

## A Review of Macroeconometric Modeling Practices

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### Abstract

*This paper presents a general historical survey of macroeconometric modeling, which includes objectives, historic background and major types of macroeconometric modeling. Historic background includes beginning of macroeconometric modeling, advancements, criticisms and responses during the course of time. Major types of macroeconomic modeling and alternatives to the basic methodology of Cowles Commission approach along with their drawbacks are discussed. At the end, review of some available macroeconometric models is presented in a tabular survey.*

**Keywords:** Macroeconometric Modeling, Survey, Historical Advancements

**JEL Classification:** B23, C3, C51, C52, C53, E17

### 1. Introduction

Quantitative economic analysis is almost three centuries old. However, econometrics began to emerge as a recognized branch of economics in the 1930s and the 1940s with the foundation of the Econometric Society, the Cowles Commission in United States and the Department of Applied Economics in Cambridge, England. Econometrics comprises of economic theory, data, econometric methods and computing techniques.

The field of macroeconometric modeling has been fascinating both modelers as well as policy makers because of its usefulness. Review of the literature regarding macroeconometric modeling will be helpful for all those who want to construct such type of model for any economy. This study has been conducted to make familiar for different type of methodologies along with drawbacks and criticisms and presentation of key points of available macroeconometric models. Hence, the next two sections of this paper explain meanings, objectives and historic background of macroeconometric modeling. The fourth section includes major types of macroeconomic modeling and alternatives to basic methodology of the Cowles Commission. The fifth

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section presents a tabular survey of some available macroeconometric models. A summary including some conclusion is given at the end of the paper.

## **2. Meanings and Objectives of Macroeconometric Modeling**

Macroeconometric modeling is a mature field in economics, which has been fascinating both modelers as well as policy makers because of its usefulness. Valadkhani (2004) defined it as “A set of behavioural equations, as well as institutional and definitional relationships, representing the structure and operations of an economy, in principle based upon the behavior of individual economic agents”. A macroeconometric model is a mathematical representation of quantitative relationships among macroeconomic variables. It is usually presented as a set of behavioral equations, accounting identities and auxiliary equations. With the help of behavioral equations, a set of endogenous variables is explained and predicted by a set of exogenous, other endogenous and predetermined variables. These equations are used to explain aggregate behavior of consumers, producers, financial institutions and other economic agents. Accounting identities reflect national income accounting framework and monetary and budgetary identities. These accounts help to check internal consistency of a model. Auxiliary equations are special type of identities describing definitions and/or interlinkages between variables. Most importantly, the models include some variables which are called macroeconomic targets and some other variables which are called policy instruments. Policy makers aim to change the policy instruments in order to attain desired changes in the target variables.

Objective of macroeconometric modeling is to explain empirical behavior of an actual economic system. These models are used to understand the workings of the national economies as well as global economy, to provide a common framework for communication, to evaluate policies, to make ex-ante forecasts under alternative experiments and scenarios. In general, there are four objectives for building a formal macroeconometric model. (1). Selection of policy instruments and macroeconomic targets. (2). Evaluation of economic policies adopted in the past and economic shocks. (3). Short-term and medium-term forecasting under different policy options. (4). Evaluation of economic theories.

To get these objectives, every macroeconometric model must ideally satisfy the following four criteria as are given by Pandit (2000). (1). It must fit into a theoretical framework. (2). Specification of the model must be done in such a way that clarifies the contextual framework of macroeconomic

policies. (3). Robust and rich data base should be used for estimation of the model and (4). Econometric methodology for estimation and solution must be justified.

### **3. Historic Background**

History of macroeconometric modeling can be divided into the following four sections. The first section describes beginning of macroeconometric modeling and also covers the advancement done during the course of time. The basic methodology, i.e. Cowles Commission approach, of macroeconomic modeling was criticized due to its weaknesses by some critiques and they suggested some alternative methodologies. But followers of this methodology responded those criticisms and tried to make improvements. So, the second section covers those criticisms and the responses, while the third and the fourth sections describe the major types of macroeconomic models and alternative methodologies to the Cowles Commission approach respectively.

#### **3.1. Beginning and Advancements**

The history of macroeconometric modeling began before the World War II, when Jan Tinbergen, a Dutch economist, developed and estimated the first macroeconometric model for the Dutch economy in the mid 1930s (Tinbergen, 1937). He built a system of equations into an econometric model of business cycle using economic theory. Initially, macroeconometric models were constructed to implement Keynes' General Theory. However, with the passage of time, other alternative theories, such as New Classical, New Keynesian and monetarist, have been incorporated into macroeconometric models (Bodkin *et al.* 1986a). According to Jansen (2002);

*.....there seems to be universal agreement that statistics enters the discipline of economics and econometrics with the contribution of the Norwegian economist Trygve Haavelmo in his treatise, "The probability approach in econometrics", (Haavelmo(1944)); see Royal Swedish Academy of Science (1990), Klein (1988), Morgan (1990), and Hendry and Morgan (1995).*

Hendry *et al.* (1989) states that Haavelmo (1944) explained in the context of an economic model that the joint distribution of all observable variables for the whole sample period provides the most general framework for statistical inference. This applies to specification, identification, estimation and hypothesis testing. Haavelmo's thoughts were immediately adopted by

Jacob Marschak who, in the mid 1940s, organized a special team at the Cowles Commission<sup>2</sup> by inviting luminaries such as T. W. Anderson, K. Arrow, G. Debreu, T. Haavelmo, L. Hurwitz, L. R. Klein, H. Markowitz, Tjalling Koopmans, F. Modigliani, H. Simon and many others (Diebold, 1998). Marschak was joined by a group of economists, mathematicians and statisticians. The team developed a research agenda for macroeconomic. The central vision of this research program was the development of a mathematical model of macroeconomy on the basis of economic theory, with parameters estimated using sound statistical methods, tested against and thus consistent with empirical evidence. The idea was that the resulting model should be useful for testing economic theories, for macroeconomic forecasting, and for advising policy makers. The work of the Cowles Commission laid the foundations of macroeconomic modeling.

