEP 1:** A CGE model produces linkage macro variables, including product-specific consumption prices, remunerations of factors, and the level of employment.

- **STEP 2:** The changes in linkage variables are imposed on individual households in the survey. In this way distributional indicators can be computed.

A microsimulation approach enables the modeler to compute various types of poverty and inequality indicators, but its implementation is difficult because the modeler has to have sufficient microeconomic knowledge. Examples of toolkits developed by the World Bank in recent years to undertake

CGE microsimulation analysis include ADePT software (Olivieri and others 2014), GIDD (Global Income Distribution Dynamics), and SUBSIM. These platforms use micro-level data from various types of surveys—such as household expenditure surveys, Demographic and Health Surveys, and Labor Force Surveys—to produce rich sets of tables and graphs for distributional analysis. Typically, the CGE model would generate linkage variables (product and factor price changes) that are used by the platform to produce inequality and poverty indicators. ADePT is one of the most flexible and is set up to simulate price changes not only from CGE models, but also from any other analysis. GIDD, which is a CGE-microsimulation, is designed to be connected to a CGE model. The GIDD model linked to a global CGE model includes distributional data for 121 countries and covers 90% of the world population. SUBSIM assesses the distributional impact of energy subsidies reforms. It is set up to estimate direct and indirect effects using household expenditure survey data combined with IO matrices. Unlike GIDD (which is connected to a CGE model), SUBSIM does not capture the second-round effects of shocks.

ENVIRONMENTAL EFFECTS AND CAPTURING EXTERNALITIES OF ENERGY REFORM

Energy reform can have important external effects on the economy and the society as a whole by changing the level of greenhouse gas (GHG) emissions. This holds especially where energy prices change, or consumption of certain forms of energy—typically renewable—is mandated. The most widely used modeling framework to assess the environmental effect of changes in energy policy is the IO approach, primarily because of its ability to account for the intersectoral links within an economy in detail,

and partly for its simplicity and transparency. However, because of the limitations of the IO approach discussed earlier, CGE models have been increasingly used to assess the environmental impacts of economic policy changes. Although not necessarily applicable to energy subsidy reforms, it is worth noting that most environmental modules linked to CGE models also consider feedback mechanisms that address how the environmental effects of policy changes affect the economy, such as the impact of an improvement in the environment—in this case limiting the global temperature rise, which may be an outcome of extensive energy subsidy reforms implemented globally—on household utility or the productivity of firms.

A good model to capture the environmental impact of energy policy changes should meet the following criteria:

- **The input data should ideally reflect how subsidies are implemented in practice, not how they are designed on paper.** As note 1 explains, artificially low energy prices due to subsidies all too often lead to energy shortages. For network energy (electricity, natural gas, and district heating), this typically means energy is sold at subsidized prices but rationed. Where consumers are not individually and accurately metered, they may be billed for estimated rather than actual consumption. Such practice in turn could make effective prices paid higher than the subsidized prices. For liquid fuels, shortages created by smuggling and illegal diversion mean that consumers may pay much higher prices on the black market. In extreme cases, the price elasticity may even be positive: ending subsidies finally frees up the supply bottlenecks, enabling domestic refiners to run refineries at full capacity and fuel importers to start importing again to meet pent-up demand, and demand

increases even as official prices are raised. Accurately capturing these aspects of energy subsidies requires resource-intensive data collection—by definition, official data on illegal diversion of fuels do not exist and are difficult to collect—but failure to account for these factors may result in grossly over-estimated impact on energy consumption and hence associated environmental effects. Many studies on environmental effects of subsidies unfortunately rely on official prices and policies, and suffer from overestimation of effects of subsidies and their reforms. Due to data limitations, this criterion is frequently not met.

- **The model should capture the lag between the positive and negative effects.** The negative effects of policy changes (such as increased production costs and consumer prices) typically come early, while the positive effect is felt later on, such as lower GHG emissions. This requires a dynamic model. A typical dynamic CGE model calculates the level of GHG emissions (from energy supply and consumption) by sector based on demand (final and intermediate) and the emission coefficients (exogenous coefficients available for at least 58 sectors in the GTAP database). The local environmental effects are more complicated to estimate, and are treated in note 8.

- **The model should capture emissions in other countries, although this is not always necessary.** The importance of policy changes that affect emissions may depend on what is happening in other countries. This requires generally a multi-country CGE model. However, it is worth noting that an energy subsidy reform in one country is not likely to have a significant impact on global GHG emissions. Furthermore, there are so many uncertainties that it might be

pointless to try to quantify the impact of the reform on global emissions. Therefore, a single-country CGE model linked to global emissions coefficients might be enough for most countries where the most pressing issue is to quantify emission reductions and to compare them with the country's objectives for emissions reductions.

- **The model should provide for sensitivity analysis to take into account the uncertainties surrounding climate change effects.** This can be achieved, for example, by implementing the CGE model in a software package that allows Monte Carlo experiments (such as GAMS, GEMPACK, and Eviews). A number of modeling frameworks developed at the World Bank and in other institutions meet these criteria (see annex A). A good example is the Environmental Impact and Sustainability Applied General Equilibrium Model (ENVISAGE), described in Roson and van der Mensbrugghe (2012).

- **The model should provide for the estimation of externalities related to GHG emissions.** CGE models featuring a standard environmental module, such as ENVISAGE, generally model the externalities through a damage function linking changes in temperature levels to key economic indicators (such as the tourism indicator, level of sea water, and health indicator). However, for a country-specific study, the externality might be better estimated in a single-country CGE model by quantifying local air quality changes and subsequent impacts on health. The benefits of reducing emissions would be much greater for these local issues than for the global temperature change, and much more relevant to the country.

One advantage of CGE models in assessing the environmental impact of energy subsidies is the ability to capture the so-called rebound effect as prices react to the change in policy. Improvements in efficiency and technological improvements in the use of energy induce an increase in consumption (see Gillingham, Rapson, and Wagner 2015 and Schaefer and Wickert 2015 for further references), which has a further impact on the economy. Given

that consumption by households and firms is determined by their budget constraints and prices, this effect is implicit in the setup of the CGE. However, calculating this effect requires measurements of efficiency and technological improvements in energy use that should be provided by external sources (a good review of the state of the art in rebound effect studies using the CGE framework can be found in Vivanco and van der Voet 2014).

5. DATA REQUIREMENTS FOR ECONOMIC MODELING

There is a varying degree of data requirements across different models. Key data required to implement a CGE model include a SAM, national account data, balance-of-payment data, a household survey, tax administration data, and GHG emission data.[6] While this may seem onerous, in most cases, this level of detailed data is needed only for a single year. By contrast, macrostructural models can be

developed on aggregate national accounts and balance-of-payments data, but a time series is needed for each aggregate indicator. This section discusses the data needed to implement the approaches mentioned in the previous sections and some potential sources of information. The minimum data requirements needed for each type of model are summarized in table 3.

