TECHNICAL REPORT

ENERGY SUBSIDY REFORM IN ACTION

MACROECONOMIC MODELING AND ENERGY SUBSIDY REFORM POLICY DIALOGUE

Recent Experience, Insights, and Perspectives

ESMAP
Energy Sector Management Assistance Program

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Dominique Njinkeu, Calvin Djiofack, Defne Gencer, Lulit Mitik Beyene, and Mosuru Olukayode Alli

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ABOUT ESMAP

The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and 20 partners to help low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets. Learn more at: https://esmap.org

ABOUT THIS SERIES

This report is part of the "Energy Subsidy Reform in Action" series produced by the ESMAP Energy Subsidy Reform Facility, with the objective of drawing insights from recent experiences and emerging approaches related to reform of energy subsidies in developing countries. The series includes issue-specific reports from various relevant domains such as energy sector reform, macroeconomic and fiscal policy, carbon pricing, poverty and distributional analysis, social protection, political economy, and communications.

Production Credits

Designer | Laura C. Johnson

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Abbreviations

CGE	computable general equilibrium
ESMAP	Energy Sector Management Assistance Program
ESRAF	Energy Subsidy Reform Assessment Framework
GDP	gross domestic product
I-O	input-output
LPG	liquefied petroleum gas
MANAGE	Mitigation, Adaptation and New Technologies Applied General Equilibrium model
PAM	policy analysis matrix
PE	partial equilibrium
PMT	proxy means testing
SAM	social accounting matrix
SUBSIM	SUBsidy SIMulation Stata Package

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Executive Summary

Energy subsidy reforms are, and will continue to be, at the forefront of policy debate in many countries around the world. International experience shows that energy subsidy reforms are a complex undertaking, requiring a comprehensive package of measures that consider and address the social, sectoral, and economywide impacts of reform. Determining the objectives, clearly articulating up front the problems the proposed reform seeks to address, and understanding who will be directly and indirectly affected by the reform options under consideration are critical. In this context, macroeconomic modeling has a useful role in facilitating an understanding of and assessing the impacts of reform options under consideration.

The potential impact of energy subsidy reforms on the economy can be analyzed using various macroeconomic modeling approaches. Energy subsidy reforms can have varied impacts across different segments of the economy, and each available modeling approach offers diverse advantages in the way it captures and assesses those impacts. Computable general equilibrium (CGE) models are one of the main macromodeling approaches for analyzing the long-term effects of large-scale reforms and can be helpful for understanding and assessing the complex effects of reforms on an economy. Indeed, in recent years, CGE models have been increasingly used for assessing energy subsidy reforms and have come to be preferred because of the analytical insights they offer.

CGE models can capture the economic interdependencies of sectors and economic actors, and thus are useful for gaining an understanding of the direct, indirect, and feedback effects of policies and shocks. These models allow a comprehensive analysis to be made of a wide range of indicators, including production, consumption, factor markets, and prices, and can be complemented by other models to provide a broader view of reforms. CGE modeling can simulate the potential impacts of different energy subsidy reform options, help decision-makers understand the range of structural effects and outcomes, and offer the opportunity to refine reform design to address the most critical impacts. By providing a comprehensive assessment of alternative policy choices, related interdependencies, and the long-term effects, CGE models can bring to light the opportunity cost of energy subsidies and what outcomes could be achieved if the fiscal resources set aside for subsidies were directed to other policy priorities.

CGE modeling enhances the quality and depth of analytical support and policy advice to governments in the context of real-world reform actions under consideration. This report draws from a review that explored how CGE models contributed to the assessment of the potential impacts of real-world energy subsidy reform efforts and helped inform their design. It examined how CGE models were used to assess actual policies, either at the planning or implementation stages, and examined how CGE models were adapted for the specific settings in which they were used. By helping strengthen the understanding of the implications of different reform design options, CGE models can serve as useful tools for policy makers—and their development partners—in designing better-informed reform initiatives.

When the context and choice of modeling approaches are aligned, there is a strong case for wider use of CGE in support of energy subsidy reforms. Key considerations include the extent to which the modeling approach is aligned with the reform and country context, the availability and adequacy of data and resources are available, and the suitability of the calibration of the models. The model also needs to take into account sector- and country-specific constraints, institutional capacity, and most importantly, the policy makers' motivation for reform. There is a strong complementarity between CGE models and other simulation tools, and when they are combined, they can strengthen the analytical basis of the broader policy dialogue. The benefits of CGE modeling are amplified when government agencies show strong ownership and are closely involved in the modeling exercise and there is an element of capacity building.

If designed and calibrated well, CGE models can contribute to an improved understanding of sector and economic dynamics and can help strengthen the design of a comprehensive energy subsidy reform effort. This is particularly true if the modeling exercise involves expertise from multiple sectors, is complemented by other simulation tools, and is augmented to allow an assessment of key environmental impacts to be made. This report's review of recent examples finds that activities that bring together a multidisciplinary team, comprising experienced macromodeling experts, economists, and sector specialists along with their government counterparts, tend to use CGE modeling more effectively and lead to better-informed and more realistic reform designs.

Assumptions regarding how the economy achieves equilibrium and how fiscal savings or additional revenue from energy subsidy reforms are utilized are key drivers of the economic outcomes captured by CGE models. An important consideration is related to the use of fiscal savings or additional revenues generated from energy subsidy reform. The review of CGE modeling exercises reveals that the way fiscal resources freed up by reforms are used is critical in determining how the reform ultimately affects different segments of the society and economy, be they for cash transfers, investment in infrastructure, human development, public debt reduction, or a combination thereof. Modeling assumptions, as well as actual reform design choices, about the use of fiscal savings or additional revenues from reform, therefore, have a strong bearing on modeling outcomes related to reform impacts on growth and welfare. For a reform's impact on economic growth, studies using dynamic models can be better suited to analyzing the growth implications of a reform effort through the impact on capital accumulation, which is not the case in static comparative models.

Going forward, given the increasing interest in macromodeling of the energy sector, data availability and quality are likely to be key considerations for government agencies and experts supporting them. Therefore, it could be worthwhile for agencies responsible for national accounts to consider including key energy subsectors in their data collection efforts.

ONE

Introduction

Energy subsidy reforms remain a key development issue. The energy crisis of 2022 and resulting concerns about the affordability of energy for households and firms demonstrated that energy subsidies will continue to feature prominently on the policy agenda in developed and developing countries. Globally, energy consumption subsidies were estimated to be more than US$1 trillion in 2022 (IEA 2023). Energy price subsidies often tend to be regressive and costly, and government spending on energy subsidies in many countries exceeds budget allocations for social protection (Helmyl, Ghoneim, and Siddig 2019). These subsidies put significant pressure on a country's fiscal balances, especially by absorbing resources that could otherwise be used for pro-poor and business-friendly public spending (Coady et al. 2015; IMF 2013). The consequences of energy subsidies can also go well beyond fiscal costs across at least four dimensions. First, subsidies can depress growth by reducing investment in the energy sector, crowding out critical public spending on other priorities, or leading to the overallocation of resources to energy-intensive sectors. Second, subsidies can exert pressure on the balance of payments of energy importers. Third, to the extent they increase the production or consumption of fossil fuels, they generate additional negative externalities such as local air pollution and climate change. Fourth, subsidies can reinforce inequality, with their benefits often disproportionately accruing to higher-income households, thereby contributing to worsening inequality and undermining sustainable and inclusive growth aspirations (Breisinger et al. 2018). In view of the various impacts, interests, and policy dynamics involved, each energy subsidy reform effort requires a coherent reform package that addresses the negative impacts of subsidies, manages fiscal pressures, addresses opportunity costs, and redresses any regressive features of the subsidy schemes. An economy-wide modeling framework is an essential tool that can enable the analyst and the decision maker to capture, in a coherent manner, these dimensions of a reform.

Energy subsidies and their reform involve multifaceted and interconnected economic, financial, fiscal, social, and political implications in both the short and long run. Therefore, energy subsidy reform efforts should ideally take into account the multiple dimensions, stakeholders, and impacts involved. The use of comprehensive macroeconomic models, with built-in modules for assessing a diverse set of impacts on household welfare, firms' competitiveness, and the environment, can help provide an understanding of the multiple dimensions and impacts involved, thereby enabling the completeness of analyses that will inform the design of the reform.

International experience suggests that a comprehensive reform package that is carefully designed to consider multiple dimensions and supported by a coalition of key stakeholders and champions can enable the smooth implementation of the reforms. Energy subsidy reform design and implementation approaches and good practices have been widely documented, including through the Energy Subsidy Reform Assessment Framework (ESRAF) of the Energy Sector Management Assistance Program (ESMAP). According to ESRAF, the main components of a comprehensive reform package include, among others, undertaking adequate analysis of the policy challenges underpinning the reform, incorporating an assessment of fiscal and other key impacts as well as plans to efficiently offset harmful effects, fostering an understanding of key reform stakeholders and their roles and perspectives, and developing a well-sequenced set of complementary actions, from analysis and design through implementation.

