Chapter 2
Literature Review

The history of macroeconometric model-building is comprehensively documented in Fair (1984, 1994), Bodkin et al. (1991), Hendry and Mizon (2000), Favero (2001), Pagan (2003a, b), Bårdsen et al. (2004, 2005), Valadkhani (2004), Hendry and Muellbauer (2018), Jelić and Ravnik (2021) inter alia. Also, history and macroeconometric modeling activities over the world and their classification are documented in Welfe (2013).

This section reviews only general equilibrium macroeconomic models that have been built for the Saudi Arabian economy. In other words, we do not review either partial equilibrium models built for Saudi Arabia (e.g., see Mohaddes et al. 2020) or general equilibrium models built for other resource-rich economies. The former ones are not in line with our objectives, and the latter ones are out of the scope of this book and have been reviewed by Welfe (2013) and Hasanov and Joutz (2013) to some extent, among others. Our review here is limited to models that are publicly available or available to us.[1] Table 2.1 documents these models.

As the strengths and weaknesses of each model are documented in Table 2.1, we do not discuss them again here. However, it is worth mentioning that their strengths and weaknesses are also determined by their type that they belong to among other factors. In general, structural, that is theory-guided models, such as computable general equilibrium (CGE) and dynamic stochastic general equilibrium (DSGE) models have the main strengths of being strongly consistent with textbook economic theory, useful for long-term projections and analyzing the effects of changes in policy variables. The studies listed below discuss that these models have the following main weaknesses: using micro-foundations strictly as theoretical foundations and not allowing data 'to speak freely'; they do not incorporate information about behavioral economics and information economics; they are calibrated to

[1] Of course, we are unable to review the models that are not publicly available, including those built and used by government agencies, international institutions, academia and research centers, and private companies. We also do not review master or dissertation theses such as Tawi (1984), Taher (1987), Aljerayed (1993) and Al-Teraiki (1999).

F. J. Hasanov et al., *A Macroeconometric Model for Saudi Arabia*,
SpringerBriefs in Economics, https://doi.org/10.1007/978-3-031-12275-0_2

Table 2.1 Macroeconomic models for Saudi Arabia

Name	Period	Type	Strengths	Weaknesses	Note
Ezzati (1976)	1963–1972	Combined dynamic intertemporal, multi-sectoral, empirical linear programing model and macroeconometric model	Combination of optimization with MEM.	Insufficient theoretical underpinning (e.g., private investment and consumption equations contain only income; export, and import equations ignore relative prices or real exchange rates; production function ignores labor. The model does not capture labor and monetary markets (we could not find a consumer price inflation (CPI) or gross domestic product (GDP) deflator and exchange rate in the model).	Designed to analyze the impact of oil price and production on macroeconomic indicators in OPEC member countries including Saudi Arabia.
Looney (1986)	1980–1985	Optimal control Macroeconomic model	Macroeconomic model within the framework of optimal control can distinguish the most efficient growth path to the end target.	Stochastic properties (unit root and cointegration) of the time series variables used in the econometric estimations were ignored. Therefore, one can argue that the study might suffer from spurious regression issues. Addressing these issues is particularly important for this study, as it is designed for policy analysis. It would be informative for readers if the study reports	The Optimal Control Macroeconomic Model has been used to examine the Saudi Arabia's third Five Year Development Plan (1980-1985) for goal feasibility and tradeoffs among the plan's major goals.

				post-estimation test results, so that they can see the adequacy of the estimated relationships.	
Looney (1988)	1986–1992	Optimal control Macroeconomic model	A macroeconomic model within the framework of optimal control can distinguish the most efficient growth path to the end target.	The stochastic properties (unit root and cointegration) of the time series variables used in the econometric estimations were ignored. Therefore, one can argue that the study might suffer from spurious regression issues. Addressing these issues is particularly important for this study as it is designed for policy analysis. It would be informative for readers if the study reports post-estimation test results so that they can see adequacy of the estimated relationships.	This model has been developed to examine the socio-economic planning dilemmas confronting Saudi Arabian policy during an era of falling oil revenue.
Johansen and Magnussen (1996)	1980–1991	Combination of MEM and IOT	Combination of MEM and IOT. Accounts for the stylized facts of Saudi Arabia. Employs ECM specifications in the model.	The model does not capture the monetary aspects of the economy. The empirical analysis does not consider the integration and cointegration properties of the data used. So, the risk of spurious results and consequently misleading recommendations exist.	Developed by the Research Department, Statistics Norway for the Kingdom of Saudi Arabia's Ministry of Economy and planning. Its main purpose is to assist in the Kingdom's five-year development plans by analyzing fiscal and monetary