TABLE 3: Minimum Data Requirements for Each Type of Model

Modeling tool	Minimum data requirements
Macrostructural	Magnitude of energy subsidies, energy sector data, and time series data for national accounts
IO and SAM multipliers	Magnitude of energy subsidies, energy sector data, and IO table
CGE	Magnitude of energy subsidies, energy sector data, and IO table
DSGE	Magnitude of energy subsidies, energy sector data, and timer series data for national accounts

Source: World Bank staff.

MAGNITUDE OF ENERGY SUBSIDIES

A key data input into each of the models is an estimate of the size of the subsidy and the mechanism by which the subsidy is delivered. The simulation of subsides is

relatively straightforward if the subsidies are in the form of price controls and implemented as designed (official prices and prices paid are the same, and consumption is by eligible recipients), and if budgetary transfers are used to pay for the subsidies, because the prices faced by both consumers and producers

incorporate taxes and subsidies in economy-wide models. The magnitude of the transfer from the government budget to the producer or consumer receiving the subsidy can be found in the budget documents, and is also generally reported in the SAM.

If there are price subsidies, but there is no immediate transfer from the government to a company to cover the shortfall in revenue due to the subsidy, the model would have to compute the price gap as defined in note 1 (the difference between the reference market price and the subsidized price). note 1 explains in detail how to deal with different forms of energy and how to take the trade status of each type of energy into account.

Other forms of energy subsidies, especially those that do not affect prices paid, are more difficult to analyze and have typically not been modeled.

ENERGY SECTOR DATA

Data for specific forms of energy that are being subsidized are needed to study the effects of subsidies and their reforms. Identification of specific energy subsectors under consideration for the reform is crucial in preparation for simulations. However, most standard SAMs and IO tables include only broad energy categories; some even combine energy with other utility services, such as water. It is not uncommon to see all hydrocarbons aggregated in a single category, whereas subsidy reforms may be for gasoline and diesel but not kerosene. Therefore, a study aiming to use a CGE to assess a subsector not directly represented in the SAM or IO table should consider disaggregating the single sector into more relevant categories. An example of how to go about disaggregating a SAM is described in box 1.

BOX 1: CONSTRUCTION OF A NEW SOCIAL ACCOUNTING MATRIX

An existing Social Accounting Matrix (SAM) may not disaggregate the energy sector sufficiently to be of use for analyzing energy subsidies. For example, deregulation of gasoline but not diesel may be envisaged, whereas the existing SAM lumps all transportation fuels into a single category. Finer disaggregation might entail cases where subsidy removal for high-octane, but not low-octane, gasoline may be envisaged, or price subsidy for liquefied petroleum gas would be removed for all consumers with the exception of households. In such cases, the question is whether and how to modify the existing SAM to separate out the forms of energy being considered for subsidy reform. The following steps represent one option.

1. Identify a proxy country from which technical coefficients will be borrowed to complement the existing IO table. If the subsidy involves electricity, natural gas, or district heating, data from energy and utility companies on their cost structures can also be used.

2. Compile aggregate macroeconomic data and construct a macroeconomic SAM (macro-SAM).

3. Develop a larger SAM (unbalanced micro-SAM) that disaggregates the information by commodity and activity.

4. Balance the SAM (balanced micro-SAM) using the RAS (iterative scaling method) or minimum cross entropy method.

5. Verify that the balanced micro-SAM is consistent with the aggregate macroeconomic data.

6. Disaggregate subsectors of interest, factors, and household accounts.

The introduction of a new sector into a SAM requires information from both supply and demand sides that are generally found in a supply-use table. The data required from the supply side include production, intermediate consumption, and value added; and from the demand side, final demand (that is, household and government consumption), investments (public and private), and exports. The only source of information that provides all this information is a supply and use table.

Alternative domestic and international data sources can be used to collect additional data for disaggregation when the IO table does not provide enough data. Domestic sources are generally best suited for sectoral energy data, when available. In the event that the study team does not have access to the relevant data in the country, a default option is to use data from the International Energy Agency (detailed forms of which are available for a fee).[7]

The household income and expenditure survey will be required if the study includes more than one representative household. Because the IO table provides information only on a single representative household, income and expenditure surveys are generally needed to create additional household categories by providing detailed information on sources of income (labor, capital, transfer, remittances), and household spending (basket of consumption, savings, transfers).

MACROECONOMIC INDICATORS

Economy-wide models require a similar range of macroeconomic indicators. These indicators include

- National income accounts;
- Balance of payments;
- Government financial statistics;
- Inflation;
- Exchange rate;
- Population; and
- Labor force data.

These are available from government, and also from the World Bank (World Development Indicators[8]) and the International Monetary Fund (World Economic Outlook[9]). Sectoral trade data are available from international trade sources (United Nations Comtrade[10] and World Trade Organization[11]).

SOCIAL ACCOUNTING MATRIX

The main database required for a CGE, IO, or SAM-multiplier model is the SAM, which is a comprehensive economy-wide data framework including both social and economic data.[12] A SAM captures in a single square matrix the interaction between production, income, consumption, and capital accumulation of domestic and external institutions.

The first source of a SAM is the national accounts administration. However, important international initiatives to build comparable SAMs for different countries have emerged in recent years. The Global Trade Analysis Project (GTAP) is arguably the most important international source for SAMs. It includes data for 57 sectors in 140 "regions," which include 118 countries. Importantly, the energy sector is well specified in GTAP. The standard database distributed by Purdue University covers 6 energy subsectors—coal, oil, gas, petroleum, and coal products, electricity, and gas distribution, although the most recent available version of the GTAP database (Version 9.2) has 11 subsectors within the

electricity sector. However, because of their efforts to reconcile data for all countries integrated in the database, the GTAP database can present some discrepancies that have to be corrected when used for a single-country study. The International Food Policy Research Institute (IFPRI) also estimates SAMs for number of developing countries, but this is not a systematic effort; the number of countries is limited and access is not guaranteed.

If a SAM is not available, constructing a new SAM would require an IO or supply-use table. To construct the SAM, the IO table should be complemented by national account data, international trade data, balance-of-payments data, a household survey, and tax administration data.

The IO table chosen should be as recent as possible to reflect the current structure of the economy and technology. The IO table should be taken from a year when no important international shock (such as a major international financial crisis) or domestic shock (for example, a natural disaster) occurred, when economic relationships may not have reflected the long-term structure of the economy. The first source of the IO table is the national account administration. For most French-speaking African countries, AFRICSTAT[13] has developed IO tables, which are also available through government sources. The Asian Development Bank provides IO tables for selected countries in Asia and the Pacific.[14] For other countries, the World Input-Output Database[15] can potentially be a source of data, although only a handful of developing countries are among the 43 countries in the database.

