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HISTORY OF MACROECONOMETRIC MODELLING: LESSONS FROM PAST EXPERIENCE*

By

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ABSTRACT

This paper reviews briefly the general literature on macroeconometric modelling and highlights some important lessons from more than half a century of model-building. It appears that from the late 1940s to the 1960s this field has contributed to the expanding knowledge of both economists and econometricians. However, from the early 1970s, several issues invalidated macroeconometric models. These issues are: theoretical contrasts with rational expectations theory, structural instability, the arbitrary division of endo-exogenous variables of the model, the existence of the problem of unit roots (spurious regressions) and insufficient amount of econometric "know-how". It is argued that with advancement of econometric "know-how", the disparity of opinions between advocates and critics of macroeconometric modelling can be narrowed.

INTRODUCTION

The origin of macroeconometric modelling dates back to after World War II when Marschak organised a special team at the Cowles Commission by inviting luminaries such as Tjalling Koopmans, Kenneth Arrow, Trygve Haavelmo, T.W. Anderson, Lawrence Klein, G. Debreu, Leonid Hurwitz, Harry Markowitz, and Franco Modigliani (Diebold, 1998). Since then macroeconometric modelling has undergone major changes. The main

* I wish to acknowledge Professor Ronald G Bodkin, of the University of Ottawa, for his useful comments on a previous draft of this paper. The usual caveat applies.

objective of this paper is to review the literature on macroeconometric modelling and highlights some important lessons from more than half a century of model-building.

However prior to undertaking a historical review of macroeconometric modelling it is important to define a number of technical terms and present a classification of macroeconometric models (MEMs). A MEM is a set of behavioural equations, as well as institutional and definitional relationships representing the main behaviours of economic agents and the operations of an economy. The equations, or behavioural relations, can be empirically validated to capture the structure of a macroeconomy, and can then be used to simulate the effects of policy changes. In this context it is useful to consider some definitions of macroeconometric modelling provided by some leading luminaries in this field.

First, consider the following statement by a nobel prizewinner, Lawrence Klein: "a schematic simplification that strips away the non-essential aspects to reveal the inner working, shapes, or design of a more complicated mechanism" (Klein, 1983: 1). This statement emphasises the simplifying characteristic of a model. The second definition suggests that "a macroeconometric system is a macro system whose relationships are numerical. This means: (a) that all relationships have specific mathematical form characterised by various parameters (intercepts, coefficients of variables, exponents of variables, etc.); and (b) that all parameters appear as specific numbers, having been estimated in one way or another from the relevant statistical data" (Challen and Hagger, 1983: 2). This definition highlights the technical properties of econometric analysis of the data.

A third conception defines macroeconometric modelling as being "a reproducible framework for systematic thought about economic phenomena" (Howrey *et al.*, 1981: 23). This quotation emphasises that a MEM involves systematic reasoning about the how the economy works. A fourth definition suggests that "modelling is an instrumental activity [involving], the explanation of some particular data set of interest [and] is designed to contribute to better decisions as a result of greater economic understanding" (Pesaran and Smith, 1985: 127). This statement points to the utility of MEMs in the decision making process. The last definition considered here indicates that macroeconometric modelling is an exact science which "provide[s] a formal and quantified framework that is an irreplaceable adjunct to the processes of policy thought" (Wallis, 1993: 113). This definition highlights the fact that MEMs are unique tools for policy evaluation by using a quantified and systematic framework of analysis.

Therefore, it is clear that macroeconometric modelling is multi-dimensional and both a science and an art. However, as a summary of these definitions, a MEM can be defined as a quantitative analysis of an economy via the estimation or computation of an interrelated system of equations using economic theory, data and a good knowledge of econometrics to achieve three objectives, *viz.,* structural analysis, forecasting and policy evaluation. These three purposes correspond, respectively, to the descriptive, predictive, and prescriptive uses of econometrics (Intriligator, Bodkin and Hsiao, 1996: 430).