Inspired by the work of Tinbergen, Klein (1947; 1950) was the first who constructed a macroeconomic model for the US economy using the Cowles Commission approach. Like Tinbergen, he also constructed a small simultaneous equations model. Soon others followed Klein's lead. Over a short period of time, macroeconomic models were built for almost every industrialized country, and even for some developing countries. These models became an important tool for forecasting and policy analysis and began to grow in both size and sophistication.

Model building grew into a large industry in the United States in the next three decades (Bodkin *et al.* (1991) and Wallis (1994)). Large scale macroeconomic models flourished during the 1960s. Adopting the Cowles Commission approach in the 1970s, most of the model builders developed comprehensive models on commercial basis for private enterprises. Quarterly or monthly data were used for estimation with the objective of keeping the models up-to-date for commercial gain. As a result, "model-builders became commercially successful" (Fair, 1987). Those models were mainly designed for forecasting. Later models became extremely large and econometric problems could not be treated properly in such large models. When the models failed to forecast the effects of the oil price shocks in 1973 and in 1979, the macroeconomic modeling became unpopular and lost much of its

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<sup>2</sup> The "Cowles Commission for Research in Economics" was founded in 1932 by Alfred Cowles at Colorado Springs. It moved to the University of Chicago in 1939. It was again moved to Yale University in 1955, where it was renamed the "Cowles Foundation". Marschak remained as the director from 1943 to 1948.

position. Some critiques, like the pioneers of LSE methodology<sup>3</sup>, ascribe the failures of those early macroeconometric models to model mis-specification. Other critiques, like Lucas (1976) and Sims (1980, 1982) consider weak theoretical basis of those models as the main cause of failure.

As a result of these failures, macroeconometric modeling and the Keynesian theory were criticized from theoretical as well as practical viewpoints. At theoretical level, it was criticized due to lack of necessary microfoundations based on the optimizing behavior of economic agents. At practical level, the Cowles Commission approach to the identification and estimation of simultaneous equations macroeconometric models was criticized by Lucas and Sargent and by Sims, although from different viewpoints (Lucas, 1976; Lucas and Sargent, 1981; Sims, 1980). Geweke *et al.* (2006) points out that there was a move away from macroeconometric models towards micro foundations and the emphasis gradually shifted from estimation and inference to specification, diagnostic testing, validation, model uncertainty, parametric variations and structural breaks.

Due to the forecast failures of conventional demand orientated models in the face of supply shocks of the 1970s, supply side was introduced into macroeconometric modeling. Supply side determines long run properties of a macroeconometric model.

Macroeconometric modeling has been internationalized via Project LINK, adopted by the United Nations. It was initiated in 1968 under the leadership of Nobel Laureate Lawrence Klein. The project has expanded from a core of 11 researchers and seven country models to more than 250 researchers and 78 models at the present time for a comprehensive coverage of the global economy. It links up the macroeconometric models that are developed originally for national economies. The project LINK contains a closed system of several thousand equations which “allow trade, capita flow and possible exchange rate and other repercussions to influence systematically the individual national economies” (Bodkin, 1988, p. 222).<sup>4</sup>

Another major step in the internationalization of macroeconometric modeling was taken by Fair (1984) with the construction of a multi-country model which has been revised by Fair (1994) and Fair (2004). It has 39

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<sup>3</sup> London School of Economics methodology, to be describe in Section 2.3.4.

<sup>4</sup> For detailed account of the LINK project.

visit the website <http://www.chass.utoronto.ca/link/>.

countries (including Pakistan) for which behavioural equations are estimated using the available data for 1959-2002 by 2SLS method. Other examples include the IMF's MULTIMOD multi-regional model that has been designed to study the transmission of shocks across countries as well as the consequences of alternative policies and the National Institute's Global Econometric Model (NiGEM) which estimates/calibrates a common model structure across OECD countries, China and a number of regional blocks.

Uebe has tabulated a useful summary and a list of macroeconomic models for a number of countries at <http://www.unibw-hamburg.de/uebe/modelle/titelseite.html>. By selecting a particular country, we may view a list of the constructed macroeconomic models for that country including construction date, modeler's name, the type of model and the number of equations.

Macroeconometric modeling in developing countries is a relatively difficult task as compared to developed countries. The problems of these economies are different from those of developed economies. There are several constraints to the construction and use of formal models as input into policy making in developing countries. The constraints include the nature of underdevelopment, skill shortages, non-availability of data, shocks and the ad-hoc nature of policies and economic management. Valadkhani (2004) describes briefly the history of macroeconomic modeling in developing countries. Narasimham (1956) developed the first macroeconomic model for a developing country, i.e. India, under the supervision of Tinbergen. The early models for developing countries contain only demand side of the economy. However, neoclassical formulations and expectations have been incorporated in the later models. ECAFE (1968) and UNCTAD (1968) constructed macroeconomic models for about 40 developing countries for forecasting purpose. Shourie (1972) criticized these models due to insufficient sample size, severe multicollinearity and mis-specification. Some macroeconomic models of developing countries, which are available in the literature, will be discussed later in Section 2.4.

### **3.2. Criticisms and Responses**

Criticism against macroeconomic models based on the Cowles Commission approach began in the late 1960s, which, later on, reflected in the Lucas critique, Sims critique and switch from the model's Keynesian foundations. These criticisms can be classified as theoretical and statistical. The theoretical criticism directed at its Keynesian foundations. The statistical

criticism focused on the identification processes of large-scale macroeconometric models and their poor forecasting in the 1970s. A survey of criticisms has been provided by Diebold (1998). According to Pesaran (1995), the major criticisms on the traditional macroeconometric models based on the Cowles Commission approach may be summarized in the following six points. (1). Inadequate forecasting. (2). Theoretical contrasts with rational expectations theory. (3). Structural instability (Lucas critique). (4). Arbitrary assumption of zero restrictions (i.e., causal ordering). (5). Endogenous-exogenous division of the variables (Sims critique) and (6). Existence of the problem of unit roots and ignorance of cointegration and the time series properties of the data

According to Fair (1994), commercialization of macroeconometric models and Lucas critique were the two most important events in the 1970s which contributed to decline in popularity of the Cowles Commission approach. The Lucas critique negatively influenced the application of macroeconometric models for policy analysis. Lucas claims that under alternative policy formulations, because all the economic agents base their decisions on full information and rational expectations, therefore, “Any change in policy will systematically alter the structure of econometric models” (Lucas, 1976, P-41). It means that the estimated coefficients of a macroeconometric model are likely to vary as a result of agents anticipating and knowing policy measures. Lucas, therefore, rejects the use of macroeconometric models for policy analysis due to the reason that the estimated parameters are not invariant to change of policy regime.