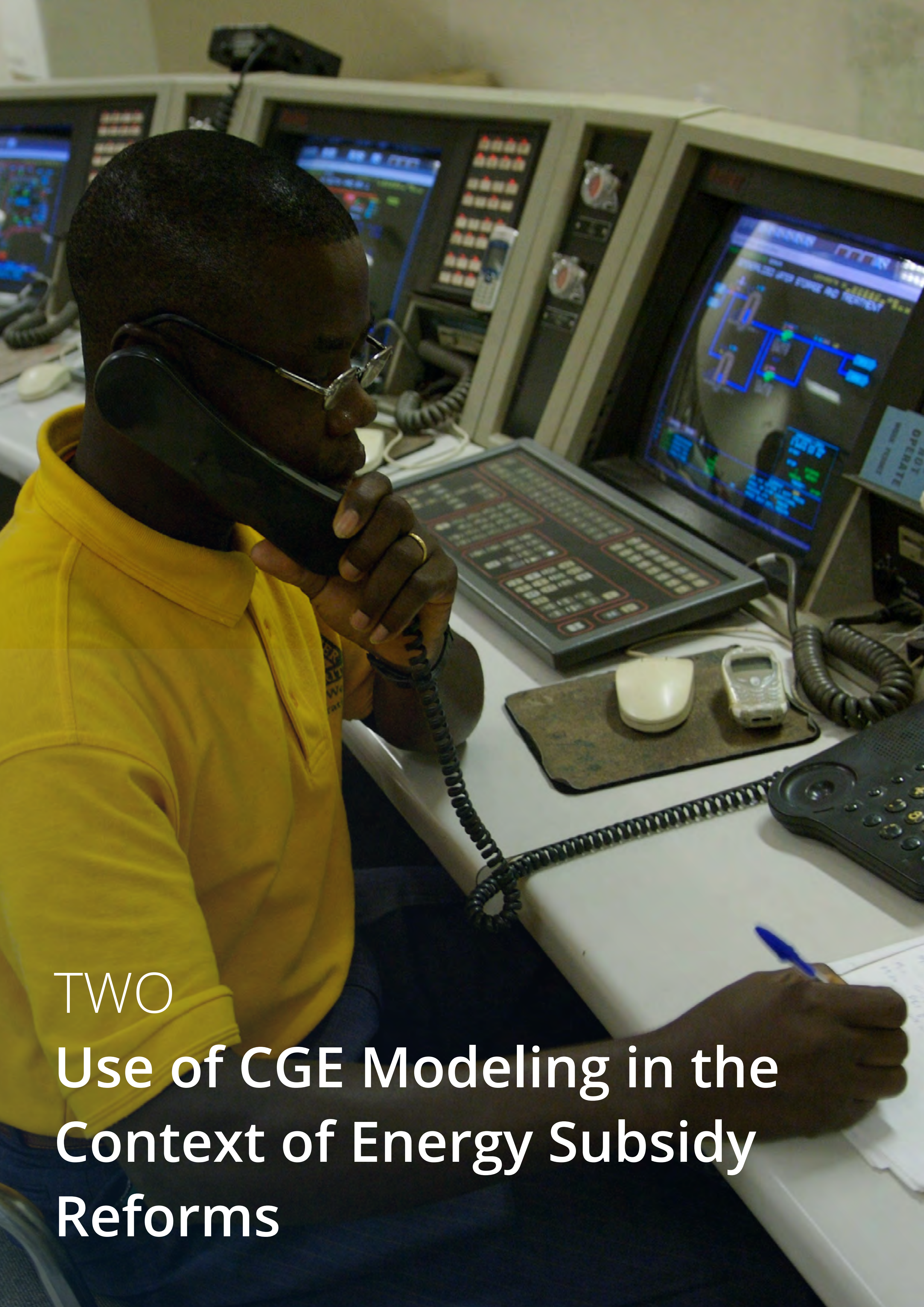
ESMAP, through its Energy Subsidy Reform Facility, supports analytical and advisory activities helping developing countries advance their energy subsidy reform efforts. As part of ESMAP, which is a global knowledge and technical assistance program administered by the World Bank, the Energy Subsidy Reform Facility has provided nearly US$27 million in grants as of 2022. The facility's technical and financial support for developing countries' energy subsidy reform efforts has tended to contribute to several key outcomes. These outcomes include helping expand the evidence base and innovative solutions, drawing on the latest research and past experience; contributing to the development of strategies and policy decisions to guide reform efforts; and supporting the strengthening of the institutional capacity of client countries to plan, manage, and oversee the implementation of policies, strategies, and programs.

As part of the growing global knowledge base on macroeconomic modeling for energy subsidy reforms, computable general equilibrium (CGE) models are being increasingly used for comprehending the complex impacts resulting from these reforms. CGE models have come to be increasingly used, thanks to their numerous useful attributes. First, they can capture the major structural features of an economy, representing interactions between industries. Second, they enable industry disaggregation in a quantitative description of an economy through a set of mathematical equations. Third, they enable the evaluation of economywide impacts of policies and shocks in the presence of economic distortions that require capturing interactions between industries and second-best effects. Finally, they can model policy reforms that touch a significant share of economic transactions that can modify the sectoral structure of output, trade, demand, employment, and prices. CGE models are, however, not suitable for assessing the short-term impacts of price reform on households and firms. For these purposes, partial equilibrium (PE) and macrostructural models can be used to quickly quantify the likely short-term macroeconomic impacts of a reform measure.

In an effort to contribute to the global knowledge in this field, this report reviews a set of real-world activities supporting energy subsidy reform efforts, which were informed by CGE modeling. To that end, the report undertakes a qualitative review of recent technical assistance activities supported by ESMAP's Energy Subsidy Reform Facility (ESRF). The review dedicates special focus on ESRF-funded activities carried out between 2017 and 2020, and complements this select group with a broader set of activities supported by the World Bank and other institutions in support of energy subsidy reforms. The report aims to document and understand the design choices and implementation approaches for the use of CGE modeling in support of energy subsidy reform efforts in very different contexts, and attempts to draw insights for practitioners based on this review. For this review, CGE modeling carried out as part of operational and analytical engagements supported by the World Bank in the context of energy subsidy reforms in 16 jurisdictions were reviewed. These were Abu Dhabi, Algeria, Bangladesh, the Arab Republic of Egypt, Ghana, India, the Islamic Republic of Iran, Iraq, Jordan, Kurdistan

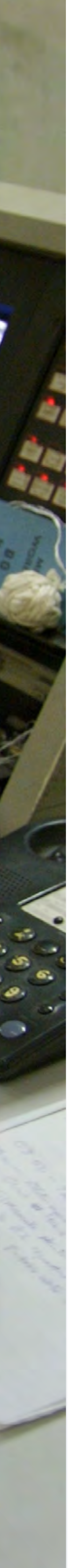
Regional Government of Iraq, Kuwait, Lebanon, Malaysia, Morocco, Turkey, and the West African Economic and Monetary Union with coverage of Burkina Faso, Côte d'Ivoire, Mali, and Senegal.

The report explores modeling approaches, designs, and impacts of CGE modeling exercises carried out for energy subsidy reforms in different country settings. The report reviews approaches used as part of operational and analytical engagements supported by the World Bank, including those funded by ESMAP, as well as activities by other institutions. The review considers four main dimensions: (1) energy subsidy reform context and challenges, (2) transmission channels covered by the model, (3) data collection and consolidation process, and (4) key model parameters, including calibration of shocks, choice of elasticities, and others. The review explores the ways in which CGE models were adapted for the situations in which they were used, and how they informed energy subsidy reform design and implementation, paying attention to the drivers, impacts, and lessons from the use of these models. Finally, the report offers insights, conclusions, and considerations for future work on CGE modeling supporting energy subsidy reform, with attention to the choice of approach, data availability, and capacity needs for effective modeling that can render analytical results that are useful for policy engagements. Given the strong case for using CGE in energy subsidy reform engagements, the report draws practical insights and lessons for future work.



TWO

Use of CGE Modeling in the Context of Energy Subsidy Reforms



The economic impacts of energy subsidy reforms can be analyzed using different models, and the choice of the model depends on the objective of the analysis and the transmission channels of the reforms. An effort that analyzes a potential energy subsidy reform initiative with the goal of capturing the potential effects on various interconnected economic agents and sectors would need to adopt an economywide modeling framework. The reform under consideration is likely to have differentiated impacts across a wide range of economic and social indicators. It is therefore important to adopt a model that can capture the impact of a reform across multiple dimensions, including the national accounts (gross domestic product [GDP], consumption, investment), the fiscal framework (government revenue, expenditure, and deficit and debt), the external accounts (trade, foreign direct investment, and the current account), the labor market (sectoral employment and wages), and household welfare.

CGE models focus on the long-term effects of policy changes across the many segments of a national economy. In the policy analysis literature (Burns, Djiofack Zebaze, and Prihardini 2019; Roos and Adams 2020) CGE models are increasingly being used for analyzing the long-term effects of large-scale reforms because they capture many complex direct and indirect effects of these reforms on the structure of an economy (Guo et al. 2020; van der Mensbrugghe 2020). CGE models have come to be preferred because of their advantages for capturing the direct, indirect, and feedback effects of policies and shocks. The models use axioms of market clearance, zero profit, and income balance conditions to solve simultaneously for the set of prices and goods and factor allocations that support general equilibrium. One of the advantages of using a CGE model is that they are structured to allow income and consumption to be determined endogenously. As such, the microeconomic foundations of consumer and producer profit maximization are critical elements informing the modeling framework.

CGE modeling takes into account the economic interdependencies of multiple sectors and economic actors within a specific country and across the world. The model is calibrated using the economic data in a social accounting matrix (SAM) that reflects the principle of double-entry bookkeeping, which requires that for each account, total revenue must equal total expenditure. Energy policy variables in CGE models can take the form of parameters that are exogenously specified by the analyst and are either price- or quantity-based constraints on demand, supply, or both. CGE models rely on an input-output (I-O) table or SAM for data and take into account interactions between different sectors. A SAM therefore provides a consolidated and consistent mapping of the relationship between households, firms, and the rest of the world. A CGE model's algebraic framework results from the imposition of the axioms of producer and consumer maximization on the accounting framework of the SAM. CGE models combine the abstract general equilibrium structure with realistic economic data to solve numerically for the levels of supply, demand, and price that support equilibrium across a specified set of markets.