Attention is now directed to a dichotomy associated with macroeconomic models. According to Bautista (1988) and Capros, Karadeloglou and Mentzas (1990) there are basically two types of macroeconomic models: first, MEMs, and second computable general equilibrium (CGE) models. It is also relevant to consider different types of MEMs.

Challen and Hagger (1983: 2-22) classify MEM into five categories: the KK (Keynes-Klein) model, the PB (Phillips-Bergstrom) model, the WJ (Walras-Johansen) model, the WL (Walras-Leontief) model, and finally the MS (Muth-Sargent) model.

The main purpose of the KK model is to explain the Keynesian demand-oriented model of macroeconomic fluctuations. This model deals with the problems of short-run instability of output and employment using mainly fiscal policy. The basic Keynesian model has been criticised as it does not consider the supply side and the incorporation of the neoclassical production function. Furthermore, this model does not give adequate attention to the role of the money market, relative prices and expectations. In this respect, the St Louis model was constructed by the monetarist critics (Anderson and Carlson, 1970) in order to highlight the impacts of money on the real variables in the economy.

Five noteworthy characteristics of the KK models are: first, they assume that there is economy-wide clearing in the product market, implying that aggregate desired demand always equals aggregate supply. Second, this model is formulated on the basis of discrete time (*i.e.* annually, quarterly, monthly etc.) not on the basis of continuous time. Third, the use of lagged dependent and independent variables gives a dynamic dimension to the model. Fourth, the KK model is known to be non-linear even though only one of the relationships has been postulated non-linearly. Fifth, the KK model captures stochastic behaviour by incorporating a random disturbance term.

The second type of MEM, the PB, emerged in the literature when Phillips (1954, 1957) used both the Keynesian and the Neoclassical theories within a dynamic and continuous time model to analyse stabilisation policy.[1] The PB model is also a demand-

[1] For a recent and detailed background see Bergstrom (1990).

oriented model. Generally speaking, the PB model mainly employs differential or difference equations to estimate the structural parameters of a stochastic model. Thus, in this approach the steady state and asymptotic properties of models are examined in a continuous time framework. However, this method is difficult to implement especially for large scale models.

The third type of MEM, the WJ, is mainly a multi-sector model. Walras (1954) postulates that the economy consists of various interdependent markets, which reach an equilibrium state by the profit maximising behaviour of producers and utility maximising of consumers in competitive markets. The various sectors in the WJ model are linked together via their purchases and sales from, and to, each other. The WJ model is highly non-linear and uses logarithmic differentiation. This means, given the percentage changes in the predetermined variables at a point of time, the percentage changes in the endogenous variables can be computed.[2]

The fourth type of MEMs is the WL model, which has been more widely known as the most appropriate MEM for developing countries (Challen and Hagger, 1983). The WL model is an example of a general equilibrium system. This type of modelling incorporates an input-output table into the Walrasian general equilibrium system. By using an input-output table, given the values of the sectoral, or aggregate, final demand components, the sectoral output (or value added) can be obtained.

The fifth type of MEM, the MS, is based on the evolution of the theory of rational expectations. The MS model is very similar to the KK model with regard to being dynamic, non-linear, stochastic and incorporating the use of discrete time. One of the

[2] For example, given the growth potential of the economy, the WJ model determines the various policy impacts such as changes in tariffs, taxes etc. on sectoral output, income, employment and prices.

distinguishing features of the MS model pertains to the formation of expectations. In this model the formation of expectations is no longer a function of previous values of dependent variables. In fact, the expectation variables are not observed values, but can be obtained when the complete model is solved. By highlighting the role of the supply side and expectations in this model, the New Classical School aims at interpreting the inadequacy of demand management policies. On these grounds, Sargent (1976) devised a forward-looking MEM. Variants of this model indicate that there is no trade-off between inflation and unemployment in the short term, which is in contrast to both the Keynesian and Monetarist modelling perspective.