The Sims critique (1980, 1982) pointed out that many variables were taken to be exogenous in macroeconometric models by default rather than as a result of solid economic or statistical arguments. Therefore, he also rejected the use of macroeconometric modeling based on the Cowles Commission approach and suggested an alternative methodology which is called Vector Autoregressive (VAR) methodology.

The responses to the criticism consist of two types. One is the development of alternative approaches to Cowles Commission approach. These efforts include the Hendry methodology aided by the advent of cointegration analysis, Leamer methodology, vector autoregressive (VAR) methodology, Dynamic Stochastic General Equilibrium (DSGE) models and computable general equilibrium (CGE) models. The second is the modification of Cowles Commission approach. Yap (2002) summarizes

responses of the second category in the following three points. (1). Greater use of economic theory in the specification, particularly the introduction of supply side and microfoundations. (2). More focus on the long-run relationships using cointegration analysis. (3). Incorporation of rational expectations or model consistent expectations in response to the Lucas critique.

These developments led to a new generation macroeconometric models to share a number of important features in terms of the three basic building blocks, which are equilibrium conditions, expectations formation, and dynamic adjustments (Garrat *et al.*, 2000). Greater emphasis on the use of economic theory and long-run invariably resulted in the inclusion of supply side of the model, and vice-versa. The Lucas critique was responded by specifying the formation of expectations separate from the model.

The responses of some leading model-builders to the criticisms may be presented here. Klein (1989) accepts importance of the Lucas critique, but adds that “I believe that there is more persistence than change in the structure of economic relationships. The world and the economy change without interruption, but that does not mean that parametric structure is changing. Random errors and exogenous variables may be the main sources of changes”. Criticizing rational expectations and the Lucas critique, Bodkin and Marwah (1988) pointed out the irrational assumptions of the rational expectations theory with respect to complete access of economic agent to the raw data and the true model of the economy. Fair (2004) tested rational expectations hypothesis and rejected in most cases. Klein (1986) points out that macroeconometric models are based on economic theories and estimates of the way people do behave and not on the way they ought to behave. Hence, statistical evidence contradicts the hypothesis of rationality. According to Gandolfo and Padoan (1984), simulation exercises may be classified into following four types. (1) Exogenous variables are assumed to follow a different path from the actual one. (2) Endogenous variables, other than policy variables, are chosen to follow a given time path. (3) There is policy change which is uncertain and insincere. It means that policy makers either do not explain their policy or their policy statements do not match with the one actually implemented. (4) The policy changes are sincere, certain and once and for all. Sims (1982) has pointed out that Lucas critique applies only to simulations of the fourth type. The reason is that economic agents have enough time and information in only this case, to adjust their behavior according to the new policy regime. Such events, however, rarely happen in the real world. Valadkhani (2004) quoted six points from Hendry and Richard

(1983) that the macroeconometric models can be made applicable if the following six issues are addressed. (1). Consistency between economic theory and interpretation of parameters. (2). Exogeneity of explanatory variables. (3). Stationarity of the stochastic residuals. (4). Stability of the estimated parameters over the period under study. (5). Data admissibility, i.e. the domain of an economic variable should be placed in an acceptable range. (6). Testing of superiority of the model to all the rival models.

On the above six points, Pesaran and Smith (1985) also supports macroeconometric modeling. McNees (1982) and Smith (1984) discuss the usefulness of a macroeconometric model for ex-ante forecasting performance. Intriligator *et al.* (1996) states that macroeconometric models are useful in structural analysis, forecasting and policy evaluation provided they are subjected to some parametric tests prior to and after the release. While conceding that the demand side has been overemphasized, Klein (1986) strongly defends the basic approach and suggests the introduction of supply side. He calls the resulting model Keynes-Leontief methodology. Commenting on the heritage of macroeconometric models, Diebold (1998) says; “Although the (early) large-scale macroeconomic forecasting models did not live up to their original promise, they nevertheless left a useful legacy of lasting contributions from which macroeconomic forecasting will continue to benefit. They spurred the development of powerful identification and estimation theory, computational and simulation techniques, comprehensive machine-readable macroeconomic data-bases and much else..... We learn from our mistakes. Just as macroeconomics has benefited from rethinking since the 1970s, so too will macroeconomic forecasting”. Paying tributes to the work done at the Cowles Commission, Diebold (1998) say; “The intellectual marriage of statistics and economic theory was beautifully distilled in the work of the Cowles Commission at the University of Chicago in the 1940s and early 1950s”. Hall points out that neither computable general equilibrium models (which are purely theory driven) nor other approaches such as vector autoregressive (VAR) models (which are purely statistical) “can replace the approach of structural modeling and the formal use of econometrics as the best tool for policy analysis at the macro level” (Hall, 1995, p. 983).

Significant advancements in the literature of macroeconometric modeling include the introduction of supply-side economics, rational expectations theory, and open economy macroeconomics which have given rise to further research in this field. The disparity between modelers and

critiques can be settled by implementing the above mentioned requirements. For more detail, see Lucas (1976), Sims (1980, 1982, 1986), Hendry and Richard (1983), Bodkin *et al.* (1986b, 1991), Klein (1989), Pesaran (1995), Diebold (1998) and Valadkhani (2004, 2005).

### 3.3. Major Types of Macroeconomic Modeling

Today, there are macroeconomic models of individual countries, regional blocks and even the global economy. There are many ways of classifying existing models. Depending on the purpose of classification, models can be classified by methodology; by policy focus; by the underlying theoretical structure; by the nature of agencies that develop such models etc. According to Bautista (1988) and Capros, *et al.* (1990), basically, there are two types of macroeconomic models, which are macroeconometric models and computable general equilibrium (CGE) models.