HOUSEHOLD SURVEY

Surveys of incomes or expenditures by households are key inputs for distributional analysis. They are necessary if the SAM is to include multiple factors and household categories. The government is the main source. Among publicly available data sources, the Living Standard Measurement Study surveys provide data on household expenditures using standardized survey questionnaires.[16] Surveys for all Latin American and the Caribbean countries are harmonized and available through SEDLAC (Socio-Economic Database for Latin America and the Caribbean).[17]

ENVIRONMENTAL DATA

The environment module requires two types of information that are determined externally to the economy-wide model. Emissions of carbon dioxide (CO_2) and other GHGs (in CO_2-equivalent) for 57 sectors can be found in the GTAP database. The International Energy Agency has a database of CO_2 emissions from fuel combustion for 136 countries, broken down in detail by fuel type, activity, and end-use.

ELASTICITY OR BEHAVIORAL PARAMETERS

The calibration of the CGE model must rely on some externally calculated elasticities for behavioral functions determining production, factor use, consumption, trade, migration, and other variables. The results of CGE models are sensitive to the specification of these parameters. For example, elasticities determine the ease with which one input can be substituted for another. Elasticities relating to energy consumption are particularly important for estimating the impact of the elimination of consumer price subsidies,

including its impact on GHG emissions. If, for instance, an industry is able to substitute away from energy with relative ease, the price of its output may not change much when the price of previously subsidized energy increases.

Ideally, the elasticities should be determined for each study through rigorous econometric regressions. However, this approach is more the exception than the rule, in part because the data needed to carry out credible regression analysis is often not available. As an illustration, if a country has had pan-territorial pricing of subsidized energy and prices have not changed for years, there is not enough variation in the data for meaningful regression. As a result, most studies use parameters selected from the literature (see McKibbin and Wilcoxen 1999). GTAP proposes a series of elasticities for different categories of countries according to the level of development.

This lack of grounding in data has attracted criticisms. To ensure a robust study, it would be useful to carry out sensitivity analysis

for key parameters to illustrate the range of possible results. For particularly important parameters, country-specific estimates can be drawn from the country-specific literature or commissioned work.

Macrostructural models estimate their parameters from historical data. However, since these parameters are based on historical responses of economic agents to past changes in policy and economic shocks, they may not capture the response of agents to a new change in policy.

Own and cross-price elasticities are meaningful only if actual prices paid by consumers are known and energy is not rationed, two conditions that are often not met. In some regions, power outages are the norm rather than the exception. Fuel shortages resulting in long queues and even physical fights among consumers have known to occur in a number of countries with price subsidies, most recently in Nigeria for subsidized gasoline (*Nigerian Tribune* 2018).

6. CONCLUSION

Designing a successful energy subsidy reform involves identifying the winners and losers from such a policy, so that those who were eligible to benefit from subsidies and will shoulder the burden of the reform can be appropriately compensated as needed. Identifying the sectors or agents that are affected by the reform and the extent to which they are affected requires a model that can capture the distortions that are introduced by the subsidy. There are many issues to consider when choosing a model to help design energy subsidy reform. This note has focused primarily on cases where

prices actually paid by energy consumers will rise and where there are no acute energy shortages. Subject to these limitations, the issues to consider include the following:

- The distortions caused by a subsidy vary depending on **how it is implemented.** This means that the model's ability to depict the subsidy's implementation is important.

- **The price increases induced by price subsidy removal are caused by both the direct effect of the subsidy on energy prices and its indirect effects.** The indirect effects can be significant for those forms of energy

that are used in the production of other goods and services, such as diesel fuel, natural gas, and electricity. A model's ability to capture these indirect effects is crucial. Often people and firms that are little affected directly by a subsidy sustain large indirect impacts. For example, the main channel of higher transportation fuel prices to poor households is through higher public passenger transportation and food costs, and the combined effects of these two alone may be larger than that on spending on energy.

- Thinking beyond the first-round effects, the long-term impact of direct and indirect effects depends on **how easily industries and households can adapt to higher energy prices** (substitute towards less expensive alternatives, adopt more energy-efficient products) and for firms, the extent to which they can pass price increases on to their customers. Hence, the model needs to capture the response of firms and households to higher energy prices and needs to include an intertemporal component as the profitability of sectors changes. So, too, will investment and, over time, the structure of the economy.

- **Higher energy prices would introduce short-term adjustment costs in the economy**, such as price inflation and unemployment.

Understanding and mitigating these short-term costs would be an important aspect of ensuring the viability of the reform. Hence, the model should be able to estimate both the short-term costs and long-term gains.

- The **economy-wide impacts of higher energy prices will depend importantly on how the government manages the fiscal windfall (if any) from the subsidy reform**. The various options include paying down debt, investing in public infrastructure, offsetting harms on specific population groups, and targeting assistance to certain industries. A strength of using economy-wide models is their ability to compare the effects of different options in a consistent manner.

- **Being selective about the compensation of firms and households allows the government to preserve the majority of the fiscal benefits from energy subsidy reform**. Designing a targeted compensation policy relies on a model that has both industry and household detail, so that those most affected can be identified.

- The wider *benefits* of energy price subsidy reform potentially include lower emissions of GHGs and harmful local pollutants. A model that captures environmental externalities will be able to capture the effects of energy subsidy reform on the environment.

ANNEX A: LITERATURE REVIEW

This annex provides examples of studies that have used models covered in this note to study the impact of reforming consumer price subsidies for energy and, in some cases, associated energy taxes. No other types of energy subsidies are modeled. None of the examples provided in this annex take energy shortages into account or actual (as opposed to official) prices paid, potentially overestimating the reduction in energy consumption following subsidy removal. Several do not provide details on how subsidies were measured, and some that do make simplifying assumptions that compromise quantification of price gaps. For example, some papers compare the domestic prices of refined products to import- or export-parity prices, which would be prices at the national border rather than in the market. To the border prices must be added storage, transportation, and retailing costs including additional taxes and profit margins. As a result, the quantitative results reported, especially with respect to the fall in emissions from fuel combustion, should be interpreted with caution, and these papers should not be seen as providing guidance on how to calculate price gaps. The purpose of this annex is not to draw attention to the results, which are affected by the above shortcomings, but to show various ways in which the available models can potentially be used, both in terms of methodology and scenarios tested.