It is noteworthy that the subsequent advances in the WJ and WL models led to the formulation of CGE modelling, which is categorised here as the second type of macroeconomic model. The Neoclassical CGE models are based on the optimising behaviour of economic agents. The main objectives of CGE models are to conduct policy analysis on resource economics, international trade, efficient sectoral production and income distribution (Capros, Karadeloglou and Mentzas, 1990).

The distinction between MEMs and CGE models can be related to the time horizon. The (early) CGE models involve comparative statics. This means that the CGE models generate the values of endogenous variables, but only for an initial equilibrium and a new equilibrium after shocks are imposed. The CGE models do not convey information on the adjustment process and only provide a snapshot of the macroeconomy. More recently, some CGE models, *e.g.* Dixon and Malakellis (1995), involve a dynamic adjustment process which can be used for short-term (3 to 5 years) and medium-term (5 to 7 years) analysis. However, MEMs provide information on the dynamics of the adjustment

process, which is useful for short-term and medium-term forecasting and policy analysis. But it has been stated that neither CGE models nor other approaches such as vector autoregression (VAR) models "can replace the approach of structural modelling and the formal use of econometrics as the best tool for policy analysis at the macro level" (Hall, 1995: 983). However, it should be noted that these distinctions are now somewhat blurred as, *e.g.* some CGE models are now being linked to econometric models thus producing a complementary, rather than a substitutable, relationship between them. See, *e.g.* Murphy and Brooker (1994).

The rest of this paper is structured as follows. The next section presents a concise historical review of the origins of MEMs in developed and developing countries, and derives some lessons from more than half a century experience. In the penultimate section of the paper, I review the major criticisms of macroeconometric modelling, including that of Lucas (1976). Responses of some leading model-builders to these criticisms are also presented in this section. The last section provides some concluding remarks.

A BRIEF LITERATURE REVIEW OF MACROECONOMETRIC MODELLING

Macroeconometric modelling has an interesting history of more than half a century. Initially MEMs were constructed to implement Keynes' General Theory. However with the passage of time other alternative paradigms such as monetarist, New Keynesian and New Classical have been incorporated into MEMs (Bodkin, Klein and Marwah, 1986b). In the following sections a brief literature review of macroeconometric modelling is presented for two categories of countries, *viz.* developed and developing. It should be mentioned that these sections highlight only some general trends in macroeconometric modelling.

Needless to say, providing a review of the macroeconometric modelling literature is beyond the scop of this study. For a comprehensive literature review of MEMs see Bodkin, Klein and Marwah (1986a, 1986b), Bodkin (1988a, 1988b) and Bodkin, Klein and Marwah (1991).

Macroeconometric modelling in developed countries

Tinbergen is a pioneer of macroeconometric modelling. Prior to World War II he constructed a MEM for the Dutch economy. The major purpose of his model was to assist the Dutch Central Planning Bureau in formulating appropriate economic policy. Another important step was also taken by Tinbergen in his seminal work in 1939 on business cycle analysis of the US economy (Bodkin, Klein and Marwah, 1991).

After World War II macroeconometric modelling was developed in earnest when Marschak organised a special team at the Cowles Commission. An interesting feature of macro modelling in this group was that there were three divisions to undertake the modelling procedures: first, economic theory or model specification; second, statistical inference (including model estimation, diagnostic tests and applications); and third, model construction which was dealing with data preparation and computations. The use of a team approach in macroeconometric modelling has been regarded as both cause and effect of large scale macroeconometric modelling (Intriligator, Bodkin and Hsiao, 1996). Klein joined this team and conducted his first attempt in the mid 1940s to build a MEM for the US economy. See Klein (1983), Bodkin, Klein and Marwah (1991) and Intriligator, Bodkin and Hsiao (1996) for discussions of the MEMs which have been constructed for developed countries such as the Klein interwar model, the Klein-Goldberger model, the

Wharton model, the DRI (Data Resources. Inc.) model, the CANDIDE model, the Brooking model etc.