The strength of CGE models lies in their ability to define the character and magnitude of the economic impacts of energy and environmental policies. Balanced accounting rules are the cornerstones of a Walrasian general equilibrium: the flows of goods and factors are absorbed by the production and consumption activities in an economy. Firms' outputs are fully consumed by households, and households' endowments of primary factors are in turn fully used by firms. Thus, for a given commodity, the quantity produced equals the sum of the quantities that are demanded by the other firms and households. Likewise, for a given factor, the quantities demanded by firms completely exhaust the aggregate supply to households.

Because energy is an input to virtually every economic activity, the effects of energy subsidy reforms would be felt through multiple markets, with far larger consequences than energy's share of national income might suggest. This phenomenon is the central characteristic for the general equilibrium approach. Energy policy variables in CGE models can take the form of parameters that are exogenously specified by the analyst and are either price-based or quantity-based constraints on demand, supply, or both. Like I-O models and SAM-multiplier models, CGE models rely on an I-O table or SAM for data and take into account interactions between different sectors of the economy. The CGE model then adds consumer preference behavioral functions determining agents' choices using microeconomic theory. Unlike PE 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 the expenditures of households.

CGE models capture the opportunity cost of energy subsidies. These models can account for the impact on economic growth if savings from subsidy removal are invested in productive sectors, can be used to simulate mitigation measures, and can measure the improvement in social welfare if savings are recycled to households as cash transfers. Distributional effects can be captured by assessing the impact on households, distinguished by income level or other social or geographic criteria. This attribute enables the analyst to identify vulnerable groups that would be most severely affected by an energy price increase and to evaluate the contribution of mitigation measures toward alleviating adverse effects, information that is critical to the design of alternative uses of public savings following the reform in the short to medium term.

CGE models offer a comprehensive assessment and analysis of a wide range of indicators, including production, consumption, factor markets, and prices, and can be complemented by other models to inform a comprehensive reform approach. Standard CGE analysis is focused on equilibrium conditions in macroeconomic variables such as real GDP levels, or the price level that will balance aggregate supply and aggregate demand. Where there is interest in other aspects and impacts of reform, CGE models can be complemented with specific modules such as public debt, the environment, or poverty. Other models can also be linked to the CGE model so that results from the CGE can inform the other models and vice versa. A microsimulation model would complement the CGE model by helping the analyst (1) understand the distribution of subsidies in the population, (2) assess the impacts of the reform on households by quintile and identify the most vulnerable populations, and (3) explore different mitigation measures and methods for targeting social protection.

An energy price reform can trigger changes to macroeconomic variables that usually materialize over time; therefore, it is important to consider the temporal variation of impacts. In such situations, the decisions and behavior of consumers and producers should be modeled to understand future intra- and intertemporal equilibria. The resulting dynamic CGE models can be used to assess the potential short-term and medium- to long-term impacts of energy subsidy reform. In these models, agents adopt profit or utility maximization behavior, and market prices are adjusted to reconcile endogenous supply and demand decisions, thus determining levels of production, employment, and consumption. Partial economic modeling remains an option if the intersectoral relationship is not the main concern of the analysis.[1]

CGE analysis provides a framework for the assessment of an energy price reform when it is aligned with the context and objectives of the modeling effort. A key prerequisite is to determine whether and the extent to which the CGE is the appropriate tool for addressing the issues at hand. A CGE model may best be used to consider the effects of a reform on (1) the fiscal balance; (2) social welfare, focusing on the most vulnerable segments of the population; (3) the environment, such as during a shift to more environmentally friendly sources of energy; or (4) factors that undergo dynamic effects. If the objective is to assess the impacts of reform on these elements, then CGE modeling can be the right tool.

The features that can enable an effective CGE modeling exercise include adequate calibration, identification of the right stakeholders, modeling of subsidy delivery mechanisms, and capturing of trade-offs involved. The first feature of an effective CGE modeling exercise is adequate calibration of the fundamental aggregates used to model the macroeconomic equilibrium. The second feature is the proper identification of key stakeholders, together with their interests, to gain an adequate understanding of those who will be affected by the reform and to assess the extent to which they will be affected, which is critical for identifying potential resistance to reform, including from those benefiting from the status quo. The third feature relates to the modeling of the mechanisms used to provide the subsidy (e.g., budgetary transfers of government funds, government-induced transfers between producers and consumers, forgone taxes and other government revenues, and underpricing of goods and services). The fourth feature is the modeling of the trade-offs between components of the reform package, which can help identify a solution acceptable to most stakeholders as well as strategies for overcoming the vested interests likely to resist the reform. For example, removing energy subsidies without an income transfer scheme may reduce welfare and increase household expenditures on energy, whereas redistribution of the subsidy revenue back to the households may increase their welfare (see Farajzadeh and Bakhshoodeh 2015). A good CGE model can help identify these tradeoffs and inform the design of the reform, including the mitigation measures that accompany the price increases.

1 A brief comparison between the static or dynamic model, and a partial or general economic model, is available later on, although a thorough examination of these issues is beyond the scope of this report.

Overall, CGE models serve as useful tools for analyzing and informing energy subsidy reform design when they are aligned with the context and modeling objectives and are properly calibrated. The main strength of the CGE model is its ability to reflect the interdependencies within the economy and capture long-term structural effects. When designed well, CGE models can contribute to the design of a comprehensive energy subsidy reform effort, especially when the model involves expertise from multiple sectors, is complemented by other simulation tools, and is augmented to support the assessment of key environmental impacts.

THREE

Review of Select CGE Modeling Approaches in the Context of Energy Subsidy Reforms

This chapter reviews various CGE modeling exercises and the approaches followed in the context of energy subsidy reform efforts. Although the focus is primarily on energy subsidy reform efforts in developing countries, supported by World Bank technical assistance activities funded by grants from the ESMAP Energy Subsidy Reform Facility, a select set of non–World Bank CGE modeling studies were also reviewed to enrich the review and help draw further insights. In the review of the CGE modeling exercises, the report explores the approaches that different modeling efforts followed to provide an understanding of the impacts of the reforms under consideration.

The review explores different modeling experiences and approaches to draw insights for practitioners. The ESMAP-funded CGE modeling exercises for energy subsidy reform were carried out as part of official technical assistance collaboration between country governments and the World Bank. Although some of these collaborations have resulted in final reports that were publicly disclosed or have informed academic publications, others were retained as confidential analyses to underpin the government's own work and were not publicly disclosed because of either data confidentiality or sensitivity considerations. Therefore, although this report summarizes different approaches and design choices to help inform future work, the focus is on the broader set, rather than the data or findings related to individual country cases, especially where findings are not publicly available. This report indicates where data are publicly available, and relevant CGE analysis findings that are relevant are then summarized.

The review considers the models' treatment of, and findings related to, select impacts of energy subsidy reform. These impacts include (1) the direct impact of higher energy prices on firms' use of inputs and households' final consumption; (2) second-round effects, such as a change in the level of production in energy-intensive sectors; (3) the extent of agents' behavior change in response to the change in energy prices; (4) the differentiated impact on households, especially vulnerable ones; and (5) environmental effects. This review finds that, indeed, these impacts are consistently covered in modeling exercises that were supported by ESMAP and the World Bank Group (Flochel and Goopta 2017; Flochel et al. 2019; Tchana Tchana 2019).

The review also assesses how each CGE modeling exercise made certain design choices, including (1) incorporating energy sector data, (2) building coherence in baseline data, (3) selecting model type; (4) designing and setting up simulations, (5) specifying the production technology and energy demand, (6) capturing the market structure of energy firms, (7) determining how the economy achieves equilibrium and the different ways to use fiscal savings or additional revenue, if any, made available to the government, (8) specifying how reform can affect growth and affect energy efficiency, (9) estimating distributional impacts and how they can influence overall impacts, and (10) estimating environmental effects and capturing externalities from subsidy reform. The review finds that coverage of the factors listed above is not uniform across all the studies and depends on the issues prioritized, as explored in greater detail in the sections that follow.

3.1 Incorporating Energy Sector Data

As a general principle, the SAM to which a CGE model is calibrated includes adequate data on the energy sector and subsidy beneficiaries, disaggregated to the degree possible to allow for a proper analysis of the impacts of subsidy reform. On the supply side, the SAM needs to incorporate the energy subsectors of interest with their own production technologies. This is particularly important if these subsectors benefit from subsidies linked to the production process and if there are strong backward production links. When data are not available at the subsector level, an alternative is to adopt a single-sector, multi-output approach. In this way, multiple energy commodities of an aggregate energy sector can be captured. Information needed on the supply side includes the structure of supply in domestic and export markets and the corresponding price structure and price-setting mechanisms. To be able to capture the distributional effects of reform at the sector and household levels, it is important to ensure that the data in the SAMs capture the structure of demand and prices. Because output tables and SAMs are rarely at a level of sectoral aggregation that matches beneficiaries on the household and firm side (the main concern of policy makers), it is important to disaggregate households either by welfare level or employment status. It is worth noting that the preparation of an appropriate SAM and model for energy subsidy reform requires financial and human resources, as well as time to undertake the necessary disaggregation and to parameterize the benchmark model with a proper functional form to capture firm and household behavior and markets on the production and consumer sides. The level and rate of consumption subsidies should reflect the effective rates of subsidies as well as taxation of the energy sector and its products.

The disaggregation of the energy sector is crucial for a proper assessment to be made given that different energy products can influence each aspect of the economy in ways that vary. For example, a subsidy applied to kerosene consumed in rural areas would have much bigger implications for poverty than a subsidy for gasoline consumed by car owners in urban areas. All ESMAP-funded studies reviewed for the purposes of this report undertook a degree of disaggregation of the energy sector, with the level of detail depending on the availability of data, the type of simulations considered in each case, the urgency of the input for policy dialogue (and hence time available for the analysis), and the specific interests of the study. For example, among the studies considered, the number of energy subsectors was 12 for Egypt, 11 for Algeria, 7 for Tunisia, 4 for Iraq, and 2 for Bangladesh. This indicates that all country teams using ESMAP funds made commendable efforts to treat data in the SAM to disaggregate the energy sector into subsectors of interest given that I-O tables and supply and use tables generally come with a single, aggregated energy sector.