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Table 2.1 (continued)

Name	Period	Type	Strengths	Weaknesses	Note
				There are some assumptions which are hard to believe can hold in reality in Saudi Arabia. E.g., export categories are treated as exogenous; coefficients in the linear expenditure system are not estimated but calibrated using studies on other countries; the real oil price is included in the private consumption equation along with disposable income, which may cause double accounting of the oil effect; neither consumption nor investment equations include interest rates.	policies and shocks from the oil sector and abroad.
Cappelen and Magnussen (1996)	1989	CGE model	Well-established theoretical foundation combined with the stylized facts of Saudi Arabia. Very disaggregate representation of the Kingdom's economy.	The modelling of production sectors and capital stock data are based on weak data foundations and strong assumptions. Some rough assumptions of the labor market (e.g., wage rate and foreign workers are exogenous). The governmental sector is aggregated in the model;	Designed for the preparation of five-year development plans, especially to explore the outcome of investment programs.

				there is no breakdown of government consumption.	
Bjerkholt (1993)	NR	MEM		The model does not capture monetary, labor, and energy aspects of the economy. It does not have an explicit price block (Johansen and Magnussen 1996). The model's equations do not consider the integration and cointegration properties of the data used. So, the risk of spurious results and consequently, misleading recommendations exist. Important linkages are ignored. For example, changes in government consumption and private consumption do not affect GDP. Lack of theoretical foundation. For example, non-oil GDP is only the function of its own lag and non-oil investment; some sectors' production capacities are modeled as only the function of the time trend. The model does not account for simultaneity.	Designed as a planning model for the fifth development plan of the Ministry of Economy and planning.
Bjerkholt (1993)	NR	AGE	Very disaggregate representation of the economy	Given the level of granularity, it was very difficult to	

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Table 2.1 (continued)

Name	Period	Type	Strengths	Weaknesses	Note
			(model contains 36 production sectors, 14 household types, 5 labor skill categories, 31 consumption groups).	handle, maintain, update, and upgrade the model due to (a) the technical capacity of the Ministry of Economy and planning employees, and (b) periodic surveys had to be conducted to obtain the required data, which was not resourceful and cost effective.	Coopers & Lybrand built the model for the Ministry of Economy and Planning.
Bjerkholt (1993)	1969–1989	MEM	Very disaggregate representation of the economy (model contains 36 production sectors, 14 household types, 5 labor skill categories, and 31 consumption groups).	The model does not capture monetary, labor, and energy aspects of the economy. The model's equations do not consider the integration and cointegration properties of the data used. So, the risk of spurious results and consequently, misleading recommendations exist. Important linkages are ignored. For example, spillover from the oil sector to the non-oil sector is only through oil revenues, not via intermediate consumption and investment. The exogeneity assumptions are overly set. For example, non-oil export and oil	Designed as a planning model for the sixth development plan of the Ministry of Economy and Planning By The Research Department of Statistics, Norway. The project was financed by the United Nations' Department of Economic and Social Development as part of a technical cooperation project to strengthen the planning capabilities of the Kingdom of Saudi Arabia's Ministry of Economy and planning.