The 1960s witnessed the flowering of the large scale macroeconometric modelling. This decade saw the construction of the Brookings model, in which an input-output table was incorporated into the model. Adopting the team approach in modelling procedure in the 1970s, the majority of model builders aimed at the commercialisation of the comprehensive macro models, such as DRI, Wharton and Chase, by providing information to private enterprises. Modellers designed their models on the basis of quarterly or monthly data with the goal of keeping the models up-to-date, for commercial gain. As a consequence of taking such measures, model-builders became commercially successful (Fair, 1987). It is believed that in this era, the full-grown models "would contribute substantively to enlarging our understanding of economic processes and to solving real-world economic problems" (Sowey and Hargreaves, 1991: 600).

During the last three decades, MEMs have been internationalised via Project LINK which was first operated at the University of Pennsylvania. In 1987 according to Bodkin (1988b) Project LINK consisted of 79 MEMs of individual countries or aggregations. In Project LINK the world is treated as a closed system of approximately 20,000 equations which "allow trade, capita flows, and possible exchange rate and other repercussions to influence systematically the individual national economies" (Bodkin, 1988b: 222).

Macroeconometric modelling in developing countries

Macroeconometric modelling in developing countries has also a relatively long history. The first MEM for a developing country was constructed by Narasimham (1956) for India

under the supervision of Tinbergen. The earliest models for developing countries were small versions of the KK model capturing the demand side of the economy.

According to Nugent (1975), over time with the relative improvement in the quality and length of time series data, the early models were modified in four areas. First, later MEMs incorporated neoclassical formulations by underlining the role of relative prices and profit maximisation. Second, some of these models emphasised the importance of expectations and lag formulations. Third, other MEMs incorporated an input-output table in the production side. Fourth, some modellers tried to link MEMs with long-run planning models.

Given the objective of forecasting the foreign capital needs of developing countries, ECAFE (1968) and UNCTAD (1973) constructed a series of MEMS for about 40 developing countries. However, Shourie (1972) criticised these models on the basis of three major deficiencies, *viz.*, insufficient sample size, multicollinearity, and mis-specification of the models. In a response to this critique, it is argued that the UNCTAD models "exhibit a fair measure of stability and provide a reasonable basis for projections" (Sastry, 1975: 158). Nevertheless, to some extent Sastry reiterated (1975) Shourie's criticisms, and pointed out that these deficiencies may not only be true in the context of developing countries, but might also be relevant in the case of developed countries. Sastry (1975) stated that MEMs can be useful if the value of the key parameters are checked and compared with those of other countries with a similar economic structure.

Evaluating some simulations for 10 MEMs for 10 different countries[3], Adams and Vial (1991) highlighted four important issues. First, inflation was highly related to the

[3] These countries are Brazil, Chile, Hong Kong, India, Korea, Mexico, the Philippines, Taiwan, Thailand, and Venezuela.

performance of the monetary sector. Second, the impact of government investment on economic growth was lower than that of the government consumption. This contradicted the expected outcomes and was associated with mis-specification or the absence of appropriate linkages between investment with production capacity. Third, the simulation performance of the MEMs was shown to be more accurate in the short-term than the long term. Fourth, it is concluded that the majority of these models suffer from excessive "Keynesianism", that means the modellers gave insufficient attention to the role of the supply side in the long run.

The persistent economic predicaments in many developing countries such as stagflation, trade and budget deficits, and enormous debt burdens led a significant number of developing countries to use MEMs. See, *inter alia*, Ichimura and Matsumoto (1994) and Uebe (1995). Nonetheless, there are some limitations in these models which should be considered. Corden (1985) discusses the relevance of the recent developments in Keynesian public choice and rational expectations theories for the implementation in developing countries. On the other hand, Seers (1963) criticised the application to developing countries of models which were appropriate for developed countries, since they had been designed for different purposes and thoroughly diverse economic structures.