ANNEX A.1: Summary of Case Studies on the Impact of Energy Subsidy Reforms—CGE Models

Study/author	Methodology framework	Simulation specification	Alternative use of additional revenue	Findings (fiscal, growth, and distributional)
Indonesia (Durand-Lasserve and others 2015)	Dynamic global and multisectoral CGE model. Specifically, extended version of the OECD's ENV-Linkages model (Chateau, Dellink, and Lanzi 2014) integrating a module describing the behavior of more than 10,000 representative household groups for Indonesia. Gasoline, diesel, kerosene, and liquefied petroleum gas (LPG) are disaggregated. CGE model and the household-level model are formulated separately and adjusted iteratively until convergence, enabling the model to represent many household groups endogenously. Price gaps appear to be taken from the International Energy Agency's calculations.	Gradual phase-out of energy consumption (fuel and electricity) subsidies between 2012 and 2020.	• Unconditional cash payments on a per-household basis in which each household receives the same amount. • Increase in the subsidies for food products. • Households are compensated by payments proportional to their labor income from the formal sector (such as reduced tax rates on labor, or a subsidy on labor income if the compensation is larger than the existing tax rate). • Cash transfers as part of a global multilateral subsidy phase-out.	Depending on the redistribution scheme assumed, subsidy removal raises GDP by between 0.4% and 0.7% in 2020. The redistribution through direct payment on a per-household basis performs best in terms of GDP gains. The aggregate welfare gains for consumers are higher, ranging from 0.8% to 1.6% in 2020. Both GDP and welfare gains arise from a more efficient allocation of resources across sectors. Cash transfers and, to a lesser extent food subsidies, can make the reform more attractive for poorer households and reduce poverty. By contrast, compensating households in proportional to labor income benefits higher-income households more, and increases poverty. This is because households with informal labor earnings, which are not eligible for these payments, are more represented among the poor. Phasing out energy subsidies is projected to reduce Indonesian CO_2 emissions from fuel combustion by 10.8% to 12.6% and GHG emissions by 7.9% to 8.3%, in 2020 in the various scenarios, with respect to the baseline, excluding emissions from deforestation.
Indonesia (Dartanto 2013)	CGE-microsimulation. The static CGE model is built based on the extension of the 2005 Indonesian SAM, and household welfare is estimated using the 2005 household expenditure survey. The subsidy for LPG is not considered in this study, presumably because consumption of subsidized LPG was small in 2005. Unit subsidies appear to have been taken from data provided by the Department of Energy and Mineral Resources.	A reduction in fuel subsidies (gasoline, kerosene, and diesel) of 25%, 50%, 75%, and 100% (zero subsidies).	• A 25% cut to fuel subsidies and reallocation of the resulting savings to government spending and government transfers to households. • A 50% cut to fuel subsidies and reallocation of 50% of the savings to government spending and government transfers to households. • Removal of fuel subsidies and reallocation of 50% of the savings to government spending, government transfers to households, and other government subsidies.	The first scenario increases the incidence of poverty by 0.259 percentage points before reallocation of the savings. Full reallocation of the savings reduces the poverty incidence by 0.27 percentage points. The third scenario could decrease the incidence of poverty by 0.277 percentage points.

Study/ author	Methodology framework	Simulation specification	Alternative use of additional revenue	Findings (fiscal, growth, and distributional)
Malaysia Solaymani and Kari (2014)	Static CGE model including 22 sectors The main data source for this study is the Malaysia IO table and SAM for the year 2005. The authors disaggregated lumped energy categories, separating electricity from natural gas and crude oil from natural gas. How subsidies are calculated is unclear.	All energy subsidies are completely removed. Special attention is paid to the impact on transportation. Subsidies are estimated at 5% of GDP.	Revenue used to reduce the government deficit. No further recycling of savings from subsidies to households and enterprises.	Subsidy removal would increase real and nominal GDP by 0.63% and 0.51%, respectively. This is due to a rise of 13.15% in real investment in the economy. Investment increases because the redistribution of income from the private sector to the government increases the government's savings, thus increasing the economy's overall capital stock (Breisinger, Engelke, and Ecker 2012). The reform reduces the demand for energy, thus reducing the level of carbon emissions. However, households experience significant declines in their consumption and welfare. Output and exports of the transport sector fall, while its imports increase. The transport sector is significantly influenced through an increase in production costs due to an increase in the prices of intermediate inputs. Transport use by households decreases significantly due to higher transport prices.
Mali (Kpodar and Djiofack 2009)	Standard CGE model—draws on de Melo and Tarr (1992) and Decaluwé, Martens, and Savard (2001)—calibrated on the SAM and the Mali 2000–01 household survey. Gasoline, kerosene, and diesel are modeled.	Simulations looked at the size and distributional effects of a 34% rise in oil prices on the real income of households. The price increase would have brought domestic prices to import-parity levels in 2005. The study evaluates the effectiveness of subsidies in protecting poor households through three scenarios: 1. Fixed kerosene price to protect the poor. 2. Removal of electricity price controls. 3. Cash transfers to poor households.	Sixty percent of the savings generated by subsidy removal is transferred to the poor under the cash transfer program and 40% is used to cover administrative costs.	The study finds heterogeneous results depending on the household income level. Higher diesel prices affect primarily richer households, while the poorest households tend to suffer more from higher kerosene and gasoline prices. High-income households benefit disproportionately from gasoline and diesel subsidies. Petroleum price subsidies are ineffective in protecting the income of poor households compared with a targeted subsidy. Overall, the impact of fuel prices on household budgets shows a U-shaped relationship with expenditure per capita.
Iran (Manzoor, Shahmoradi, and Haqiqi 2012)	A small open economy CGE model for the Iranian economy. The model is based on a modified SAM, which includes consumer price subsidies and sector-specific capital. The model consists of 36 commodity categories and 18 production activities. Domestic prices are compared to export-parity prices. In that case, it is unclear how electricity is treated for subsidy calculation.	Impacts of reducing price energy subsidies, which entails large increases in domestic prices of electricity, gas, gasoline, kerosene, gasoil, fuel, oil, and LPG.	Not applicable	The reduction in subsidies lowers economic activity, reduces private sector economic activity in favor of sectors dominated by the public sector, increases prices, and reduces welfare. These results are robust to simulations that include different elasticity parameters for production.