Although many studies reveal considerable efforts to disaggregate energy sectors, the suitability of the disaggregation of production sectors in the SAMs can be constrained by data availability. At least two studies used either the energy matrix or the national energy inventory to disaggregate the energy sector. The choice of approach generally depends on data availability, and each approach has some constraints. Although the energy matrix and inventories are very good sources of detailed and updated information on the demand side (i.e., energy product consumption by key agents and sectors in the economy), they are silent on the supply side (technology of production). The best practice in collecting information on the structure and composition of production is to obtain data from agencies responsible for the national accounts or for energy companies. However, in practice, several studies reviewed for this report involved the use of assumptions, either because of limited time, data access, or availability. For example, the construction of the SAM in one of the cases reviewed was delayed by a year because of efforts to obtain energy supply-side data, but ultimately it was not possible despite the government's fairly strong collaboration in the process. In another case study, the national electricity and gas company provided data on the use of energy products (disaggregated into low-, medium-, and high-voltage electricity, and natural gas) by different sectors of the economy (intermediate consumption), households, and government agencies for final consumption. In the end, a reconciliation was undertaken to maintain the macroeconomic balance of the SAM because there were differences between the data provided by different sources. Another challenge arises when the modeler tries to incorporate more than one household category along with additional energy subsectors because the energy matrix and inventory do not provide household consumption by categories. Such information is generally collected in household surveys, but these surveys may not be available to the analyst or may be outdated. For example, in one country, the team used a household survey from 2012, with a 2015 SAM, for the analysis of 2018. Going forward, given the increasing interest in macromodeling of the energy sector, data availability and quality are likely to be key considerations for government agencies and experts supporting them. In this context, it could be worthwhile for agencies responsible for national accounts to consider including key energy subsectors in their usual nomenclatures.

3.2 Adapting the Baseline Data for Dynamic CGE Models

Adapting the baseline data, in a way that enables dynamic analysis of a reform effort, is an important part of the modeling work. The elaboration of a SAM adapted to analyze an energy subsidy reform effort can be complemented by baseline data characterizing the pre-reform equilibrium. The baseline would be compared to the "with reform" scenario to quantify the potential effects of the reform on various sectors and economic agents. Because of the potential impact, in many settings it can be common practice to roll out the planned reform gradually and progressively. This approach would make the time dimension of the model important. Calibration of the baseline scenario with appropriate data, in a way that can accurately reflect past performance and enable plausible projections for the future to be made, is needed. The calibration of the baseline, therefore, requires the use of data from multiple sources. Furthermore, the baseline scenarios need to be calibrated to reflect the evolution of subsidies, prices, and other indicators important in the reform effort in question, while at the same time maintaining coherence with official data for the main macro indicators. When the baseline data are coherent, simulation results of the CGE model and those of other PE methods tend to converge.

The assumptions made for energy prices and production are key considerations in building a dynamic baseline for energy reform analyses. For production data, assumptions about output levels, and the extent to which they can be affected by the actions of the host country or its policy decisions, tend to vary by country. For the energy price, the focus is on formulating expectations and on how uncertainty is modeled. In many oil-rich countries, the production of oil is not entirely determined by market forces; the level of production is determined, in some cases, by the evolution of reserves, and in others, by political issues. For example, in the CGE model of Algeria, oil production is exogenous, and its baseline value is based on the government's oil projections. A similar approach is adopted in the case of Iraq.

3.3 Choice of Model Type

Different CGE models have different strengths and weaknesses. As outlined in Table 3.1, there are two main types of CGE models from the perspective of time frame, namely, dynamic and static, and, within each, various design options from which to choose. The choice of model type depends on multiple factors, including country context, modeling purpose, and data availability, and each approach offers different advantages. Both static and dynamic models can capture the effects of a reform in the long term, as well as the impact of shocks on redistribution across households, factors, and sectors. Whereas the dynamic model traces the path of the economy to equilibrium through capital accumulation, the static model enables the modeler to obtain the end result. The dynamic model is more flexible than the static comparative model because it offers more possibilities for simulations.

The majority of the CGE models reviewed for this report used dynamic modeling. Two out of the five ESMAP-funded CGE analyses reviewed for this report relied on static comparative models and the rest on recursive dynamic models. Studies that use a dynamic model (such as those for Algeria, Iraq, and Tunisia) can take into account the progressive aspect of reforms, given that most reforms are phased in over more than one year. For example, in the modeling carried out for Algeria, the scenarios included different timing options for reform implementation. The studies using dynamic models are also better suited to analyzing the growth implications of a reform effort through the impact on capital accumulation, which is not the case in static comparative models. This aspect is crucial

TABLE 3.1

Choice of Model Type and Modeling of Special Features for Select CGE Modeling Exercises

Characteristics	Algeria	Egypt	Gaza	Iraq	Jordan	KRG Iraq	Lebanon	Tunisia	WAEMU
Model Type									
Static	No	Yes	No	Yes	No	No	No	Yes	No
Dynamic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Modeling of Special Features									
Distributional module	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Environmental module	Yes	Yes	No	No	No	No	No	No	No
Compensation module	Yes	Yes	No	Yes	No	Yes	No	Yes	No

Source: Authors' compilation based on outputs from technical assistance activities reviewed.
Note: KRG = Kurdistan Regional Government; WAEMU = West African Economic and Monetary Union.

when discussing how the use of revenue generated by a reform might affect that reform's outcomes. However, dynamic models require additional data and modeling efforts that might not be available. In that case, the use of a static comparative model is appropriate.

3.4 Calibration of Shocks: Setting Up Simulations within a CGE Model

CGE models provide highly flexible frameworks with which to undertake simulations of a wide range of subsidies, delivery mechanisms, and reform options. 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. Given 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, factors, and consumers. Table 3.2 offers examples of scenarios considered in ESMAP-funded CGE modeling exercises.

For the model scenarios to properly reflect and assess the impact of different reform options, the shocks must be adequately calibrated. The model calibration process is highly demanding in terms of data, which are not always available. Where adequate data are not available, the modeler can explore the use of alternative methods for calibrating

TABLE 3.2

Examples of Scenario Shocks in Select Energy Subsidy Reform CGE Models

	Scenarios Considered
Country A	1. Total elimination of tax subsidies, except for LPG and select fuels 2. Partial reduction of subsidy for petroleum products combined with a gradual increase in input price toward cost recovery by 2025 3. Partial reduction of subsidies for gas and electricity combined with a gradual increase in sales price toward cost recovery by 2030 4. Partial successive reduction of subsidy and increased taxation toward cost recovery by 2023 5. Partial successive reduction of subsidy and increased taxation toward cost recovery by 2030 6. Partial successive reduction of subsidy and increased taxation toward opportunity cost by 2023 7. Partial successive reduction of subsidy and increased taxation toward opportunity cost by 2030
Country B	1. A partial removal of electricity subsidies with a fourfold increase in tariffs. 2. The full removal of electricity subsidies or increase in tariffs to cost-recovery levels. 3. The simultaneous reform of crude oil, natural gas, and electricity prices. This is an elimination of the implicit subsidy for crude oil and natural gas, the equivalent of 98 percent and 63.3 percent of household energy expenditures, respectively. 4. Energy price reforms plus the introduction of a program of offsetting social transfers. Increase in electricity tariffs to cost-recovery levels and the elimination of petroleum and gas subsidies, that is, the combination of reforms under scenarios 2 and 3.
Country C	1. 50 percent price increase in LPG prices 2. 50 percent price increase in natural gas prices 3. 50 percent price increase in gasoline, fuel oil, and diesel 4. Cost recovery of LPG 5. Cost recovery of LPG with bottom two quintiles compensated 6. Cost-recovery tariffs for electricity and natural gas 7. Cost-recovery prices for gasoline, fuel oil, and diesel with no mitigation transfer 8. 25 percent reduction in energy subsidies with no mitigation transfer 9. 25 percent reduction in all energy subsidies with mitigation transfers to bottom two quintiles
Country D	1. Total elimination of tax subsidies, except for LPG and select fuels 2. Partial reduction of subsidy for petroleum products combined with a gradual increase in input price toward cost recovery by 2025 3. Partial reduction of subsidies for gas and electricity combined with a gradual increase in sales price toward cost recovery by 2030 4. Partial successive reduction of subsidy and increased taxation toward cost recovery by 2023 5. Partial successive reduction of subsidy and increased taxation toward cost recovery by 2030 6. Partial successive reduction of subsidy and increased taxation toward opportunity cost by 2023 7. Partial successive reduction of subsidy and increased taxation toward opportunity cost by 2030
Country E	1. An increase of 10, 20, 30, 40, and 50 percent of the price of middle- and high-voltage electricity 2. An increase in the prices of hydrocarbons (LPG, Gasoil, and others) by 10, 20, 30, 40, and 50 percent
Country F	1. Elimination of direct electricity subsidy, implemented in the model as a 33 percent tax added on to the subsidized price of electricity 2. Simulation of gas subsidy removal as an increase over time in the domestic retail price of natural gas toward opportunity cost

Source: Authors' compilation based on country-specific CGE models.
Note: CGE = computable general equilibrium; LPG = liquefied petroleum gas.

the shocks to avoid under- or overestimating the impact of the reform. For example, in the case of electricity subsidy reform, reflecting the practice that electricity tariffs are often differentiated by type of user and by consumption level, CGE models can be designed to differentiate tariffs by user. However, incorporating the methods for calculating tariffs based on consumption (e.g., rates that are fixed with a flat rate per kilowatt-hour, that can change with the amount of use, or that can vary depending on the time of use) is difficult in a CGE framework and requires the calculation of average rates.