Klein (1965, 1989a) suggested that a Keynesian MEM which is relevant to developed countries can also be appropriate for developing countries provided that relevant modifications are undertaken particularly in the specification of investment and production functions. In this regard, Bodkin, Klein and Marwah (1986a) recommended that special attention should be directed to the specification of price, wage, interest rate

and exchange rate relationships on the one hand, and on the other unemployment, channels of distribution and demographic characteristics.

It is also argued that the economic development obstacles in developing countries are not due to having adequate effective demand, but are associated with the supply constraints. Therefore, model-builders should take account of production inter-dependencies by incorporating an input-output (IO) table. In other words, in a developing country where intermediate demands among various sectors are of a large magnitude, the implementation of an IO table is very important. By using an IO table in a MEM, the supply side has not been neglected since both intermediate and final demand encompass demand for capital goods and other factors of production (Klein, 1965: 323).

It is imperative to point out that the availability of data in most developing countries is a restrictive factor. Indeed, model-building is an arduous task since there are relatively few reliable databases and they are subject to frequent revisions. For this reason, one should use robust and simple methods which are not too sensitive to data quality. The application of equation system methods of estimation such as maximum likelihood must be avoided under these circumstances (Klein, 1989b: 297).

Behrman and Hanson (1979) also argued that macroeconometric modelling is useful for developing countries if the appropriate modifications are undertaken. For instance, they mention that there are some potential policy variables which are obviously subject to change. Therefore, these variables should not be assumed to remain constant over the period under study. In their view, the use of a fixed and overvalued exchange rate is a clear example which should be contemplated.

In order to construct suitable MEMs for developing countries Khayum (1991) calls attention to two important issues. The first relates to the way in which the financial sector is modelled. He states that, in most cases when the financial sector is modelled, interest rate is not always an appropriate variable to link the real sector to the financial sector. Khayum (1991) suggests the use of some other variables as proxies like banking credit, output or inflation. Khayum's second point concerns the modelling of investment equations. Given the vigorous impacts of investment on both the supply and demand sides, he argues that in any MEM for developing countries substantial attention should be placed on capital formation.

Lessons from past experience

After more than half a century of macro-modelling, the question arises of, what are the main lessons that can be learned from the experience of the developed countries. This section discusses some of the lessons proposed by leading model-builders.

According to Bodkin, Klein and Marwah (1988a, 1991) the new generation of modellers should take advantage of the current developments to build large scale MEMs and run various econometric diagnostic tests. These current development consists of improvements in computational capacity, new developments in econometric methods, new macroeconomic theories and advances in the quality and availability of the required data.

However, in construction of large scale models there is a data limitation in that the number of observations should exceed the number of stochastic equations plus the number of predetermined variables (Kloek, 1988: 369). Since the analysis of the economy will be more difficult when there are numerous equations in the model, advocates of small scale

modelling conclude that the small model can explain the economy in a better way.[4] They believe that it is "much easier to see the forest when the trees are fewer" (Bodkin and Marwah, 1988a: 301).

In addition, Bodkin, Klein and Marwah (1991) highlight the following important lessons from past experience. First, although there are occasional structural, cyclical, and regime shifts which must be taken into account, linearity usually is the best approximation for estimation of a system of equations. Second, a complete model encompasses three sub models, *viz.* national income, input-output and flow of funds. Third, the iterative transition from theory to empirical specifications is inevitable in macroeconometric model building in order to obtain superior and theoretically consistent results.