Study/ author	Methodology framework	Simulation specification	Alternative use of additional revenue	Findings (fiscal, growth, and distributional)
China (Lin and Jiang 2011)	CGE model, SAM, and price gap approach. An energy-environment SAM is developed. Cross-entropy is used to balance SAM. Does not take fuel shortages into account. Oil and gas are combined. It is not clear how CO_2 emission factors are calculated for this combined category.	Energy subsidies considered include those for oil products (gasoline, diesel, and fuel oil), natural gas, electricity, and coal.	Reallocation of 0%, 35%, and 50% of the savings from subsidy removal to agriculture, services, and light industry.	If all energy subsidies (estimated to be 1.4% of GDP in 2007) are removed and there is no further redistribution of the savings, GDP, employment, and CO_2 emissions all decline significantly. The more the savings from subsidy removals are reallocated to certain sectors, the greater the positive effects will be on macroeconomic variables, with smaller reductions in emissions and energy intensity.
Egypt (Lofgren 1995)	CGE model based on data for the 1991/92 fiscal year. Oil is a single sector representing crude oil and refined products. Electricity is the only other energy sector. A RAS procedure was used to balance the SAM.	Short-term impact of removing price subsidies for oil products sold domestically and for commodities covered by the consumer subsidy program. Two sets of policies are considered: 1. Raising the price of domestic oil products to international levels by adding a tax while keeping the producer prices the same. 2. Removing consumer subsidies.	Each policy increases government savings. The analysis focuses on three alternative macro closures in order to explore tradeoffs between alternative uses for these savings: foreign debt repayment (adding to Egypt's net foreign assets), domestic investment, and government transfers to the households.	• Both policies are contractionary across the three macro closures. The largest declines in real GDP and other indicators result from paying back foreign debt. • At the micro level, the oil policy simulations show a decline in domestic oil use by 6–8% (with an accompanying reduction in air pollution) and larger exports. For the consumer subsidy cut, the household consumption fall is relatively limited for food due to low income- and price-elasticities. Most of the decrease in consumption affects industrial goods and services. • Sensitivity analysis suggests that price mark-ups and excess capacity in much of the economy affect the results strongly. When profit maximization and no excess capacity are assumed for most sectors, the changes in real GDP and other variables are much smaller.
Pakistan (Walker and others 2014)	GTAP-E model and a microsimulation module. SAM was sourced from the GTAP 8 database. Unit electricity subsidies are calculated as the difference between cost-recovery tariffs, determined by the National Electric Power Regulatory Authority, and the actual tariffs charged.	Estimating the effects on the economy and welfare from lowering electricity subsidies (from 1.5% of GDP to 0.4% of GDP between fiscal year 2014 and fiscal year 2016) and providing compensation to households.	The CGE and microsimulation models are used to estimate the effects of a reduction in electricity subsidies with and without compensation. The possible types of compensation packages include • A permanent increase to an existing cash transfer program • Targeting subsidies to the poor • Temporary cash transfers	The reduction in electricity subsidies without household compensation reduces GDP growth from 4.2% per year to 4% per year. Welfare falls for all households, but the richest households suffer most in absolute and relative terms because they are the largest beneficiaries of the subsidy.

Study/ author	Methodology framework	Simulation specification	Alternative use of additional revenue	Findings (fiscal, growth, and distributional)
Mexico (World Bank 2013)	Dynamic CGE model based on a 2003 IO table. Subsidy quantification is from the finance ministry.	Gradual removal of subsidies on electricity, LPG, gasoline, and diesel for both households and industry between 2012 and 2018. Elimination of energy taxes on electricity, gasoline, and diesel. Partial removal of social security employee-employer contributions, and the expansion of VAT to food, medicines, and medical service. Combination of subsidy elimination and healthcare expansion supported by tax measures.	• Spent on government expenditures (in a way that maximizes government welfare). • Transfer to all households. • Transfer to the poorest 50% households.	Only the results of energy subsidy removal are summarized below. • Redirecting the savings from subsidy removal to government investment according to its welfare goals has a negative short-term effect on GDP, but positive effects in the long term. Aggregate welfare increases and welfare gains are greater for poor households because they consume a relatively small proportion of energy compared to rich households. • If the savings are used to make lump sum transfers to all households (where each household receives the same amount of cash), the aggregate welfare gain is lower than in the first case, but the GDP effects in the long term are similar. • Using all the savings to compensate only the poorest 50% leads to larger welfare gains to the poor and similar macroeconomic effects. The boost to the agriculture sector is larger because a large proportion of the expenditures of poor households is spent on food.

ANNEX A.2: Summary of Case Studies on the Impact of Energy Subsidy Reforms—IO or SAM Multipliers

Study/author	Methodology framework	Simulation specification	Alternative use of additional revenue	Key findings (fiscal, growth, and distributional)
Islamic Republic of Iran (World Bank 2003)	IO model using the 1994–95 IO table and corresponding household survey. IO table was split into sectors with controlled prices and those without price controls. Annex to chapter 5 details methodological approaches.	A 308% rise in the average energy price, intended to bring all energy prices to import parity. Considered several price adjustment profiles, including phased and front-end loaded. Subsidies for electricity, natural gas, gasoline, kerosene, diesel, and fuel oil are examined.	Accompanying reform schemes: 1. Compensate the bottom 60% (some 39 million people) exactly for the estimated loss of consumer surplus. 2. Give a flat rate compensation to all people, regardless of income level. 3. Give the same flat rate compensation to just the bottom 60%. Choose the flat rate of compensation so that the third richest quintile is fully compensated. As a reference, flat compensation based on the return to consumers of 100% of the savings.	Without offsetting action by the government, households would experience a 30.5% loss in consumer surplus. The total bill for the government for compensation increases from scheme 1 to 3 and then to 2. Schemes 1 and 3 are administratively not practical. A phased scheme transitioning from scheme 2 to scheme 3 (preparation for which would take some time), which is eventually replaced by targeted and enhanced social protection measures, is proposed.
Pakistan (World Bank 2001)	IO model using the 1989–90 IO table and the 1996–97 household survey	The study examines how to change consumer behavior by addressing the artificially low prices of diesel fuel prices compared to gasoline set by the government. Two scenarios are simulated: 1. A 10% fall in the price of gasoline and a 67% increase in the price of diesel. 2. A 29% fall in the price of gasoline and a 10% increase in the price of diesel.	Social policies to mitigate adverse effects are qualitatively assessed but not modeled.	Scenario 1 has major economy-wide consequences. It generates substantial additional revenues, reduces the budget deficit, reduces imports significantly, and improves the balance of payments at the cost of somewhat lower growth (due primarily to contraction of the road transport sector), significantly higher short-run inflation, and slightly higher unemployment. The impact on the cost of living is regressive, with the poor being the most severely affected. The poor are conservatively estimated to increase in number by almost 1.5 million. Scenario 2 benefits the richer car users considerably, and encourages private car use in urban areas. It causes much smaller dislocation to the economy than scenario 1. There are some minor revenue losses and a small worsening in the balance of payments, but it marginally affects the poorer sections of society while conferring some benefits to car owners.
Developing countries (Del Granado, Coady, and Gillingham 2012)	IO approach to identify indirect effects. Model of price shifting to estimate indirect impact Data on household expenditures (on gasoline, LPG, kerosene, and electricity, to calculate the direct impact of fuel price increases on households. Only the impact of higher diesel prices on electricity is modeled, and 20% of total cost of electricity supply is assumed to be for diesel fuel purchase, which is not applicable in some of the countries studied in the paper.	Review of country studies that estimate the welfare impact of fuel price increases on households. A uniform fuel price increase of US$0.25 per liter is used to compare the results across different studies.	Not available	• On average, the burden of subsidy reform is substantial and is approximately neutrally distributed across income groups. • A US$0.25 decrease in the per-liter subsidy results in a 5% decrease in income for all groups. More than half of this impact arises from the indirect impact on prices of other goods and services consumed by households.