Clearly identifying, quantifying, and incorporating the reform of both types of subsidies in the model is critical. An energy subsidy reform may affect explicit subsidies that are funded through fiscal transfers to consumers or producers, as well as implicit subsidies for which there may not be direct budgetary transfers but there is an opportunity cost, as in the case of energy exporters setting domestic retail prices below the opportunity cost, that is, below international market prices that could have been earned by exporting the energy commodity. Whereas explicit subsidies are easily introduced in the model, the introduction of implicit subsidies may not be straightforward. For example, in the CGE model prepared for one country case reviewed, explicit subsidies were captured in the SAM along with the modeling of producer and consumer behavior. In some cases, implicit subsidies can be greater than explicit ones. For example, in one of the case studies, implicit upstream and downstream subsidies represented 98.4 percent of energy subsidies in the study year. In another case reviewed, the data showed that the electricity sector was not only subsidized directly by the government through a budget transfer, but also indirectly through low prices of natural gas, the main fuel used to produce electricity.

When subsidies are implicit, determining their level is a significant challenge. Two main approaches have been considered by ESMAP-funded studies using CGE modeling to determine the level of subsidies (see Kojima 2018): (1) the opportunity cost approach, followed in the case of Algeria, which involves calculating the implicit subsidy as the gap between the domestic price and the international price for the main product plus (where considered) the average tax burden on general consumer goods; and (2) the cost-recovery approach, which consists of calculating the implicit subsidy as the gap between the domestic price and the private or social production cost of the product.

3.5 Specification of the Production Technology and Energy Demand

The production function in many standard CGE models relies on a fixed-coefficient assumption for modeling the demand for intermediate goods, which is not well suited for the energy sector. Consumption of energy is often strongly related to the level of investment in the economy and the improvement of technology. Assuming a fixed relationship between energy demand and production may contradict the empirical evidence of increasing energy efficiency and conservation in response to, among other things, higher energy prices. To account for a potential link between energy consumption, investment, and technology, the energy sector can be incorporated as an additional value-added component (in addition to labor and capital) in the model, with some level of substitutability with both capital and skilled labor. Of the ESMAP-funded studies reviewed in this report, the analyses in Bangladesh, Egypt, and Iraq consider energy as an intermediate input modeled as a complement or near-complement with other intermediate inputs. Only the Algeria analysis, which relies on the framework for the Mitigation, Adaptation and New Technologies Applied General Equilibrium (MANAGE) model used by the World Bank (van der Mensbrugghe 2020), considers energy consumption as potentially a substitute for capital (energy is a near-complement for capital in the short run, but a substitute in the long run) and allows for substitution between nonenergy inputs (Table 3.3). Thus, the increase in energy prices would tend to raise production costs in the short run when substitution is low, but in the long run, the adoption of energy-saving technologies, along with operational and process changes, would dampen the increase in costs.

TABLE 3.3

Modeling of Energy-Intensive Production Sectors

Characteristics	Algeria (Flochel et al. 2019)	Egypt (ESMAP 2014)	Iran (Farazjadeh and Bakhshoodeh 2015)	Iraq (World Bank 2017)
Treatment of energy	Energy consumption is modeled as a fixed proportion (Leontief). The model integrates energy as a substitute for capital. The model allows substitution between nonenergy inputs.	Energy as intermediate consumption.	Zero substitution among energy inputs and between energy and other intermediate inputs.	Consumers' preference represented by breaking down each good's expenditure into its own equation following a linear expenditure system instead of standard production functional form such as a Cobb-Douglas.
Assumptions about energy production function	Production is based on vintage capital structure: high substantiality for new capital. Perfect competition: market mechanism.	Perfect competition: market mechanism.	Production technology represented with a Cobb-Douglas production function.	Uses standard substitution and transformation assumption in modeling.

Source: Authors' compilation.

3.6 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 from that in a market where firms have monopoly power. A standard assumption in most models is perfect competition in product and factor markets. However, energy companies in several developing countries operate as monopolies or oligopolies 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), in which the fixed production costs are represented by some fixed combination of capital and labor. These models incorporate the markup effect, which captures the difference between the marginal cost and consumer price. However, the implementation of this approach is particularly demanding in terms of data because the modeler would need to determine the level of markup as well as the level of fixed costs.

All models used in the studies reviewed assume a total pass-through of energy costs to consumers, which might be on the high side given the structure of energy markets and the role of government. The assumption of 100 percent pass-through means that the models in question would likely overestimate the price increase passed to households in countries where energy firms have market power or where the government is able to maintain price controls. The level of competitiveness, government regulation, and union power in major energy-using sectors—for example, transportation—would also affect the extent to which consumers experience an increase in prices due to the reduction of subsidies. It is possible that certain assumptions had to be made because of information constraints, given that the determination of the proper pass-through rate is an exercise that relies on detailed sectoral information and econometric analyses generally beyond the scope of CGE projects. Where information on competition, the composition of market power, and pass-through rates is not available, one way of exploring the impact of different market power and competitive situations is to make the pass-through an exogenous variable that can be adjusted, and run the model with different pass-through options (say, 75 percent or 50 percent) as part of the analysis of reform scenarios.

3.7 Macroeconomic Closure Rules and Policy Options for Using Fiscal Savings

The macroeconomic closure assumptions are critical, particularly where subsidy reforms make more government revenue available for expenditures other than energy subsidies. The macroeconomic closure in a CGE model defines which variables are exogenous and which ones are endogenous and will adjust to yield an equilibrium. The decision about which macro variable adjusts to achieve equilibrium imposes a multisectoral and multi-agent adjustment process, which affects model outcomes in significant ways. Closure rules range from changes to fiscal aggregates such as government revenue, to financial variables such as savings or reserves, to trade balance or balance of payments (Yuan and Burfisher 2021). The macro adjustment processes in the three closures are fundamentally different and result in differences in macroeconomic and sectoral outcomes. The main guiding principle in the analysis is the policy question at hand. The policy recommendations that will be informed by the modeling exercise should be based on the analyst's understanding of the adjustment behavior that drives the macroeconomic and sectoral outcomes in the model. The closure rule is only one aspect driving the result; equally important are the model's macroeconomic structures.

The closure rule and policy options for reform are based on the macroeconomic variables of government accounts. The closure rule may assume that the government (1) increases overall expenditures or reduces taxes by the amount of the decline in subsidies (when the reform is fiscally neutral), (2) reduces public debt, or (3) increases targeted

TABLE 3.4

Examples of Closure and Policy Options for Government Accounts

Government Accounts	Closure Rule 1	Closure Rule 2	Closure Rule 3	Closure Rule 4
Current expenditures	Fixed	Fixed	Fixed	Endogenous
Capital expenditures	Fixed	Fixed	Endogenous	Fixed
Tax rates	Fixed	Endogenous	Fixed	Fixed
Government balance	Endogenous	Fixed	Fixed	Fixed
	The adjustment is made through the government balance.	The adjustment is made through a change in tax rates.	The adjustment is made through public investments.	The adjustment is made through current expenditures (salary, transfers, etc.).

Source: Burns, Djiofack, and Prihardini (2019).

TABLE 3.5

Examples of Model Closure Rules Used in Case Studies

	Main Macro Closure Rule Assumptions
Algeria	Flexible government saving (deficit) Exogenous expenditures and constant taxation rate
Egypt	Adjustment by expenditure Adjustment by income (taxes) Adjustment by how deficit is financed (relaxed fiscal rule)
Iraq	Growth of government expenditure and the current account deficit remain constant

Source: Authors' compilation.

spending (see Tables 3.4 and 3.5). These alternative macroeconomic closures provide important insights into real-world options that are associated with macroeconomic adjustment patterns (Lofgren, Harris, and Robinson 2002). These assumptions also may reflect the constraints facing the economy.

Assumptions regarding how the economy achieves equilibrium and how the additional revenue is used are key drivers of the economic effects the model captures as being caused by subsidy reform.[2] In many cases, these assumptions determine whether the reforms boost GDP and household welfare. Table 3.4 provides examples of different fiscal closure assumptions to analyze the effect of alternative uses of public savings. The first closure rule considered here assumes that the government would use the additional

[2] A sensitivity analysis can be used to test the robustness of these assumptions. Alternatives that can be considered include the structure of the economy, such as, for example, the modeling of the informal sector; or the extent of substitution or complementarity of goods or products; or the functional forms adopted.

revenue to reduce its deficit. The second closure rule assumes that the government would use the additional revenue to reduce direct or indirect tax rates. The third closure rule assumes that the additional revenue is used to increase capital expenditures, with a positive effect on productivity. Finally, the fourth closure rule assumes additional revenues are used for specific spending, for example, to support selected household groups via transfers or to increase government salaries.

Given the implications of the selection of closure rules and other model parameters for outcomes, the modeling exercise should ideally include a sensitivity analysis to explore how results change depending on how the government uses the increased fiscal space provided by reform. A mix of the different closure rules, which is often how governments behave, can be considered in the modeling. Among the country case studies reviewed, several of them (Algeria, Egypt, and Iraq) indeed applied this good modeling practice by analyzing at least two of the abovementioned fiscal closure assumptions (Table 3.5).

A good example of alternative closure rules come from an ESMAP-funded CGE modeling exercise on subsidy reform options that were under consideration in one of the cases reviewed. Scenarios of the impact of the proposed reform were built around three assumptions for how the additional resources generated by reforms could be used: (1) to reduce the government deficit or to fund new government expenditures; (2) to provide a uniform, direct transfer to all households; or (3) to provide a uniform, direct transfer to all households in the bottom 40 percent of the income distribution. The analysis indicated that although the provision of transfers to the poorest would contribute to shared prosperity, its growth effect could be smaller than in the other scenarios because of poor households' lower propensity to save relative to richer households.