Apart from the above-mentioned issues, there are some other notable lessons from past experience, which can be classified as follows. First, the model-builder should give adequate attention to data quality and the use of appropriate and validated economic theory (Sowey and Hargreaves, 1991: 601). Second, the model-builder should appropriately handle proxies, measurement errors, additional variables, functional form, dynamic structure and stochastic specification (Pesaran and Smith, 1985: 128). Third, causality, parameter interpretation, identification and time series properties of the data should be carefully addressed (Kloek, 1988). Fourth, it is important to contemplate the micro foundations of the model. However, in this regard Schlicht (1985) suggests that even without having a comprehensive knowledge of microeonomic foundations, one can still construct a MEM and obtain fairly reasonable results. On the other hand, Fisher (1983), Houthakker (1956), and Stiglitz (1969) mention that, due to the differences in the

[4] Further arguments from advocates and critics of large scale models can be found in Friend and Taubman (1964), Fair (1971, 1974), Kmenta and Ramsey (1981), and Klein (1989a).

qualitative relationships between micro and macro laws, the generalisation of microeconomic rules to a macro level does not usually yield consistent generalisation.

CRITICISMS OF MACROECONOMETRIC MODELLING

From the 1970s onward, macroeconometric modelling was criticised predominantly on academic grounds. According to Pesaran (1995) the major criticisms of the traditional MEMs based on the Cowles commission approach can be summarised in terms of six issues: first, forecasting inadequacy; second, theoretical contrasts with rational expectations theory; third, structural instability (Lucas critique); fourth, arbitrary assumption of zero restrictions and the endo-exogenous division of the model variables in order to pass the identification conditions; sixth, the existence of the problem of unit roots and ignorance of the time-series properties.

However, the Lucas (1976) critique, *inter alia*, had a powerful influence in decreasing the application of MEMs for policy analysis. The Lucas critique led to a new area of research which is referred to as analysis of "deep structural parameters" (Fair, 1987). It is mentioned that under alternative policy formulations, because all the economic agents base their decisions on the full information, "any change in policy will systematically alter the structure of econometric models" (Lucas, 1976: 41). Therefore, it is highly likely that the estimated coefficients of a MEM will vary as a result of agents anticipating and knowing policy measures. Consequently, Lucas rejects the use of MEMs for the policy analysis.

In criticising the Cowles commission approach, which is based on the structural multi-equation modelling, three methodological alternatives of modelling have emerged in

the literature, those by Sims (1980, 1982), Leamer (1983), and Hendry (1980), which are reviewed briefly below. See Pagan (1987), and Darnell and Evans (1990) for a concise and comprehensive critical appraisal of these three methodologies.

First is Sims's atheoretical VAR, which underscores the role of data with no theoretical foundation. In this type of modelling there is no exogenous variable and consequently no endo-exogenous division of the variables in the system. Sims's methodology suggests that the traditional macroeconometric modelling is badly under-identified. Therefore, the VARs approach has been proposed in which an unrestricted reduced form is estimated. This approach is extremely difficult to implement when there are more than five variables due to "overparameterization" and resultant multicollinearity.

Second, Leamer's methodology starts with redefining the concept of exogeneity. In this methodology, the conditional distribution of y given x remains stable to any changes in x (where y and x are endogenous and exogenous variables, respectively). In other words, Leamer defines a variable as an exogenous variable to which the Lucas critique does not apply. His approach is heavily based on the OLS method and the implementation of the Bayesian approach. The main message of Leamer is that "pure macroeconometric modelling can never replace judgement in the formulation of wise economic policies, or even in the tentative assessment of the state of the world" (Bodkin, Klein and Marwah ,1991: 551).