ANNEX A.3: Summary of Case Studies on the Impact of Energy Subsidy Reforms—DSGE Models

Study/author	Methodology framework	Simulation specification	Alternative use of additional revenue	Key findings (fiscal, growth, and distributional)
Poland (Bukowski and Kowal 2010)	Multisector dynamic stochastic general equilibrium (DSGE) model of Polish economy divided into three main blocks (households, firms, and government) interconnected on three markets (labor, capital, and goods).	Assess the macroeconomic impact on the Polish economy of the diversified package of about 120 different GHG mitigation levers identified in the bottom-up sectoral analysis. Subsidies to the energy sector, and particularly for emissions mitigation technologies, are included.	Government divides its tax income and EU funds subsidy into public investments, public consumption, and social transfers to households for the unemployed and retired.	• Simulation methods composed of purely econometric estimates of the business-as-usual scenario, financial assessment of alternative investment options, and macroeconomic projections can be used in the climate policy assessment, which includes subsidies for clean energy. • The DSGE macro modeling framework can integrate the microeconomic, technological bottom-up approach (see McKinsey & Company 2009), with purely macroeconomic general equilibrium modeling traditionally represented in the field by the static and dynamic CGE models. • Nine scenarios are analyzed, with varying degrees of costs for mitigation (and subsidies required) and effects on GDP growth.

ANNEX A.4: Summary of Case Studies on the Impact of Energy Subsidy Reforms—Macrostructural Models

Study/author	Methodology framework	Simulation specification	Alternative use of additional revenue	Key findings (fiscal, growth, and distributional)
Indonesia Asian Development Bank (2015)	Three separate models are used: • MARKAL partial equilibrium model of the electricity sector. • SAM model. • A macrostructural model, the E3MG (precursor to E3ME).	Elimination of all subsidies, estimated to be about US$36 billion in 2012. Subsidies are all assumed to be "on budget," so that the government's budget balance improves by the full amount of the subsidies quantified.	Alternatives considered include • No reallocations; • Transfers to bottom 40%; • Transfer to all households; • Increase in government expenditure; and • Lower taxes.	Removing subsidies leads to a 3% increase in inflation irrespective of how the additional revenue is spent. Using the savings from subsidy removal to compensate households and increase government expenditure leaves GDP broadly unchanged and household consumption about 0.5% lower than in the baseline. By contrast, using the savings to compensate households through tax reduction leads to a positive effect on GDP and consumption. Distributional estimates show that urban workers will see the greatest fall in real incomes, reflecting the large share of energy in their consumption bundle relative to others.

ANNEX B: MACROSTRUCTURAL MODELS FOR ENERGY SUBSIDY ANALYSIS

Macrostructural models use econometrically estimated relationships to explain the behavior of economic agents. These models estimate both the short- and long-term relationships between economic variables generally using an error correction framework. The short-term relationships are based on historical data, while the long-term relationships are based on both economic theory and data.

Macrostructural models assume that economic activities are demand-driven in the short term, but are supply-driven in the long term, reflecting long-term constraints on the economy. The adjustment path between the short to medium and long term are determined by data and thus reflect the historical behavior of the economy.

EXAMPLES OF MACROSTRUCTURAL MODELS THAT CAN BE USED FOR ENERGY SUBSIDY ANALYSIS

Standard MFMod

MFMod is maintained by the World Bank and produces forecasts and estimate the effects of changes in government policy in the short to medium term. Policies captured include monetary policy, energy subsidies, and other types of fiscal policy (for example, changes in the company income tax rate or labor income taxes). The model is currently available for about 160 countries and can be accessed at https://isimulate.worldbank.org/. The model is modular and, for analyzing a given country, the standard model can be run independently for that country or simultaneously with the rest of the world as a global model. In addition to the standard output from a macrostructural model, MFMod also includes four sectors (agriculture; mining, which includes oil and gas; manufacturing and construction; and services) and disaggregated government financial accounts. The standard MFMod model does not have the energy sector, which needs to be added. Disaggregation of the government's financial accounts varies between countries, but generally includes direct tax revenue, indirect tax revenue, other sources of revenue, expenditure on goods and services, expenditure on interest payments, and other expenditure (sum of all other expenditures).

The standard version of MFMod can provide quick-and-dirty estimates of energy subsidy reform. Unmodified, the models are not suitable for more in-depth analysis of the impacts of different reforms because not all of the channels through which subsidy reform affects the economy are fully captured. However, the model can estimate the effects of alternative options for the additional revenue raised or freed up. In addition, because the model has already been developed, it is an expedient option when time is limited.

Stand-Alone MFMod

Stand-alone MFMods are customized macrostructural models. The standard MFMod country model, described above, is used as a starting point, after which the model is extended—starting with addition of the energy sector—so that it is able to estimate the effects of the policy of interest.

The customized macrostructural model can address some of the weaknesses discussed above. To estimate the effects of consumer price subsidy reform, additional detail can be added to the structure of the model to focus on energy-sensitive sectors so that the interlinkages between the energy sector and the rest of the economy can be more explicitly modeled. Possible extensions include the following:

- Incorporating links between the energy industry and other industries of the economy

- Capturing the effects of energy subsidy reform on household consumption

- Identifying subsidies within the government budget

E3ME

E3ME is a global macrostructural model maintained by Cambridge Econometrics, an economic consulting firm. The model addresses some of the drawbacks present in standard macrostructural models. E3ME includes industry disaggregation (43 industries) and detailed modeling of energy production, including various fuel types and energy technologies.

The current version of the model would be appropriate to use for a regional study of energy subsidy reform. The country coverage is focused on developing countries, with most grouped into regions. National-level analysis would require some customization of the model.

ANNEX C: CGE MODELS AND THE ASSESSMENT OF ENERGY REFORMS

STRUCTURE OF A CGE MODEL

CGE models try to capture the behavior and interactions of economic agents, such as households, business, government, and the external sector. By explicitly incorporating economic behavior, they are able to estimate the response of the economic agents to subsidy reforms, and hence its effect on the structure of the economy.

The standard assumptions underlying CGE model are neoclassical:

- Agents make optimizing decisions subject to constraints (for example, firms maximize profits subject to the technology and households maximize utility subject to their income).

- There is perfect competition.

- The size of the economy is determined by supply-side factors.

- Prices adjust to clear markets (for example, wages adjust to clear the labor market).[18]

A CGE model accords an important role to prices, and agents respond to changes in prices. An increase in energy prices from subsidy reform would encourage households to substitute away from energy-intensive goods and services (substitution effect) and reduce overall consumption (income effect).