				refining are exogenous. Very weak theoretical foundation. E.g., government consumption is a residual of GDP identity; production capacity depends only on investment; private consumption is a function of income only; the deflator is only dependent on wages. The model does not account for simultaneity and fine-tunings.	
Laxton et al. (1998)	1998	IMF MULTIMOD Mark III	The long-run properties of the MULTIMOD III have solid theoretical foundations and dynamic equations. The dynamic equations in MULTIMOD Mark III have a steady-state analogue equation.	IMF-MULTIMOD Mark III includes explicit country sub- models for each of the seven largest industrial countries. The remaining countries are then aggregated into separate blocks of developing and transition economies.	MULTIMOD is a dynamic multicounty macro model of the world economy that has been designed to study the transformation of shocks across countries and the short-run and medium-run consequences of alternative monetary and fiscal policies.
De Santis (2003)	1990	Static multisector CGE model	Theoretically well-established foundation combined with the stylized facts of Saudi Arabia.	The model does not capture labor market aspects of the economy. The energy sector is represented mainly by crude oil. Exogeneity assumptions are overly set. For example, investments and the current	The model is designed to analyze the impact of the crude oil price, demand and supply shocks on prices, output, profits, and welfare in Saudi Arabia.

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Table 2.1 (continued)

Name	Period	Type	Strengths	Weaknesses	Note
				account deficit are exogenous. There are a few assumptions, which are hard to believe can hold in reality in Saudi Arabia. E.g., the sources of private income are wages and returns to capital; the budget balance is always in equilibrium.	
Alam (1982)	NA	GE model	Theoretically well-established foundation combined with the stylized facts of an oil-dependent economy.	This is a theoretical model and not simulated using data for Saudi Arabia. The model has very limited coverage as it includes only tradable and non-tradable goods, reserves, and prices of non-tradable goods.	This is a theoretical model designed to investigate the impact of oil revenue-financed government expenditure on the indicators included in the model.
Bayoumi et al. (2004)	2004	IMF-global economy model	The main advantage of GEM is that it can provide evaluations of policies in a general equilibrium setting, allowing for the full range of effects across equations. The model is based on explicit microeconomic foundations; changing one of the deep parameters in the model can affect a wide range of relationships.	Calibrating GEM is time-consuming because the concepts in the model often do not match the existing data. Moving to a model with a tight theoretical structure also imposes limitations, at least in the short term.	GEM is a large-scale version of a micro-based open economy model. It primarily focuses on creating a unifying framework for the analysis of international interactions.

Nakov and Nuno (2013)	Average of January 1973–April 2009	GE model	Theoretically well-established	This is a very specific (oil-focused) model. There are a few assumptions, which are hard to believe can hold in reality. E.g., there is no labor and wage in production function and profit maximization of oil exporters, respectively; the oil-exporters maximize their profits only through oil production.	*It is built to investigate the impacts of oil production options, taxes, and subsidies mainly on oil importers' welfare and oil-exporters' oil production and oil revenues.
Blazquez et al. (2017)	1995–2014*	DSGE model	Theoretically well-established	This is a very specific (renewable-focused) model**. Hence, it covers only three sectors, i.e., a representative household, firms producing energy and aggregate non-energy products, and a restricted government. Again, since this is a very specific model, it has some restrictive assumptions. E.g., government revenues are only from energy sales; government expenditures only comprise of investment and transfers to households; natural gas is utilized only in electricity generation.	* This is the model calibration period not the estimation period. ** Designed to investigate the effects of renewables penetration and a reduction in energy subsidies on some macroeconomic indicators in Saudi Arabia.

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Table 2.1 (continued)

Name	Period	Type	Strengths	Weaknesses	Note
Gonand et al. (2019)	1980–2016*	GE model	The OLG model takes a finite lifetime into account and offers a more realistic approach to the study of long-run effects. The OLG model deals with the life cycle behavior of human capital, and the implication of the allocation of resources across generations.	Economic interaction takes place between agents belonging to many different age groups. Competitive equilibria may be Pareto suboptimal.	* This is the model calibration period not the estimation period. The authors developed an energy sector augmented dynamic macroeconomic model with overlapping generations for Saudi Arabia. This is a bespoke model for Saudi Arabia that builds on and develops the overlapping generation (OLG) model of Gonand and Jouvet (2015) by including the characteristics of the Saudi economy.
Soummane et al. (2019)*	2013, 2014–2017**	CGE model	Theoretically well-established foundation. Compared to other CGE models for KSA it has the following merits: (i) Uses original dataset That reconciles national accounting and energy balance data; (ii) performs a dynamic exploration; (iii) considers exogenous energy consumption pathways backed by a bottom-up mode; (iv) considers	Does not have monetary sector Behavioral specifications of the model are limited to non-energy trade-offs as all dimensions of energy trade, supply, and demand are treated as exogenous. It has some restrictive assumptions, such as foreign and domestic price ratio is unity; labor is only the function on unemployment.	* The CGE models in Soummane et al. (2022) and Soummane and Ghersi (2022) are very similar to the one in Soummane et al. (2019). ** This is the model calibration period not the estimation period.