Third, the Hendry methodology is known as the "general to specific modelling approach" in the literature. This approach starts with a general dynamic autoregressive distributed lag (ADL) model which is postulated in terms of economic theory. Then, by performing a number of likelihood ratio restriction tests on this model, a specific model

can be obtained, so that it is congruent with the data generation process (DGP). In other words, theory determines the explanatory variables, whereas the static or dynamic nature of the relationship will be defined by the data. The model evaluation in this methodology is extensively examined by a battery of diagnostic tests based on forecasting performance and residuals. One should note that Hendry in all his empirical studies "only provides the value of a test statistic comparing the two models at each end of the path, with very little discussion (if any) of the route followed from one end to the other" (Pagan, 1987: 7). In other words, passing different types of diagnostic tests is a necessary but not sufficient condition. In addition, Hendry's approach expects too much from the data. In this respect, Griliches (1986) states that "we want them [the data] to test our theories, provide us with estimates of important parameters, and disclose to us the exact time form of the interrelationships between the variables" (Intriligator, Bodkin and Hsiao, 1996: 175).[5]

In order to have a balanced and fair discussion, the responses of some of the leading model-builders to the criticisms presented here are provided in the rest of this section. For instance, Bodkin, Klein and Marwah (1986a, 1991) responded to these criticisms resorting to Eckstein's (1983) investigation of the DRI model and the reliable forecasting performance of MEMs, as investigated by McNees (1979) and Zarnowitz (1978). On the basis of these empirical investigations, they state that: "We feel that the track record of continuing macro-econometric modellers is not so bad as the occasional horror story of an unsuccessful forecast would suggest....Compared to their alternative (naive models, time series analysis of single series, or judgmental forecasts) the

[5] Engle and Hendry (1989, 1993) also proposed the concept of superexogeneity testing to investigate the validity of the Lucas critique. It is argued that if x_t (as an exogenous variable) is superexogeneous with respect to y_t (as a dependent variable), it can be concluded that the Lucas critique does not apply.

econometric models do reasonable well, particularly as the forecasting horizon lengthens" (Bodkin, Klein and Marwah, 1986a: 50).

Klein (1989a) acknowledges the 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" (p. 290).

In a rebuttal to the theory of rational expectations and the Lucas critique, Bodkin and Marwah (1988a) draw attention to the irrational assumption of the rational expectations theory with respect to the complete access of the typical economic agent to the raw data and the true model of the economy. They contend that these assumptions are most unrealistic and cannot be accepted. Nevertheless, they acknowledge the New Classical School for raising such a vital issue, and suggest further clarification and research on expectations formation.

Hendry and Richard (1983) assert that the MEMs can nevertheless be applicable if the following issues are addressed. The first point is referred to as "data admissibility" which means that the domain of an economic variable should be placed in an accepted range. Second, there should be consistency between the economic theory and the interpretation of parameters of the model, *i.e.* an appropriate theory should support the signs of the estimated parameters. Third, estimated parameters remain stable over the period under study. Fourth, the model must be data coherent, which means that the residuals should be random and not predictable from their path. In other words, the stochastic residuals must be stationary. Fifth, an exogeneity test should be undertaken to

ensure that the explanatory variables are at least weakly exogenous. Sixth, an encompassing test is also suggested to be undertaken to test whether the estimated model is superior to all the alternative rival models.

Pesaran and Smith (1985) support macroeconometric modelling on much the same grounds as Hendry and Richard (1983) but also emphasise some additional points. First, they argue that a model should be relevant to the purpose of construction. Second, they suggest that empirical results should be consistent with theoretical propositions. The evaluation of models with different levels of exogeneity can be done by using the above-mentioned two criteria. Third, they argue that the estimated model should be adequate. The model adequacy itself can be investigated at two levels: models with the same exogeneity and/or specification assumptions and models with different levels of exogeneity. Pesaran and Smith referred to relevancy and consistency, the first two conditions, as necessary or admissibility conditions. However, the sufficient condition amongst comparable models implies further investigation and comparison via two approaches, namely model selection and hypothesis testing.

The model selection criteria minimise an expected loss function in order to identify a good model. Some of the model selection criteria are, Theil's adjusted R^2, Mallows' C_p criterion, Amemiya's prediction criterion, Akaike's information criterion, Generalised Cross Validation criteria, and Schwarz's Bayesian information criterion.