These models are able to estimate the direct and indirect effects of subsidy reform by explicitly capturing the interactions between economic agents. The cornerstone of a CGE model is the circular flow of income (see figure C1), which summarizes how different agents interact with one another. Households who own factors of production earn income derived from production. Income is then converted into demand for goods and services. The government participates in this circular flow by collecting taxes that are transferred to firms and households, and also used for investment and consumption. Domestic absorption (of households and government) is allocated between demand for domestically produced goods and (aggregate) imports.

FIGURE C1: Illustration of the Circular Flow of Income in a CGE Model
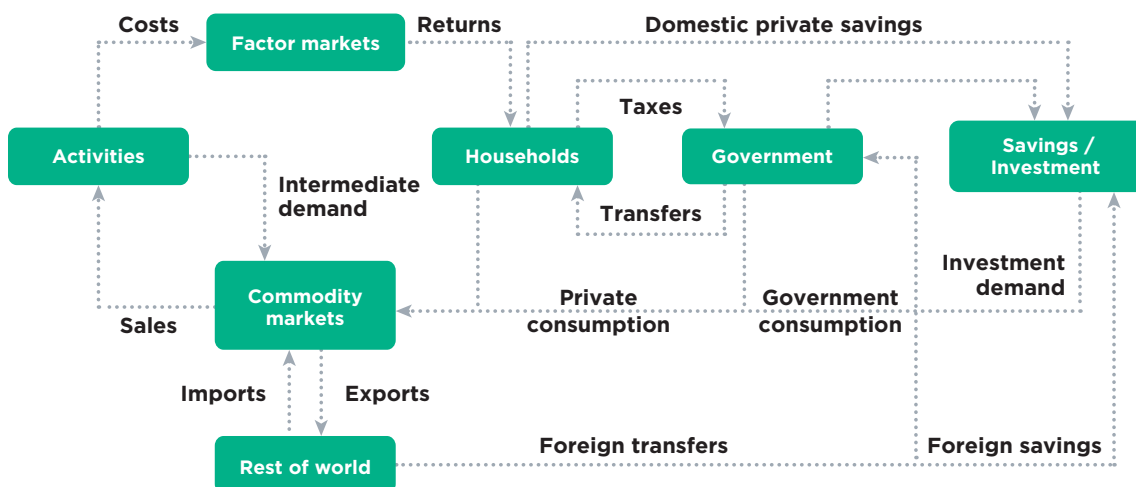
CLOSURE ASSUMPTIONS

Government balance. The standard closure rule for the government account is that government consumption and all tax rates are fixed. This implies that government saving is flexible and that any additional revenue generated or freed up by the reform will be used by the government to reduce the deficit. This closure assumption is appropriate for countries where there is resistance to reducing government spending and/or increasing taxes and where the government does not face any fiscal rule constraint (see table 2). If the reform is conducted in a country with a fiscal rule, alternative closures with fixed (or controlled) government savings might be more appropriate.

Savings-investment closure. Two closure rules are generally considered to ensure that savings equal investment. The savings-driven neoclassical closure rule implies that saving rates for all nongovernment institutions (households and firms) are fixed, and investment adjusts to equal the value of total savings. This closure rule would be appropriate for economies where the investment decision is governed by the market, and therefore determined by available savings. An alternative is the investment-driven closure rule, in which investment is fixed and one source of savings (private, government, or foreign savings) has to adjust to satisfy the targeted investment. This closure rule would be more appropriate in a country where government can determine investment, either through the public investment it directly controls or private investment through indirect control. Alternatively, a closure where foreign savings adjust is appropriate when there are open capital markets in the country. If the modeler wants to capture the effect of energy subsidies reform on growth, the first closure rule would be more appropriate, since it captures the effect of additional revenue generated or freed up by reform on investment.

External balance. Two alternatives closure rules are generally considered to achieve external balance. The first assumes that foreign savings (the current account deficit)

and international prices are fixed. Changes in the real exchange rate adjust domestic prices, which results in changes in imports and exports to achieve the current account target. For example, in a net oil importing country, the reduction of subsidies might reduce the volume and hence the value of oil imports, leading to an appreciation of the exchange rate, which in turn affects production and consumption of other tradable products. An alternative closure rule is to assume a fixed exchange rate and flexible foreign savings.

Importantly, the three closures are interrelated. The government balance closure determines government savings and the external balance closure determines the level of foreign savings. This implicitly means that the savings and investment closure determines how household saving will respond.

SELECTION OF THE CGE APPROACH

Two categories of CGE models are generally used: comparative static and dynamic. There are two variants of dynamic CGE models: recursive dynamic CGE and intertemporal CGE. There is no particular category that is used more for energy analysis than others. The choice of CGE approach will depend on the sequence of reforms to be implemented, the type of effects to be captured, the transparency requirement, and data availability. Comparative-static models are more widely used in policy analysis because dynamic models are more theoretically complex and more computationally demanding, for example to employ various numerical methods to achieve a solution. This leads to less transparent results.

Comparative Static CGE Model

To the extent that the principal focus of the energy reform analysis is to determine how the new equilibrium looks after the reform, a comparative static CGE model will suffice. Comparative static CGE models are used to examine how a change in an exogenous variable due to a policy change affects the endogenous variables at one point in time. No attention is given to the transition or the process of adjustment required to move from the initial equilibrium to the final one. The main goal is to compare prices, quantities, and welfare between the initial and final equilibrium of the economy. As such, this model would be suitable for subsidies that affect prices, such as price controls or export restrictions.

However, this approach may fail to capture some of the costs and benefits associated with the transition period and thus overstate or understate the benefits from energy reform. For example, in some energy price reforms, the process of adjustment may involve some distortions in the labor market for uncompetitive sectors that depend on subsidized energy to be profitable. Displaced workers may suffer temporary unemployment, or some retraining may be necessary, before they are fully reallocated

to more productive activities. Similarly, capital might not be easily transferable to the expanding sectors, so the reform may temporarily reduce the capital stock.

This model also lacks the timing dimension, crucial for environmental aspects of energy reform impact.

Dynamic CGE Models

Dynamic CGE models are able to capture some of the costs associated with adjustments to changes in energy policy. Dynamic CGE models examine not only the nature of the final equilibrium but also the evolution of the economic system from the initial to the final state.

Additionally, these models incorporate other dynamic effects that can modify the equilibrium estimated by a static CGE model. For example, the model can analyze the impact of changes in the pattern of capital accumulation or a higher rate of technological innovation.