3.8 Treatment of Energy Efficiency Gains

The assumptions in some CGE models may have led to an underestimation of the extent to which technology may evolve in response to higher energy prices. Energy subsidy reform can potentially affect the level of investment in the economy and hence the economy's growth rate. As explored in the earlier discussion on closure rules, if a subsidy reform makes additional revenue available to the government for alternative uses, that extra revenue can be used for, for example, infrastructure investment. This growth channel is captured by neoclassical models. However, there is a risk that these models may underestimate the extent to which technology may evolve in response to higher energy prices because they do not model the creation of these technologies. The specification of energy productivity is overlooked in most standard CGE setups, mainly because the data are generally not accessible to the macro modelers, who typically tend to be economists. On the other hand, energy sector experts may be familiar with how to access these data, which, in turn, highlights the importance of having multisectoral teams with an understanding of the country and sector context in such modeling exercises.

Select CGE models do allow the incorporation of energy efficiency improvements beyond technology. For example, the MANAGE model addresses energy productivity through the notion of "autonomous energy efficiency improvement." One ESMAP-funded modeling exercise reviewed for this report relied on MANAGE accounts for this assumption about productivity, while other studies did not. Going forward, the different pathways for energy conservation and efficiency could be taken into account in the modeling exercise.

3.9 Environmental Impacts and Externalities

Energy sector reforms can have an important impact on the economy, the society, and the environment by affecting emissions of local air pollutants and greenhouse gases. This is especially important where end-user energy prices change, or the consumption of certain forms of energy—typically renewable—is mandated (Marten and Garbaccio 2018). The most widely used modeling framework with which to assess the environmental effect of energy policy change is the I-O 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 I-O approach discussed earlier, CGE models have been increasingly used to assess the environmental impacts of economic policy changes. 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 on household utility or the productivity of firms).

One advantage of CGE models in assessing the environmental impact of energy subsidy reform is the ability to capture the so-called rebound effect as prices react to the change in policy. Improving energy efficiency can lower the cost of using energy-intensive goods and may free up wealth through energy savings. But less energy might be saved than expected because of a "rebound effect," in which the end-user reacts to the reduction in energy costs by increasing energy use. Gillingham, Rapson, and Wagner (2015) present various estimates of this effect and conclude that the current understanding of the macroeconomic rebound effect remains limited because it could be related to whether and the extent to which energy efficiency improvement is related to induced innovation and productivity growth. Technological improvements are key to mitigating the impacts of economic growth on the environment. For example, Turner and Hanley (2010) show that the validity of the rebound effect depends on the elasticity of substitution between energy and nonenergy inputs, or responses in the labor market, or the structure of the economy. Borenstein (2015) argues that key calibration parameters and a CGE model's structure also play a decisive role in results. The author concludes that the magnitude of the rebound could depend on three factors: whether energy is priced at marginal cost, whether consumers are imperfect optimizers, and the extent and nature of technological progress.

The literature on the extent of the rebound effect arising from subsidy reform is not conclusive. Improvements in efficiency or technological improvements in the use of energy induce an increase in consumption (see Gillingham, Rapson, and Wagner [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 rebound effect studies using the CGE framework can be found in Vivanco and van der Voet [2014].)

The introduction of dynamic modeling enables an assessment to be made of the multigenerational impacts of a reform (Ross 2005, 2014). The short-term adjustment costs of policy implementation are distinct from long-term effects. An energy subsidy reform can affect current and future generations of households and firms, and one of the key factors in understanding the impact on future generations is a consideration of how, and the extent to which, the savings from reform are used over time. This use can be captured through the incorporation of intertemporal effects. Dynamic features of multiperiod CGE models are handled via two possible characteristics: (1) behavioral specifications of intertemporal decisions such as saving and investment, and (2) assumptions about which agents form expectations.

Dynamic modeling also facilitates an assessment of the environmental implications of energy subsidy reforms. None of the studies reviewed for this report assessed the environmental impacts of reform as part of a CGE modeling exercise. Reasons for this may vary from a client counterpart's lack of interest in (or mandate on) environmental aspects to limitations of the modeling framework or access to data. In one case, the MANAGE framework used for the study included a robust environmental module. However, that aspect of the analysis was not developed because it was not requested by the government, whereas there was stronger interest in understanding short-term macro and distributional implications of reform.

3.10 Distributional Effects

Understanding and mitigating the social impacts of energy subsidy reform, especially on the most vulnerable, are often essential for ensuring the sustainability and inclusivity of reform. From a macromodeling perspective, two main approaches for understanding how a proposed reform affects different segments of the society, and for analyzing the economywide distributional impact, are the parametric approach and the nonparametric approach. The parametric approach depends on the classification of households into groups assumed to share the same characteristics. In this case, microsimulation can be used to study the distributional impact of the reform within and between groups. The nonparametric approach entails defining multiple representative households in the CGE model based on data from household income and expenditure surveys, depending on the criteria of interest to the modeler. CGE microsimulations that link the CGE model and the household survey in a sequential way enable the analyst to calculate poverty and inequality indicators for each scenario. This approach can relate the distribution of energy subsidies by income level, geography, or demographic group to the challenges involved in reform, for example, the sustainability of the reform program.

The ESMAP-funded studies reviewed for this report place a strong emphasis on the distributional implications of reforms using one of the above approaches. In the case of Egypt, 10 representative households are considered in the CGE analysis, which facilitates the assessment of the impact on income distribution. The same holds for Algeria, where 20 categories of households (by region and decile of income) are considered. In the case of Tunisia, 5 household categories are considered, and in the case of Iraq, 10 household categories.

The CGE model in the Algeria case study was complemented by a microsimulation model to produce a more granular distributional analysis linking the CGE model to the household survey. The model used a sequential microsimulation to link the CGE model to the household income and expenditures survey of 2012. Proxy means testing (PMT) was used to refine the identification of the most vulnerable household categories to explore ways of compensating them for the impact of the reform and concluded that, overall, the impact of the energy price reform varies depending on households' income and consumption structure.

FOUR

CGE Modeling Results, Impacts, and Lessons

4.1 Summary of CGE Modeling Results from Selected Cases

The sector coverage and scenario designs of the reviewed CGE modeling efforts on subsidy reforms vary significantly from one country to another. The models covered electricity, natural gas, and petroleum products sectors, and combinations thereof. The models assessed explicit and implicit subsidies, which were commonly estimated by comparing retail prices with the "recovery cost" of a given energy product or the opportunity cost. The magnitude of shocks explored in the studies reviewed is quite large, ranging from a 50 percent increase in LPG prices in one case to a greater than 300 percent increase in electricity tariffs in another country, and an almost 1,000 percent increase in residential gas tariffs in another situation. The simulations generally consisted of reducing the rate of explicit subsidies or increasing consumer prices by the amount of implicit subsidy to be removed. The findings can be categorized into three main areas: macroeconomic, sectoral, and income distribution.

While a a few CGE analyses reviewed assessed that reforms could either have negligible or slightly negative impact on growth in the short term, the impacts in the long term were found to be generally positive. The models identified increasing government revenue or savings as a key immediate macroeconomic effect of energy subsidy reform. However, the removal of subsidies also means an increase in costs for both firms' intermediate consumption and households' final consumption. These price increases could depress household consumption, firm competitiveness, and ultimately production in the short term.

CGE analyses' findings on the net effect of a reform on growth were influenced by how the additional revenue generated by the reform was to be used. The studies reviewed for this report found varying growth implications from reform.[3]

- In Country A, the simulation envisaged new revenues being used to reduce the fiscal deficit. The model found that, when savings are used to reduce the fiscal deficit, the overall effect on GDP is generally not significant in the short term but is positive in the long term. On the other hand, when the reform targets energy products intensively used as inputs for other goods—such as electricity and natural gas—the growth impact is the short term growth impact could be slightly negative. This outcome may indicate that the additional investment generated by a reduced crowding-out effect due to the reduction of government spending may not be sufficient to fully compensate for the adverse impact of increases in production costs.
- In Country B, the findings on potential reform impacts were similar. When the additional revenue generated by the reform is used to reduce the deficit, the impact on growth would be negative in the short term but turns positive in the medium term,

3 Because some of the analyses were carried out in the context of bilateral technical assistance engagements, country names have been eliminated. The focus of the list is to highlight the variation in the findings.

thanks to additional investment generated by the reduced deficit. On the other hand, the model found that the higher the level of the subsidy cut, the longer the economy needed to recover, suggesting that a gradual approach may need to be considered for allowing the economy to adapt over time.

- In Country C, the modeling exercise found that the impact of subsidy removal would be negative in the short term. However, unlike in the other analyses reviewed, the use of additional revenue to reduce the deficit was assessed to create a worse outcome in the long term, compared with a case in which the additional revenue is used to compensate households and increase final consumption. A closer look reveals that this difference in results reflects the difference in model assumptions for the determinants of investment, with the choice of model assumptions based on investment decisions and their impact on GDP. Whereas other models assume that the level of investment is determined by the level of savings available in the economy and that it will change with any change in any component of savings (household, government, firm, and foreign), this model assumes that investment is determined solely by the return on investment, and any change in investment is accommodated by a change in foreign savings.
- In Country D, the model found that the effect of the reform on GDP would be almost nil when the additional revenue generated by the reform is used to reduce the deficit.