			imperfections of primary factor markets.		
Blazquez et al. (2017)	1997–2016*	DSGE model	Theoretically well-established foundation combined with some stylized facts of Saudi Arabia.	This is a stylized model.** hence, it focuses mainly on the real economic activities and does not cover the entire economy (e.g., monetary sector is missing). Again, since this is a stylized model, it has some restrictive assumptions, such as international trade is represented by net exports, not exports and imports separately.	* This is the model calibration period not the estimation period. ** Designed to investigate the effects of renewables deployment, domestic energy price reform and VAT on some macroeconomic indicators in Saudi Arabia.
OEGEM (2022)	1980–2019	Combination of MEM and IOT	Global coverage. Large database with historical and projected values. Combination of MEM and IOT. Accounts for the stylized facts of Saudi Arabia at some extent. Has energy and environmental components.	Insufficient theoretical foundation. In most cases, quarterly data is converted from annual data. Not enough attention paid to the Saudi MEM module as OEGEM has very wide global coverage*.	Commercial model available on a subscription basis. *OEGEM has 80 countries and 13 regional blocks. Saudi MEM is just one country module.
KGEMM (2022)*	1980–2019	Combination of MEM and IOT	Well-established theoretical foundation coupled with the empirical coherence, stylized facts of the Saudi economy and cutting-edge econometric methods. Flexible and simultaneous	Heavily data-intensive. Data updates and revision issues require re-estimation of behavioral equations. Data and model maintain and update requires a mid-size team.	* The model presented in this paper. The model has been built at KAPSARC and is currently in use at KAPSARC and the Ministry of Energy.

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Name	Period	Type	Strengths	Weaknesses	Note
			evaluation of different research/policy-related questions. Customizable model to address different research/policy questions. User-friendly interface and open box environment. Disaggregated sectoral demand using an input-output framework and sectoral productions from the production functions. Detailed energy block representing 14 energy demand relationships by energy type and customer. CO_2 block reflecting emissions from energy products.		

Notes: *MEM* = macroeconometric model, *IOT* = input output table, *NR* = not reported, *NA* = not applicable, *ECM* = error correction model, *CPI* = consumer price index, *GDP* = gross domestic product, *OEGEM* = Oxford economics' global economic model, *GE* = general equilibrium, *AGE* = applied general equilibrium, *KEM-SA* = KAPSARC energy model for Saudi Arabia. Calibrated models include computable general equilibrium (CGE), dynamic stochastic general equilibrium (DSGE), and hybrid, among others capture only equilibrium positions with none to limited information about short-run dynamics, and they do not provide information about the errors that they make in their representations and simulations; they rely on many assumptions, restrictions, parametrizations that are not always true in reality (see Romer 2016; Stiglitz 2018; Blanchard 2017, 2018; Hendry and Muellbauer 2018; Wren-Lewis 2018; Fair 2019; Colander et al. 2008; Colander 2006; Hara et al. 2009; Pagan 2003a; Gürkaynak and Tille 2017; Crump et al. 2021; Wickens 1995 inter alia). Additionally, Giacomini (2015), Gürkaynak et al. (2013), among others, show that DSGEs, pure structural models produce very poor forecasting performance compared to econometric models in the empirical analyses. Moreover, Wickens (1995), Pesaran and Smith (2011), Blanchard (2017), inter alia, discuss that for DSGE models to survive in the future, they should account for data and hence switch from calibration of the deterministic relationships to estimation of the stochastic specifications, they should estimate well-specified long-run relationships rather than trend approximations and consider more dynamic short-run specifications to possibly account for habits, expectational errors, learning, and the costs and frictions of search and matching, and they should relax the assumptions made, such as optimal behavior, homogenous agent, symmetric information about market conditions, etc. Furthermore, Nikas et al. (2019, p. 37–38) discuss that standard structural models assume that markets clear in the short-run and, hence, they ignore disequilibrium and short-run relationships. For example, they usually assume that there is no unemployment in their representation of an economy. This obviously is not a relevant assumption even in the long-run and, hence, leads to drawbacks in their performances. Most likely due to the above-mentioned issues, the government agencies such as central banks recently prefer hybrid type macroeconometric models, which are built using equilibrium correction equations, in their policy analyses, forecasting, and projections. Because hybrid macroeconometric models perform better than purely theory-based models (e.g., CGE, DSGE, optimal growth models) and purely data-based models (e.g., unrestricted vector autoregression models) since they are the combination of theory-guided and data-driven approaches as the literature discusses (see discussions in Ballantyne et al. 2020, Cusbert and Kendall 2018, Hendry 2018, Hendry and Muellbauer 2018, Bulligan et al. 2017; Jelić and Ravnik 2021; Giacomini 2015; Pagan 2019; Gervais and Gosselin 2014). Moreover, the behavioral representations of economic agents in the macroeconometric models are based on their historical evolution, whereas in the theory-guided models, they are usually based on the optimization of a representative agent, imposed parameters, and calibration using data from a single year or an average of years (e.g., see Lutz 2011; Lehr et al. 2012).