IS-LM-AS models and the models based on alternative approaches to Cowles Commission approach are various types of macroeconometric model. The models based on IS-LM-AS framework have found wide application mostly in macroeconomic forecasts and policy evaluation. With a Keynesian foundation, most of the early models in this class were demand-oriented. However, supply side has also been included after the supply shocks of the 1970s. Challen and Hagger (1983), classifies the models under this class into five major frameworks. These are the Keynes–Klein (KK) model, the Phillips–Bergstrom (PB) model, the Walras–Johansen (WJ) model, the Walras–Leontief (WL) model, and finally the Muth–Sargent (MS) model.

The KK model is demand-oriented model for macroeconomic fluctuations, based on the Keynesian framework, which covers the problems of short-run instability of output and employment. This type of model was criticized as it does not consider money market, supply side, relative prices and expectations. However, in more recent times, neoclassical elements have been incorporated. The PB model is a small size demand-oriented model. Difference equations are used to estimate structural parameters. The WJ and the WL models take the economy as a form of general equilibrium system. Both derive their theoretical foundations from the ideas of Walras (1954). They postulate that the economy consists of various inter-dependent markets, which reach an equilibrium state by profit maximizing behavior of producers and utility maximizing actions of consumers in competitive markets. The WJ model is mainly a multi-sector and highly non-linear model. It uses logarithmic differentiation. The WL model is an important type for

developing economies which incorporates input–output (IO) table into the Walrasian general equilibrium system. It is important to note that later developments in WJ and WL models led to the formulation of CGE modeling. Finally, the MS model bases on evolution of the theory of rational expectations. It includes supply side and expectations.

Macroeconomic disequilibrium models are associated with undesired fluctuations that may arise either naturally or from macroeconomic policies. These models may also describe the emergence of different disequilibrium regimes due to rationing of supply and demand at prevailing prices and wages. The fundamental difference between equilibrium and disequilibrium macroeconomic models is that production and exchange are not permitted at prices corresponding to nonzero excess demands in equilibrium models. In disequilibrium-type models, on the other hand, production and exchange can take place even when the economy is out of equilibrium, i.e., even when the markets do not clear. Discussion on macroeconometric models based on the alternative approaches to the Cowles Commission approach is deferred to Section 2.3.4.

Computable general equilibrium (CGE) model is the second class of macroeconomic models which bases on strong microeconomic foundations of individual behavior and optimization theory. During the period of 1970s and 1980s, there was widespread use of CGE models for analysis of economic problems. CGE models are derived from Walrasian general economic equilibrium theory. This type of modeling considers the economy as a set of agents, interacting in several markets for an equal number of commodities. Main objectives of CGE modeling are to conduct policy analysis on resource economics, international trade, efficient sectoral production and income distribution (Capros *et al.*, 1990). Basic structure of a CGE model consists of the following components.

- Specification of the economic agents,
- Observations of signals by agents, and
- Specification of the rules of game according to which agents interact.

Social accounting matrix (SAM) provides data framework for CGE modeling. Calibration of the model is done by assigning values to the parameters based on econometric estimates or results from other studies. Strictly speaking, the CGE model is not a macroeconomic model because

most of the features of a standard CGE model are microeconomic in character. In general, the main distinction between CGE models and macroeconomic models lies in the level of aggregation assumed for goods and factor inputs. A standard CGE model is highly disaggregated on demand side as well as supply side. On the demand side, different types of households are classified by the nature of their ownership of factors of production. Individual classes of households maximize their utility, thereby generating demand for domestic and foreign goods. On the supply side, CGE models contain a large number of distinct production activities and factors of production such as heterogeneous labour and land. In addition, supply of imports is also disaggregated into different types of goods available in the world market.

Main limitation of CGE models is that these are predominantly microeconomic in character. CGE models do not provide a satisfactory tool for macroeconomic policy analysis and forecasting. Moreover, data requirements for CGE models are very extensive. Aggregate data are also required for model calibration, because CGE models are parameterized using calibration techniques.

Finally we may conclude by pointing out the most appropriate type of model to use. Macroeconomic modeling is more appropriate than CGE modeling for forecasting and policy analysis. On the other hand, CGE modeling is preferred to monitor the impact on social outcomes. However, nowadays, there is a gray area between these two types of models. CGE models increasingly use econometric estimates for calibration and dynamics can be incorporated. These features enhance their forecasting ability. On the other hand, macroeconomic model can be applied to monitor social outcomes via the simulation approach.

#### **3.4. Alternative Approaches to Cowles Commission Approach**

In criticizing the Cowles Commission approach, which is based on the structural multi-equation modeling, four methodological alternatives of macroeconomic modeling have emerged in the literature. These are the Sims (1980, 1982) Vector Autoregressive modeling approach, Dynamic Stochastic General Equilibrium modeling approach, the Hendry (1980) methodology and the Leamer (1983) methodology which are briefly reviewed below.

First is the Sim's vector autoregressive (VAR) modeling approach which stresses the role of data with no theoretical foundations. This approach

has an advantage that there are no exogenous variables and, hence, no requirement of endogenous-exogenous division of variables in the system. Sims introduced identifying restrictions on error structure of the model. This approach has also been criticized. Later developments have led to Bayesian VAR model proposed by Doan, Litterman and Sims (1984) which combine unrestricted VARs with Bayesian estimation and structural VAR models. Structural VAR modeling defines cointegrating long run relationships between non-stationary variables and exogenous variables are reintroduced. The structural VAR approach builds on Sims' approach but attempts to identify impulse responses by imposing a priori restrictions on covariance matrix of structural errors. It provides some economic rationale behind covariance restrictions used, and thus aims to avoid the use of arbitrary or implicit identifying restrictions associated with orthogonalised impulse responses. However, VAR approach becomes difficult to implement when number of variables increases due to overparameterization and resultant multicollinearity. VAR models are constructed for forecasting purposes and do not capture the dynamic structure of the economy.