Most of the CGE analyses reviewed found that the removal of energy subsidies could reduce household welfare in the short term, unless price increases are complemented by measures that focus on mitigating the impact on the poor, the middle class, and other stakeholders that the distributional analysis indicated would be affected strongly. Several of the analyses found that a package of mitigation measures would be essential in securing improvements in overall welfare, which is consistent with established literature (see Groot and Oostveen 2019; Mundaca 2017). Even a positive impact on GDP from the reform may not necessarily translate into an immediate improvement in household consumption, unless select mitigation measures accompany the price increase.. The growth effect generated in most of the CGE analyses is driven by increased investment, owing to reduced crowding-out by government borrowing. Therefore, sectors intensive in investment tend to be the main beneficiaries, meaning that the increase in growth tends to favor capital, and labor only catches up with a lag on growth measured by GDP. This latter part hints at a potential role for measures targeting labor and jobs. For Egypt, Helmyl, Ghoneim, and Siddig (2019) find that removing regressive energy subsidies to finance progressive and pro-poor food and energy subsidies improved the welfare of households in low- and middle-income quintiles in rural and urban areas while reducing household welfare among richer quintiles. Furthermore, they also show that combining targeted cash transfers with the financing of progressive and pro-poor subsidies leads to a higher welfare gain than does the use of pro-poor food and energy subsidies alone.[4]

All CGE analyses reviewed considered compensatory measures to mitigate the potentially adverse impact of reform on households. In Tunisia, the compensatory measure simulated is a general transfer to all households. However, in most cases compensation is

4 ESRAF Good Practice Note 7 (Burns, Djiofack Zebaze, and Prihardini 2019), which focuses on modeling the macroeconomic impact of energy subsidy reform provides a further detailed review of key papers in the recent literature on this topic.

targeted to specific categories of households—either through income categories (Egypt and Iraq) or through a microsimulation. The direct result of compensation through transfers is to increase household disposable income and consumption, easing the adverse effect of the reform. Except for the Tunisia case, where easy access to international savings is assumed, all simulations of compensation to households generated less GDP growth as a result of reduced government savings and thus lower investment. These findings reflect fundamental aspects of the neoclassical underpinnings of CGE models, in which growth is mainly created by savings and investment.

4.2 Impact of CGE Modeling Studies

The set of CGE modeling exercises reviewed for this report, both those that were funded by ESMAP and others, produced useful results that informed the design and implementation of energy subsidy reform efforts. Although they varied from case to case, the results from CGE modeling exercises were used to (1) enhance government understanding of the potential impacts of various reform options—including, among other variables, how savings are spent; (2) raise awareness of the social and distributional impacts of subsidies and their reform; and (3) provide a better understanding of the political economy of subsidy reform, which is essential for properly managing the short- and long-term costs and benefits of reform. Further reading on this topic is available in Sovacool 2017; Tchana Tchana 2019; Timilsina et al. 2018; and Wang et al. 2016.

The modeling exercises reviewed focused on real-world policies that were under consideration, either at the planning stage or in implementation. The analyses of energy subsidy reform impacts were combined with assessments of measures to mitigate the impact on the poor, the middle class, and stakeholders who could be affected. Several country reform efforts, specific policy decisions, and World Bank lending operations drew on the CGE modeling exercises as part of broader technical assistance. For instance, the CGE model for Algeria, developed for the Ministry of Planning with support from the World Bank and ESMAP, simulated a proposed reform of subsidies following the 2014 oil crisis and was used to explore scenarios for the next round of reforms, with special focus on both fiscal and distributional implications. The CGE model for Tunisia was developed to assess policy measures under consideration by the government as part of broader fiscal reforms to boost revenue mobilization in the context of the government's engagement with the International Monetary Fund in 2019. The Iraq model was developed to assess the impact of increased electricity and oil tariffs between 2015 and 2016 as part of a broader sector reform effort. In Bangladesh, the analysis was carried out to assess the energy subsidy reform under consideration in 2018, where the revenues from the reform would be used (1) to fund investment, (2) to compensate for the reduction in income and in indirect taxes, and (3) for lump-sum transfers to households (Timilsina and Pargal 2020).

The strong government ownership of analytical activities is another critical aspect that appeared to have enhanced the impact of these studies. In almost every CGE modeling study, the analysis was requested by the government. In most ESMAP-funded activities, the government counterparts actively contributed to model development, there was close counterpart involvement throughout, and at the end of the activity, the CGE model was transferred to them. A noteworthy activity was the CGE modeling effort in Algeria. The strong ownership and commitment of the government was demonstrated by its mobilization of a team of 10 technical staff, who received training over two years in different analytical and modeling tools, and would eventually maintain the model and replicate scenarios for energy subsidies and other structural development issues. Similar technical assistance was provided in Egypt.

The majority of the activities included an element of capacity building for the government entities involved. Energy subsidy reform implies significant changes for key stakeholders, including public institutions developing the reforms themselves. Capacity-building activities are essential for supporting the design and implementation of the reform. This review found that capacity building for government counterparts was envisaged in the majority of the activities funded by ESMAP. In Algeria, for example, the focus was on providing training to government teams, designated by the Ministry of Finance, to use and update the analytical tools developed. In addition to support for modeling capacity building, in view of the importance of a well-developed communications plan for informing stakeholders and building public support, the broader activity also included strengthening the capacity of the government's communications staff to prepare and implement a communications campaign. As part of the activity, two public opinion research tools—a survey questionnaire and a discussion guide for focus groups—were developed with the team and survey experts.

The strong complementarity between the CGE models and other simulation tools appeared to contribute to the strengthening of the overall support provided to the government counterparts under technical assistance activities. As discussed earlier, a key strength of the CGE model is its ability to capture long-term structural effects. For example, in Algeria, the use of a macrostructural model alongside the CGE model enabled analysts to provide meaningful insights into the immediate fiscal implications of reform. The combination of CGE and microsimulation tools in Algeria and Iraq sharpened the assessment of the distributional impact of reforms and helped the government design mitigation measures alongside price reforms. On the other hand, CGE models have been less successful in capturing short-term cyclical fiscal effects that can be important for energy subsidy reform.

4.3 Lessons from Recent CGE Modeling Supporting Energy Subsidy Reform

Energy subsidy reforms can have varied impacts across the economy, and the use of CGE modeling to simulate potential impacts of reform options can help decision-makers understand the range of outcomes and refine the reform design to address the most critical impacts. Energy subsidy reform efforts can have a range of impacts that need to be considered and mitigated. These effects include (1) potential welfare impacts on the poor and vulnerable, along with other household segments; (2) potential macroeconomic impacts, such as on growth, employment, or inflation, resulting from the pass-through of energy price increases to other goods and services; (3) the risk for reduced competitiveness in trade-exposed sectors if firms fail to adapt to higher fuel and electricity prices; (4) the risk that poor households will substitute or shift to more polluting fuels that are cheaper, with substantial health and environmental impacts; and (5) the potential for declines in service quality, commercial discipline, and accountability if subsidies were critical for ensuring basic maintenance and operation of energy systems (IMF 2013; Sovacool 2017). CGE modeling can help policy makers better understand which sectors and segments stand to gain and lose from the reform, and enable the development of adequate mitigation measures, which can help address some of the negative impacts while garnering support from those who will benefit. Understanding the channels and the extent of impacts of energy prices across the economy and assessing associated risks are key ingredients in the design of mitigation measures as part of the reform effort, and this is where CGE modeling can be helpful.

CGE modeling exercises need to consider a range of challenges to assess the potential impacts of reform options on different segments of the economy and key stakeholders. Energy subsidies can be pervasive, broad, and complex, and are often part of non-energy-sector policies (such as trade or industrial policy) and involve various line ministries and other agencies. Energy subsidies can be indirect and hidden; therefore, a critical step is understanding the scope and magnitude of these subsidies. Often, another critical consideration is the existence of influential stakeholders with interests in maintaining subsidies even though they may be disproportionately benefiting higher income quintiles and industry.

Choosing the appropriate CGE modeling approach depends on the objectives of reform, priorities for the modeling exercise, the timetable involved, data availability, and sector- and country-specific constraints. The choice of modeling strategy depends on several factors. One issue that arises often when selecting the modeling strategy is determining the appropriate level of aggregation of an economywide model in terms of firms and households. Highly disaggregated models can allow a granular assessment to be made of a subsidy scheme's impact on the intended beneficiaries, which provides for more policy-relevant information on the distributional impacts. However, this level of granularity comes with significant data requirements. The availability of data on production should be considered in determining when it is appropriate to build a CGE model.

An important ingredient for successful analysis of energy subsidy reform options under consideration is adequate and accurate data, ideally complemented by macroeconomic statistics that allow adequate disaggregation of production structure, identification of consumers by welfare categories, labor market participation, and other human development indicators to enable proper socioeconomic analysis, as well as stakeholders that need to be empowered to champion the reform.

The optimal approach to addressing the challenges inherent in energy subsidy reform depends on the time horizon available for the modeling exercise and analysis being undertaken to inform the policy decisions in question. For urgent policy needs, where the government is interested in a rapid analysis, for example, in response to a crisis requiring swift action, it may be necessary to make the best use of existing models (CGE, PE, or both) and data sets that can be quickly fine-tuned to address the immediate problem. When more time and resources are available, it would be good to update existing databases and models. Eventually, developing the analysts' capacity is important, and the modeling can be used to provide a better understanding of the potential impacts and to fine-tune the design of the reform and accompanying communications and outreach efforts, based on the findings of the analysis.

Due attention to important elements of effective modeling can render the analysis meaningful and useful for policy makers. A very important element is the availability of data that are sufficiently disaggregated with respect to production structure and consumption preferences. The lack of good data is indeed a major obstacle to the development and use of CGE models. It is worth setting aside time and resources to build SAMs and to collect data on elasticities and calibration parameters, drawing from peer-reviewed sources for use in modeling. A set of data, collected and calculated according to consistent approaches, could also be useful to ensure continuity and comparability over time and across countries, and for sensitivity analysis. Other important elements include obtaining reliable information necessary to model the environmental impact and the dynamic features of the models, and to analyze the welfare and distributional implications of reform, which can help inform the political economy analysis down the line. Finally, linking CGE and PE models can help provide macroeconomically consistent but granular assessments of the impacts on households and firms, which can encompass aggregating country-specific results in the regional context.