There are two dynamic CGE model approaches: (a) recursive dynamic models; and (b) intertemporal dynamic models, also referred to as forward-looking dynamic models. The World Bank has developed a series of recursive dynamic CGE frameworks to assess the long-term impact of structural reforms, including MAMS, LINKAGE, and ENVISAGE. The European Commission has developed the GEM-E3 (General Equilibrium Model for Energy-Economy-Environment interactions), a recursive dynamic CGE that includes all simultaneously interrelated markets (energy, environment, economy) using a subsystem and the dynamic mechanisms of agents' behavior. E3M Lab (2017) has a full review of this model. The intertemporal dynamic CGE is far less used than the recursive dynamic CGE model. One of the main criticisms of intertemporal CGE models is that they can be too complex to solve.

SOCIAL ACCOUNTING MATRIX: CONCEPTUAL FRAMEWORK

A SAM is a matrix representation of all transfers and transactions between sectors and institutions. The matrix includes transactions in the factor markets (purchase labor and capital inputs), intermediate inputs used in production, and transaction in the final goods and services markets. Production is supplemented by imports, and the two together comprise the total supply of good and services in the economy. The matrix also identifies institutional sectors that participate in these markets: households, government, investors, and foreigners. The transactions reflect the interaction among these sectors, such that each institution's expenditure becomes another institution's income (represented by the intersection of rows with columns). Additional inter-institutional transactions, such as taxes, exports, imports and savings are registered separately, but included in the matrix. Thus, all income and expenditure flows are accounted for in the matrix, as shown in table C1.

The logic behind the SAM transactions is the following: economic activities buy intermediate inputs; pay for factors of production, thus generating the value added at factor prices; and pay indirect taxes. All these expenditures are financed with the payments that each economic activity receives for the sale of its output.

Aggregate supply and demand are recorded in the commodities accounts. For each commodity, the corresponding account records the sales of the aggregate supply (domestic output plus imports and related taxes) as follows: to activities, as these demand intermediate goods; to households, government, and investment, as these demand final goods; and to the rest of the world, as it demands the country's exports.

Factors earn returns from their involvement in domestic and foreign production, and they distribute them, net of taxes, to their owners (generally, households and enterprises).

Institutions (households, enterprises, government, and rest of the world) receive income from production factors and (net) transfers. Income is spent on commodities or saved.

Savings from households, the government (that is, the current account balance), and the rest of the world (that is, the current account balance of the balance of payments with opposite sign) add to aggregate savings and this, in turn, is equal to the level of investment in the economy.

TABLE C1: Social Accounting Matrix

	Activities	Commodities	Factors	Households	Government	Savings and Investment	Rest of World	Total
Activities		Domestic supply						Gross Output
Commodities	Intermediate demand			Consumption spending (G)	Government spending (G)	Investment demand (I)	Export earnings (E)	Total demand
Factors	Value added							Total factor income
Households			Factor payments to households		Social transfers		Foreign remittances	Total household income
Government		Production taxes and sales taxes and import tariffs		Direct taxes			Foreign grant and loans	Government income
Savings and Investment				Private savings	Fiscal surplus/deficit		Current account balance	Total savings
Rest of the world		Import payments (M)						Foreign exchange outflow
Total	Gross output	Total supply	Total factor spending	Total households spending	Government expenditure	Total investment demand	Foreign exchange inflow	

Source: Author elaboration.

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ENDNOTES

1   As explained in Good Practice Note 3, consumer price subsidies for liquid fuels may cause acute fuel shortages created by smuggling and black marketing, and in extreme cases subsidy removal could even lower prices paid by consumers.

2   The decline in energy utilization induced by successive energy crises in the 1970s and the higher level of energy prices prevailing in the 1980s has been documented in great detail by Schipper and others (1992).

3   The specification allows the model to capture the efficiency gains that are embodied in "new" capital. See Roson and van Der Mensbrugghe (2010).

4   Ideally one would integrate all households observed in the survey into the CGE. However, the data requirements would be so large as to make solving the model impossible, and the numerous assumptions required to close the model could affect the quality of results. Therefore, criteria should be established to limit the number of households to the categories of direct interest to the study.

5   There are other microsimulation approaches that adopt different assumptions for the behavior of households following the change in linkage macro variables, and the possibility or not of a feedback effect between the household survey and the CGE model. See Robilliard, Bourguignon, and Robinson (2008) for an application and discussion of the advantages and limitations of such approaches.

6   Calibrated CGE models are by far the predominant approach. There are also models that rely on production functions estimated through econometric techniques (see Jorgenson and others 2013 for a survey of econometrically based CGE approaches).

7   A data source that is available free of charge is the U.S. Energy Information Administration (EIA). The U.S. EIA has time-series statistics on fuels, including data on energy production by industry and data on coal, electricity, natural gas, and petroleum production. The EIA's Manufacturing Energy Consumption Survey (http://www.eia.gov/consumption/manufacturing/) includes data on industry-level consumption of different types of energy, and the EIA produces a handful of useful surveys, such as the annual reports on coal, electricity, petroleum, and natural gas transportation and operations.

8 http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators.

9 http://www.imf.org/en/data#data.

10 https://comtrade.un.org/.

11 https://www.wto.org/english/res_e/statis_e/statis_e.htm.

12 See the 2008 Eurostat manual on IO tables, and Hosoe, Gasawa, and Hashimoto (2004) include a chapter on how SAMs are used in CGE models.

13 http://www.afristat.org/.

14 https://www.adb.org/data/icp/input-output-tables.

15 http://www.wiod.org/home.

16 http://microdata.worldbank.org/index.php/catalog/lsms/about.

17 http://sedlac.econo.unlp.edu.ar/eng/statistics.php.

18 The equilibrium implies a macroeconomic balance for households, government, balance of payments, and savings-investment. In case of price controls, the model will assume the existence of a distortion representing the difference between observed prices and the market-clearing prices.

Energy Subsidy Reform Assessment Framework

LIST OF GOOD PRACTICE NOTES

NOTE 1   Identifying and Quantifying Energy Subsidies

NOTE 2   Assessing the Fiscal Cost of Subsidies and Fiscal Impact of Reform

NOTE 3   Analyzing the Incidence of Consumer Price Subsidies and the Impact of Reform on Households — Quantitative Analysis

NOTE 4   Incidence of Price Subsidies on Households, and Distributional Impact of Reform — Qualitative Methods

NOTE 5   Assessing the readiness of Social Safety Nets to Mitigate the Impact of Reform

NOTE 6   Identifying the Impacts of Higher Energy Prices on Firms and Industrial Competitiveness

NOTE 7   Modeling Macroeconomic Impacts and Global externalities

NOTE 8   Local Environmental Externalities due to Energy Price Subsidies: A Focus on Air Pollution and Health

NOTE 9   Assessing the Political Economy of Energy Subsidies to Support Policy Reform Operations

NOTE 10   Designing Communications Campaigns for Energy Subsidy Reform

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