Dynamic Stochastic General Equilibrium (DSGE) modeling is the second alternative approach which may be classified into two categories. These are the real business cycle models and the monetary general equilibrium models. Main difference between the two models is that the former assumes that productivity shocks derive business cycles while the later assumes that they are caused by monetary or financial disturbances. These models generally assume rational expectations and are based on optimization behavior by households and firms which imply that labour and goods markets are always in equilibrium. In a typical general equilibrium business cycle model, a theoretical framework with optimizing consumers, firms, and the government, is set up. Uncertainty is introduced into the model in the form of productivity shocks or monetary and financial shocks. The model is either calibrated using parameters from existing empirical studies or it is estimated and is, then, solved using a numerical technique.

The third alternative to the Cowls Commission approach is the Hendry methodology, which is known as “general to specific modeling approach” or the London School of Economics (LSE) methodology in the literature (see Hendry, 1980, 1995, 2000). This methodology starts with construction of general dynamic autoregressive distributed lag model on the basis of economic theory. Then, a number of likelihood ratio restriction tests are applied to obtain a specific model, so that it is congruent with the data

generation process. Hence, theory determines explanatory variables and nature of the relationship is determined by data. Expectations are too much from the data in Hendry's approach. The traditional logic of the Cowles Commission, according to which the reduced form is derived given the structural model, is reversed within the LSE approach (Favero, 2001). Later on, cointegration analysis has also been incorporated which has condensed the LSE approach to constructing a macroeconometric model.

The fourth alternative to Cowles Commission approach is the Leamer's methodology, in which the conditional distribution of  $y$  (an endogenous variable) given  $x$  (an exogenous variable) remains stable to any changes in  $x$ . The approach based on the implementation of the Bayesian regression model. The main message of the Leamer approach is that "pure macroeconometric modeling can never replace judgment in the formulation of wise economic policies or even in the tentative assessment of the state of the world" (Bodkin *et al.*, 1991).

Besides the above mentioned four alternative approaches to Cowles Commission approach, 'financial programming framework' is used by Finance Ministries and Central Banks of many developing countries including Pakistan. Basically, it was developed by IMF for macroeconomic stabilization and is used as a main tool to make proposals about macroeconomic policies in many countries. It does not consider supply side of the economy. Having its origin in Polak model, the financial programming model relies heavily on accounting identities, linking the accounts of major sectors of the economy and has very few behavioral equations. It, therefore, neglects a considerable amount of economic structure and behavioral relationships. Parameters are not estimated but these are calculated as simple historical averages or ratios over some recent period.

#### **4. Review of Macroeconometric Models**

A large number of macroeconometric models have been constructed but only some of them are available in the published literature. After the construction of the model, its structure, data and simulations are hardly made available for public scrutiny. The reasons given for secrecy of the models and their results pertain to so-called sensitive aspects of the models regarding macroeconomic policies, involving the exchange rate, balance of payments, monetary and fiscal policy variables, etc. In some cases, the model structure is not even freely discussed within the particular policy institution. Nevertheless, we here discuss a few macroeconometric models which are available in the

literature at the time of thesis write up. Some review articles about macroeconometric models are also available in the literature and we have also extracted information from these articles. We have tried to capture important characteristics of the models. A tabular survey is given at the end of this section discussing available macroeconometric models of different countries.

Shapiro (1977) examines macroeconometric models of the former Soviet Union and the socialist countries of Eastern Europe and provides a tabular survey of the models. The countries include Poland, Hungary, Czechoslovakia, former German Democratic Republic, Ukraine and former Soviet Union. Some of the common features of all models which have been given by Shapiro are (1) medium- to long-term outlook; (2) annual data for every country based on the material product system (MPS<sup>5</sup>); (3) heavy emphasis on industrial output; (4) little concern either with the feedback of end-use to production or with the complete allocation of production to various end-use categories; (5) aggregate demand; and (6) little role of either labour or capital. In general, most of the models contain three principal blocks of equations which are a production block, an aggregate demand block and a block containing identities. The tabular survey covers the models of all above mentioned countries constructed from the late 1960's to 1975. Nineteen models have been included in the survey. Most of the models are linear. However some models are nonlinear. Some are simultaneous equation model while some others are recursive. The estimation methods which have been used are OLS, 2SLS, GLS, Instrumental Variables method. The survey contains no information about simulation experiments.

Haqea *et al.* (1990) develops and estimates a small macroeconometric model for a small open developing economy and uses annual data for the period 1963-1987 from 31 developing countries. The model is the traditional Mundell-Fleming model with specific features of a developing economy. The model comprises of aggregate demand, aggregate supply, money market and government sector. GLS estimation technique is used to estimate the model parameters.

Yap (2002) provides a survey of the development of macroeconometric and CGE models for the Philippines economy during the

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<sup>5</sup> The national accounting systems of these countries reflect the "material" approach which accounts only for the contribution of "productive sectors" to the generation of national income.

period 1990-2002. The study discusses the PIDS-NEDA<sup>6</sup> annual macroeconometric model, the Ateneo<sup>7</sup> Macroeconometric Forecasting Model (AMFM), the NEDA quarterly macroeconometric model, the NEDA Annual Macro-Social Model and some CGE models for the Philippine economy. The former two models will be discussed in Table 2.1. Yap (2002) says that the NEDA quarterly macroeconometric model constructed in 2000 contains real sector as an important sector of the economy. It is capable to address many macroeconomic policies simultaneously and to check their consistency across many sectors. However, large required information may create difficulties in generating timely forecasts. The NEDA Annual Macro-Social Model (AMSM) contains more detailed financial and fiscal sectors. Engle-Granger two-step procedure is applied for estimation. There is a feedback mechanism between social sector and the real sector. Simulation exercises include currency depreciation, hike in oil prices, and restoration of tariffs to their level in 1995.