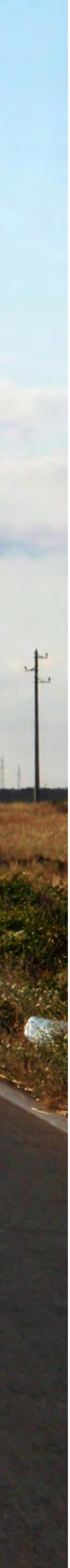
Considerable preparatory work can be done for CGE modeling for supporting reform efforts, even if the prerequisites for adequate modeling and conducting an effective assessment of reform options are missing. In some settings, the critical ingredients for successful modeling are unavailable, for example, because of a fragile and conflict-prone environment, weak institutional and statistical capacity, or lack of time or resources to undertake a comprehensive modeling effort. If so, analytical work can focus on putting in place the essential foundations for reform over time. Resources need to be devoted to compiling the data, particularly the construction of a SAM as well as other data sets, on households and firms required for impact analysis, and the information for undertaking, where necessary, an environmental and multigenerational impact assessment.

CGE modeling tends to be more useful when combined with other PE, institutional, and political economy analyses. In the case studies reviewed for this report, CGE models were used as part of a broader, comprehensive analytical framework. It is critical that the model be complemented by other analytical tools, such as I-O, SAM, or policy analysis matrix (PAM) models, to support a more complete understanding of the different dimensions and impacts of energy subsidy reform across the economy. Complementary instruments enable more granular analysis than what can be accomplished with only CGE modeling and can answer specific policy questions that might not require an economywide assessment. The ability to use such instruments depends on the availability of experts who can be mobilized on a timely basis.

Having the right skill set and team composition matters. Engagements that bring together experts from diverse backgrounds, such as macromodeling experts, economists, and sector specialists, along with their counterparts in government departments, tend to take better advantage of the potential of CGE modeling and lead to better-informed and more realistic reform initiatives. In good practice examples, the work of the modeling team feeds into and supports that of the policy advisors to help maintain the collective focus on moving the energy subsidy reform agenda forward. The review also found that analytical and advisory activities that make a deliberate effort to build government counterpart capacity in outreach and dissemination facilitate the delivery of the reform effort.

FIVE

Conclusions and Considerations for Future Work



In the coming years, energy subsidy reforms will remain at the forefront of policy debate in many countries around the world. International experience shows that energy subsidy reform is a complex undertaking that requires a comprehensive package of measures that consider the social, sectoral, and economywide impacts of reform options. Articulating, up front, the problems the proposed energy subsidy reform effort seeks to solve and understanding who will be directly and indirectly affected are critical. In this context, CGE modeling has an increasing role to play in providing an understanding of and assessing the impacts of reform options under consideration, provided the conditions are right.

This report reviews recent energy subsidy reform engagements that were informed by CGE modeling, with a special focus on ESMAP-funded activities between 2017 and 2020. The review covered CGE modeling in 16 jurisdictions, mainly in Africa, Middle East, and Asia. The review found that the use of CGE modeling as part of broader technical assistance support to government counterparts can provide useful insights into the impacts of potential energy subsidy reform options. CGE modeling and related analyses can, in turn, contribute to policy makers' strengthened understanding of the potential impacts of options under consideration, and ultimately help inform decisions and strengthen the design and implementation arrangements of reforms. In the ESMAP-funded activities reviewed for this report, CGE models added particular value by helping identify and assess long-term effects of energy subsidy reforms across the economy and taking into account the economic interdependencies of multiple sectors and economic actors.

CGE modeling adds value to energy subsidy reform engagements through different channels. Going forward, there is a strong case for using CGE in energy subsidy reform engagements in collaboration with other partners involved in reform options analysis and policy advice, as needed. There can be value for ESMAP to continue providing financial resources and technical capacity to support World Bank teams and their government counterparts through macromodeling.

A key question is whether CGE modeling is worth the required time and resources. For development practitioners considering supporting their government counterparts with macromodeling for energy subsidy reform, the choice of a suitable approach would need to be guided by context-specific factors. These factors include government reform objectives, demand, ownership, data availability, and institutional capacity. When determining the proper modeling approach for supporting an energy subsidy reform effort, a critical consideration is whether there is government demand, ownership, and existing or potential policy dialogue. If this precondition is met, the choice of modeling approach and design would depend on the conditions within which the reform is being considered. There are two guiding questions: *First, is there an existing CGE model, with adequate sophistication, readiness, data availability, and adaptability, or can a model be developed in a timely manner to inform the reform? Second, are adequate capacity and skill sets to develop and utilize the model available?*

As noted earlier, the review found that CGE models tend to generate the most meaningful insights when they are aligned with the context and reform objectives and are properly calibrated. To illustrate potential combinations of answers to the two guiding questions above, Table 5.1 presents different possible cases and considerations for determining choice of modeling approach. This matrix is only intended to illustrate different approaches that may be considered in different contexts, based on the two factors above, and is not meant to be an exhaustive list of options or a definitive decision guide. Clearly, there are many other possible combinations of capacity, model readiness, and client demand that will guide the choice, as well as other considerations that may inform government decision-makers and their development partners.

CGE modeling can be helpful and can render useful results to inform reform efforts, in the right circumstances. For example, this would be true for Cases A through D, summarized in Table 5.1. The optimal situation for use of CGE modeling for energy subsidy reform is when there is strong government ownership, clear reform goals, and strong reform dialogue, and where there is an existing CGE model in good shape that can enable a coherent and consistent analysis. The strongest case for CGE analysis is Case A, that is, when there is an existing, sophisticated model, appropriate for the reform under consideration, and strong client capacity is available, the benefits of an economywide analysis are available at low cost. In contrast, in Case D, CGE modeling should only be considered when economywide impacts are expected to be large and there is strong client demand for CGE modeling. In this case, although the costs of data compilation and model building may be high, benefits from CGE modeling may justify these costs in view of the strong potential reform impact and client demand. Under this option, a small, multipurpose CGE model can be considered. Under Case B, when a major reform is envisioned and several reform design options may have to be examined, the moderate costs and time required to adapt the model are likely to be worthwhile and may entail lower marginal costs to address new policies and substantial benefits, as opposed to building a brand new model from scratch. In Case C, both the creation of a new stand-alone CGE model and the adaptation of the existing CGE model can be considered given that the development and data costs will be similar. Finally, if no appropriate CGE model is available and capacity is modest, the development of a new model is not warranted, as in Case E. The preferred approach then would be a PE model. CGE modeling should be avoided in Case F. In summary, there is no one-size-fits-all set of rules for the relevance and suitability of a model, and the decision should be guided by the setting within which the reform is being contemplated.

Technical and policy advisory support on modeling in the context of energy subsidy reform could be differentiated according to stakeholders' capacity and readiness. The scope and design of technical assistance activities involving CGE modeling can benefit from being aligned with stakeholders' readiness and capacity-building needs. In some countries, capacity has been sufficiently developed and a fairly well-designed model (which may have been supported by ESMAP, the World Bank, or other partners) is available that has produced sound results on which to capitalize and better inform the reform effort. In other countries, the modeling capacity may already be in place but may need to be

TABLE 5.1

Matching Modeling Approach with Policy Dialogue Context and Needs

Case	Description	CGE Model Development and Data Collection Time and Costs	Technical Assistance and Capacity-Building Support Needed	Model Choice
A	Existing CGE model that is well suited to energy subsidy reform; strong in-country technical capacity	Very low	Low	Full fledge modeling using existing CGE model, complemented by other modules
B	Existing CGE model with some shortcomings (e.g., inadequate sectoral disaggregation, household disaggregation, spatial or informality dimensions); moderate in-country capacity	Medium	Medium	Existing CGE model with refinements (e.g., further disaggregation of data; refined welfare analysis)
C	Existing CGE model with significant weaknesses or data gaps; limited in-country capacity	High	High	New CGE model, or existing model with major adaptation and capacity building, only with very strong government demand
D	No existing CGE model; existing PE model; moderate modeling capacity; some data	High	Medium	Small multipurpose CGE (high-level aggregation, using existing data, one or two consumer categories) if there is strong government demand
E	No existing model; limited data; moderate capacity	High	Medium	PE model developed for specific reform
F	No existing model, serious data and capacity constraints.	Very high	Very high	Consider other alternatives (including nonquantitative approaches and institutional analyses)

Source: Original table for this publication.
Note: CGE = computable general equilibrium; PE = partial equilibrium.

enhanced or revised to align with the current modeling exercise objectives. For example, there may be a need for some fine-tuning or strengthening of key design elements, such as appropriate disaggregation of the energy sector, environmental impact analysis, welfare analysis, or multigenerational impact analysis. In such settings, support for working-level staff as well as senior leadership of the agency may be needed to familiarize them with the selected macromodeling approach and to facilitate understanding and ownership. Meanwhile, in other countries, there may be very little specific modeling work done to date, but the ingredients for successful macromodeling-informed energy subsidy reform may be available, including ongoing modeling work into which these dimensions can be integrated, or where the size of the economy or of subsidies is significant. In these contexts, technical advisory, capacity-building, and outreach support will be critical.

The cases reviewed for this report indicate that the benefits of the CGE modeling exercise are amplified when government agencies show strong ownership, are closely involved in the modeling exercise, and are equipped with the appropriate analytical capacity, ideally with a multidisciplinary team. To properly design and conduct the modeling exercise, and ultimately inform the design of a reform package that is comprehensive and considers diverse markets, sectors, and economywide impact, it is critical that a team combining expertise from different domains is in place throughout the exercise. As good practice examples demonstrate, continued, hands-on engagement of government staff in the modeling exercise enhances the quality of the model and helps build government capacity. In this context, the importance of developing local analytical and advisory capacity should be emphasized.

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