Jelić and Ravnik (2021) and Pagan (2019), among other studies, discuss four generations of macroeconometric models that are coexisted for the last more than 80 years and recent hybrid models incorporate the insights derived from the third- and fourth-generation models into the second-generation models. The main strengths of the hybrid types of macroeconometric models (MEMs) over the other types of macroeconomic models are that they have theoretical coherence to represent long-run equilibrium relationships (like CGE and DSGE models and unlike VAR models). They also possess empirical coherence, i.e., they allow the data ‘to speak freely' (unlike CGE and DSGE models and like VAR models) to represent short-run dynamics and disequilibrium. In other words, they bring together 'theory-guided' and 'data-driven' approaches (e.g., see Hendry 2018). They can represent the behavioral aspects of economic relationships based on the statistical time series properties of national data. Other advantages of MEMs are that they can be modified or customized to accommodate different policy questions and various simulations can be done in one model simultaneously, making them user-friendly for policy analyses. Their main weaknesses are, as mentioned in the Table 2.1, being data-dependent, data updates and revision issues require a reconsideration of all the behavioral equations, require a large team for data and model maintenance and update. For detailed strengths and weaknesses of different kinds of models, interested readers can refer to the above-listed references as well as Ackerman (2002), Pagan (2003b), Hoover et al. (2008), Herbst et al. (2012), Arora (2013), Hurtado (2014), and Oxford Economics (2022).

KGEMM is a hybrid model, i.e., it combines an economic theory-guided modeling approach with empirical data-driven evidence.[2] This is performed through statistical estimations and testing, not by imposing theory on the model. Practically, it attempts to adjust for econometric weaknesses in earlier models built for Saudi Arabia. KGEMM also incorporates detailed demand-side representations and CO2 emissions of the main energy products by customer type. In this regard, KGEMM is a type of E3ME model (Energy-Environment-Economy Macro-Econometric model, see Econometrics, Cambridge 2019; Nikas et al. 2019; Gramkow and Anger-Kraavi 2019; Lee et al. 2018; Dagoumas and Barker 2010, inter alia). And it is similar to SEEEM (Sectoral Energy-Economic Econometric Model, see Blazejczak et al. 2014a, b) and PANTA RHEI (see Lutz et al. 2014a, b; Flaute et al. 2017; Lehr and Lutz 2016; Lehr et al. 2012; Lutz 2011), which both cover energy-economic-environmental representations.

[2] In the view of Pagan (2019) classification, KGEMM is a type I hybrid model, i.e., the long run paths are not articulated, leaving equilibrium correction mechanisms to ensure convergence.