Using a more recent economic framework, Kannapiran (2003) constructs a simple macroeconometric model of a developing economy under the IS-LM and Mundell-Fleming model framework. The aim of this model is to provide a structural framework to carry out macroeconomic analysis, forecasting and evaluating the impacts of macroeconomic policies in small open developing economies. The model is specified around the four macroeconomic identities, including national income identity, monetary equilibrium, fiscal identity and BOP identity, and two policy equations for inflation and employment. There are six blocks in the model. However, proper financial market and labour market are not introduced. Quarterly data for the period 1975-95 of Papua New Guinea and 2SLS iterative method are used to estimate the behavioral equations which are specified in an error correction framework. A number of statistics are used: R-square for goodness of fit; LM test as a test of autocorrelation; Chi-square test, BPG test and Engle's ARCH test for testing of heteroscedasticity; Reset test as specification error test; Jarque-Bera LM test as normality test; Chow test for structural break and mean absolute error, root mean square error and Theil inequality coefficient for predictive accuracy.

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<sup>6</sup> PIDS stands for Philippine Institute for Development Studies while NEDA stands for National Economic Development Authority and this model is joint effort of both institutions.

<sup>7</sup>The Ateneo de Manila University is a private university in Philippines.

Fair (2004) constructs a multi-country (MC) model. Part of the overall MC model related to the USA is denoted by 'US' model and the remaining part is denoted by Rest of the World (ROW) model. The ROW model consists of the individual models of other 38 countries. The equations that pertain to links among countries are put in the ROW model. There are 30 behavioral equations and 97 identities for the US model alone and one additional equation when the US model is embedded in the overall MC model. There are 15 stochastic equations and 22 identities for each of the 38 countries excluding USA in the MC model. There are five additional equations that pertain to the trade and price links among countries. These five equations are estimated for 58 countries including the above mentioned 38 countries. The estimation period begins at the 1954 for USA and soon after 1960 for the other countries and ends between 1998 and 2002. There is a mixture of quarterly and annual data in the model. However, all the trade share equations are quarterly based. 2SLS method is used for estimation. However, OLS is also used when there are too few observations to make the technique practical.

Rehman (2005) examines the macroeconomic structure of SAARC countries including Bangladesh, India, Nepal, Pakistan and Sri Lanka and excluding Maldives and Bhutan due to non-availability of data. The model is designed to help the policy makers, to analyze impacts of different policy options and to explore possibility of trade expansion among these countries. OLS and GLS methods are used for estimation using annual data for the period 1972-1999.

The following is being given a tabular survey of macroeconometric models for some specific countries. The selection of the models based on the criteria that these models are available in the literature at writing stage of the thesis.

**Table 1: Summary table of available macroeconometric models**

<b>Author (Year)/ Country</b>	<b>Level of disaggregation</b>	<b>Data/ Estimation Technique/ NO. of equations</b>	<b>Simulation experiments</b>	<b>Any other remarks</b>
Srivastava (1981)/ India	Single block	Annual data, 1950-51 to 1974-75/ 2SLS/ 18 behavioral equations and 17 identities	Expansionary fiscal policy, contractionary monetary policy, increase in aid-inflow and some combinations	The model is built in the IS-LM tradition with feedbacks from the real to monetary sector and vice versa. Along with demand side, output is also considered and disaggregated into agriculture and non-agriculture output. The model is considerably expanded for fiscal sector and incorporates interdependence between monetary and fiscal sectors of the economy.
Serven and Solimano (1991)/ Chile	Goods market, labour market, assets market and prices	Annual data, 1960-1987/ 2SLS/ 11 behavioral equations and 24 identities	Baseline scenario, which is the combined effect of the monetary and fiscal adjustment measures, fiscal expansion, minimum wage increase, fall in copper prices and oil price shock.	The model is an open economy IS-LM-AS model. Key macroeconomic variables are determined by the interaction of aggregate supply and demand factors.

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<b>Author (Year)/ Country</b>	<b>Level of disaggregation</b>	<b>Data/ Estimation Technique/ NO. of equations</b>	<b>Simulation experiments</b>	<b>Any other remarks</b>
Naqvi <i>et al.</i> (1993)	Production-expenditure block, Labor market block, Foreign trade , Fiscal and monetary block	Annual data, 1959-60 to 1987-88/ 2SLS/ 45 behavioral equations and 52 identities	A large number of deterministic simulation experiments are conducted	Some output sectors relate only to supply side factors while most of the output sectors relate only to demand side components. It creates confusion about the behavior of production sector.
Christodolakis and Kalyvitis (1998)/ Greece	Aggregate demand, aggregate supply and public finance	Annual data, 1974 – 1994/ OLS/ECM/ 40 behavioral equations and 42 identities	A sustained increase in world activity, foreign prices, public sector employment, and public sector investment; and a quicker implementation of labour market reforms	Theoretical base of the model is interaction between supply and demand. Both the sides are further disaggregated. The study focuses mainly on forecasting.
IEG-DSE <sup>8</sup> Research Team (1999)/	Eight sub-models: Production; capital formation;	Annual data, 1970-94 Revised and updated in	Expansionary monetary policy, contractionary fiscal policy and exchange rate policies	Realized production is determined by demand and potential production is determined by supply. It is the most comprehensive macroeconometric

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<sup>8</sup> Institute of Economic Growth-Delhi School of Economics.

Author (Year)/ Country	Level of disaggregation	Data/ Estimation Technique/ NO. of equations	Simulation experiments	Any other remarks
India	prices; public finance; money and banking; trade and BOP; private consumption; and private savings	1999/ 120 behavioral equations and 227 identities <sup>9</sup>		model of the Indian economy that has been maintained, updated and used for forecasting and policy analyses. The model is a part of the Global LINK Model.
Bank of England (2000)/ England	Aggregate demand, aggregate supply, finance, labour market, prices, fiscal and financial sectors	Quarterly data, 1975-2000/ OLS/ECM/ 20 behavioral equations and 90 identities	Temporary increase in interest rate and fall in target price level	GDP is determined by the components of aggregate demand in short term and by supply-side factors in long term. Long run growth path of real output is independent of price level and inflation and, hence, sluggish adjustment of real variables to economic shocks.
Bank of Thailand (2000)/ Thailand	Real , government, external, monetary, prices, corporate and household sectors	Data <sup>10</sup> / OLS / ECM/ 24 behavioral equations and 43 identities	Depreciation in exchange rate and increase in crude oil prices	The model estimation and simulations are revised several times. Recent version incorporates the most recent published quarterly data.

<sup>9</sup> Model is not available in published literature. We have extracted information from Krishnamurthy (2002) who does not mention estimation technique.

<sup>10</sup> Only the appendix of the model is available and the period of data has not been mentioned.

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Author (Year)/ Country	Level of disaggregation	Data/ Estimation Technique/ NO. of equations	Simulation experiments	Any other remarks
Yap (2000)/ Philippine	Four major blocks: real sector consisting of the production, expenditure and employment; wages and prices; fiscal sector; financial and external sector	Annual data, 1967-1998/ OLS/ 34 behavioral equations and 26 identities	Baseline scenario and a counterfactual experiment including higher exchange rate and tight monetary policy	The model is structuralist in nature although expenditure sector is specified along the lines of Keynesian income-expenditure model. It takes into account supply bottlenecks as affecting certain sectors of the economy and allows for less than full employment equilibrium. However, OLS is not suitable estimation technique as the model contains simultaneous equations.
Haan <i>et al.</i> (2001)/ Macedonia	Aggregate demand, wages and labour market, prices, public sector and monetary sector	Monthly data, 1995-1999/ OLS/ECM/ 9 behavioral equations and 27 identities	Baseline scenario, increase in government expenditure and a decrease in the level of world trade	It is a demand oriented model and supply is not considered formally.
Musila and Rao (2002)/ Kenya	Aggregate supply, aggregate demand, monetary sector and prices	Annual data, 1970 to 1995/ OLS/ECM/ 20 behavioral equations and 12 identities	Devaluation of the Shilling, increase in government consumption, and cut in interest rate	It is a demand-oriented model, but the supply side also plays a role, thereby maintaining a fairly balanced synthesis between the demand and supply sides of the Kenyan economy. Both the demand and supply side are disaggregated into sub-components. The estimated structure is used for policy simulation experiments.

<b>Author (Year)/ Country</b>	<b>Level of disaggregation</b>	<b>Data/ Estimation Technique/ NO. of equations</b>	<b>Simulation experiments</b>	<b>Any other remarks</b>
Rodriguez and Briones (2002)/  Philippine	Real sector, public sector, financial sector and external sector	Quarterly data, 1984-2002/ OLS/ 13 behavioral equations and 53 identities	No simulation exercises	The model is constructed for forecasting. It incorporates Keynesian as well as Neoclassical elements.
Estrada <i>et al.</i> (2004)/  Spain	Aggregate supply, aggregate demand and the government sector	Quarterly data, 1981-98/ ECM/ OLS 29 behavioral equations and 30 identities	Contractionary monetary policy shock, expansionary fiscal policy shock, expansion of the working age population, expansionary extra-euro area demand shock, appreciation of the euro exchange rate and an increase in the oil price	The supply side of the model determines the long-run equilibrium, while demand side determines output in the short run.
Fair (2004)/  USA	Household sector, production sector, financial sector, federal government sector, state and local government sector and foreign sector	Quarterly data, 1954 to 2004/ 2SLS/ 30 behavioral equations and 97 identities	Simulation experiments regarding fiscal, monetary and national accounts variables	The model emphasizes on microeconomic foundations and allows disequilibrium in certain markets. It is part of multi-country model of Fair (1984) and is revised twice in 1994 and 2004. Rational expectation hypotheses are tested and rejected in most of the cases.

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<b>Author (Year)/ Country</b>	<b>Level of disaggregation</b>	<b>Data/ Estimation Technique/ NO. of equations</b>	<b>Simulation experiments</b>	<b>Any other remarks</b>
Hofer and Kunst (2004)/  Austria	Aggregate demand, prices, labour market, external balances, and public sector	Annual data, 1976-2002/ OLS/ ECM/ 21 behavioral equations and 57 identities	Increase in public consumption, increase in export and increase in short term interest rate	It is a demand oriented model based on the Keynesian framework. Supply side and money market are not considered. It is part of the LINK project and is updated every year.
Tjipe <i>et al.</i> (2004)/  Namibia	Real, fiscal and monetary sectors and prices	Annual data, 1983-2002/ OLS/ECM/ 9 behavioral equations and 7 identities	Two scenarios for policy simulations: (1) High government spending, weak Namibia Dollar and high interest rate and; (2) Low government spending, strong Namibia Dollar and low interest rate	It is a demand oriented macroeconometric model based on Keynesian framework. Supply side is absent.
Aysoy and Kipici (2005)/  Turkey	Prices, money, foreign trade, public finance and one equation for real GDP	Quarterly data, 1987- 2002/ OLS/ 17 behavioral equations and 14 identities	Baseline scenario, decrease in overnight interest rate, decrease in inflationary expectations and increase in exchange rate	The model is constructed to trace the factors which cause higher inflation in Turkey. Simulations are conducted to trace the reasons. It does not consider traditional demand and supply sides.

Author (Year)/ Country	Level of disaggregation	Data/ Estimation Technique/ NO. of equations	Simulation experiments	Any other remarks
Matlanyane (2005)/ Lesotho	Production, employment, aggregate demand, balance of payment, monetary sector, prices sector and public sector	Annual data, 1980- 2000/ OLS/ECM 22 behavioral equations and 43 identities	Fiscal policy shocks in public consumption and investment expenditure. A shock in nominal treasury bill rate. A shock of currency depreciation.	It is a small open economy based on IS-LM- AS framework. The model maintains a balanced synthesis of both the demand side and the supply side of the economy adequately. Sufficient disaggregation is made to explore the necessary policy options.
McQuinn <i>et al.</i> (2005)/ Ireland	Aggregate supply and factor demands, domestic demand, housing, external trade, prices and wages and public sector	Quarterly Data, 1980-99/ OLS/ECM/ 30 behavioral equations and 59 identities	Scenarios involving increase in government spending, world demand, foreign prices and short term interest rates, exchange rate appreciation, and oil price shock	The level of real output is determined by the interaction of aggregate supply and demand. If the actual output is not equal to potential output and unemployment deviates from the time-varying natural rate, it causes wage and price adjustment and the model returns to long-run neo-classical equilibrium.
Ra and Rhee (2005)/ Nepal	Aggregate demand, prices, money and credit, government sector and balance of payments	Annual data, 1974-2002/ <sup>11</sup> 20 behavioral equations and 17 identities	Baseline scenario by extrapolating current trend in policy variables and other exogenous variables, optimistic normal growth scenario and a pessimistic low growth scenario	The model is demand oriented, based on Keynesian income-expenditure approach and supply side is not considered. It can be used for forecasting and policy analysis.

<sup>11</sup> Working paper of the model is available but estimation method has not been mentioned.

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<b>Author (Year)/ Country</b>	<b>Level of disaggregation</b>	<b>Data/ Estimation Technique/ NO. of equations</b>	<b>Simulation experiments</b>	<b>Any other remarks</b>
Beokovskis and Stikuts (2006)/ Latvia	Supply side, demand side, prices, fiscal block and external sector	Quarterly data, 1995-2005/ OLS/ ECM/ 49 behavioral equations and 38 identities	Baseline scenario, transitory interest rate shock, permanent exchange rate shock, permanent oil price shock, permanent world demand shock and Permanent government consumption shock	Aggregate supply drives the long run equilibrium of the model, while aggregate demand determines the short run dynamics. Aggregate demand could deviate from the potential output in the short term, and these deviations cause price and wage adjustments, which bring the model back into the long run equilibrium.
Cagas <i>et al.</i> (2006)/ Philippine	Production, private consumption, investment, government, trade, prices, money, and labour market	Quarterly data, 1990 – 2004/ OLS/ECM/ 48 behavioral equations and 17 identities	Increase in interest rate, two experiments to decrease government budget deficit, and world oil price shocks.	GDP is modeled from both the production and expenditure sides. Both sides are linked by incorporating demand side variables as explanatory variables in the production side equations and vice versa. Fiscal sector is considered to be the most important sector and it is linked to all other sectors.
Dreger and Marcellino (2007)/ Euro Zone	Supply side, demand side and prices	Quarterly data 1991-2002/ OLS / ECM/ 22 behavioral equations and 8 identities	Slower expansion of the international trade and decrease in the short term nominal interest rate	The model considers both demand and supply sides and follows structuralist's approach. Disequilibrium between supply and demand is represented by unemployment rate and capacity utilization rate.
Lehmus	Production and	Quarterly data	Increase of government	The model follows the routes of

<b>Author (Year)/ Country</b>	<b>Level of disaggregation</b>	<b>Data/ Estimation Technique/ NO. of equations</b>	<b>Simulation experiments</b>	<b>Any other remarks</b>
(2007)/ Finland	factor demand, aggregate demand, price and wage and public sector	1990-2005/ OLS/ECM/ 15 behavioral equations and 56 identities	purchases, government investments, labour supply, NAIRU rate, interest rates, foreign demand and euro/dollar exchange rate	neoclassical synthesis as it contains supply side along with the demand side components.
Qin <i>et al.</i> (2007)/ China	Output, income and consumption, employment, investment, prices, government, trade and money	Quarterly data 1992-2004/ OLS/ECM/ 47 behavioral equations and 26 identities	Stochastic forecasts of some important variables using McCarthy method	The model contains demand side as well as supply side equations. GDP of supply side plays a central role in the real-sector part of the model and is disaggregated into primary, secondary and tertiary sectors.
Weyerstrass and Neck (2007)/ Slovenia	Aggregate supply, aggregate demand, labour market, money market and public sector	Quarterly data, 1995-2005 OLS/ECM/ 21 behavioral equations and 36 identities	Simulation analyses to (1) Slovenia's choice of participating in the exchange rate mechanism of the European Monetary System and (2) Effects of Slovenia's adoption of the euro as legal tender	The model combines Keynesian and neoclassical elements. It is demand driven and persistent disequilibria in the goods and labor markets are possible. The supply side incorporates neoclassical features.
Akbar, M. (2011)	Production sector, Private sector, Public sector, Overseas	Annual data 1964-2007/ Efficient GMM procedure based	Deterministic simulation experiments have been conducted for validation of the model, for goal-	The C. C. structural approach is followed for construction of the model which is based on a small open economy IS-LM-BOP, AD-AS

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<b>Author (Year)/ Country</b>	<b>Level of disaggregation</b>	<b>Data/ Estimation Technique/ NO. of equations</b>	<b>Simulation experiments</b>	<b>Any other remarks</b>
	sector, Monetary sector and Prices.	on 2SLS estimates 67 behavioral equations and 85 identities	seeking analysis, for analyzing shocks to the economy, for multiplier analysis and for proposed scenario	framework. Supply side and demand side of the economy is disaggregated and are linked up. Further, domestic and foreign public borrowings are linked up to public sector and overseas sector on sound analytical basis. Prices and monetary sector are also considered and linked up to demand and supply side of the economy.

## **5. Summary and Conclusion**

The article is divided into four sections. After introduction, we have described the meanings and objectives of macroeconometric modeling. Testing of economic theories, policy evaluation and forecasting are found to be the main objectives. The second section describes historic background. It describes the Cowles Commission contributions and later advancements. It also discusses the criticisms raised by different critics and the answers by the followers of the Cowles Commission approach. Forecasting inadequacy, wrong theoretical foundations, structural instability and endogenous-exogenous division of the variables were the main points of criticism. The responses to the critiques took a two-way track. One was the development of alternative approaches to Cowles Commission approach which include VAR model, dynamic stochastic general equilibrium model, Hendry methodology and Leamer methodology. These alternative approaches are discussed in a separate sub-section. The second was the modification of the traditional approach which includes incorporation of supply side economics, microfoundations, rational expectations or model's consistent expectations and open economy macroeconomics. Major types of macroeconomic modeling are also discussed in a separate sub-section. Macroeconometric modeling and computable general equilibrium modeling are the two basic types of macroeconomic modeling which are mainly based on macroeconomic and microeconomic theories respectively. After historic background, a review of some selected macroeconometric models, which are available in the published literature, is presented. Most of the models are simultaneous equations models, which have been estimated by 2SLS method and OLS method using error correction mechanism. The equations of these models have been divided into different blocks.

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