On the other hand, hypothesis testing deals with a null hypothesis against relevant alternative hypotheses, which are of substantial concern. Pesaran and Smith (1985) classify the hypothesis tests into three broad categories: first, general specification tests such as the Hausman and Ramsey tests; second, diagnostic tests such as Wald, Likelihood

Ratio, Lagrange Multiplier, Chow test, ARCH test, CUSUM test etc.; and third, non-nested tests.

Another issue in the usefulness of a MEM pertains to the *ex ante* forecasting performance of a model outside the estimation period. Nevertheless, sometimes *ex ante* forecasting is difficult to assess since a wide range of propositions regarding the exogenous variables are set by forecasters. See McNees (1982) and Smith (1984) for a detailed discussion of this issue.

It has also been suggested by Charemza and Deadman (1992) that econometricians before undertaking any econometric modelling should have a good knowledge of economic theory, access to reliable data sources, adequate knowledge about econometric estimation theory, and a good "know-how" or methodology. This "know-how" assists model-builders to combine and evaluate the economic theory, the statistical data and the econometric estimation theory in order to obtain an ideal model. A major reason for the failure of some of the traditional econometricians to develop tractable MEMs in the 1970s and 1980s, pertains to the lack of the above-mentioned requirements.

Intriligator, Bodkin and Hsiao (1996) assert that MEMs are useful in structural analysis, forecasting and policy evaluation provided that they are subjected to some parametric tests prior to and after the release. The tests they recommend, which are of paramount importance in evaluating the validity of MEMs, can be classified into two major categories: testing for individual equations of the model and testing for the full model (system) as a whole.

The first category consists of four sub-tests: first, the standard t and F tests to check for the statistical significance of the estimated parameters; second, testing for the

expected theoretical signs of the estimated parameters; third, diagnostic tests for checking various violations of the classical linear regression model such as normality, autocorrelation and serial correlation, heteroskedasticity, functional form, etc.; fourth, checking for the stability of the estimated equation by the Chow test to make sure the equation is stable over time. According to Intriligator, Bodkin and Hsiao (1996: 575) the break in structure of an equation can be "patched up" by insertion of an intercept dummy variable.

The second category consists of three sub-tests: first, the dynamic tracking performance of the full model as a system or *gestalt* should be evaluated in terms of some goodness-of-fit statistics such as the Theil inequality coefficient, the root-mean-square error (RMSE) etc.; second, the dynamic response of the full model should be evaluated in terms of impact and interim multipliers; third, before releasing a MEM and its results, the model-builder should check whether the resulting policy simulations are in line with theoretical expectations. The simulation results are not supposed to be counter-intuitive, but if they are, adequate interpretations should be provided.

As seen from the literature, the Lucas-type critiques resulted in an upgrading of the theoretical knowledge and in better empirical achievements by econometricians. This is to say, the significant advances in the macroeconometric literature including rational expectations theory, supply-side economic policy, and open economy macroeconomics have given rise to further research in this field. According to many macroeconometric model-builders, to a large extent, the implementation of the above-mentioned requirements, *i.e.* model selection, hypothesis testing, time series properties, essential tests prior to and after release, can settle the disparity of opinions between modellers and critics.

However, critics of MEMs should recognise that, compared with the VARs and CGE models, MEMs still remain "the most promising approach to understanding macroeconomic behaviour generally and is the most likely approach to provide a really powerful policy tool" (Hall, 1995: 975). By no means does macroeconometric modelling at present appear to be weaker than before. On the contrary, it "has weathered these storms rather well; indeed, it has probably emerged stronger as a result of the fundamental revaluation of the subject that has resulted from these attacks" (Intriligator, Bodkin, Hsiao, 1996: 9).

CONCLUSION

The purpose of this paper is to present a brief literature review on macroeconometric modelling. To this end, some selective basic concepts are provided including definitions and a classification of MEMs. A number of useful lessons are derived from the experience of macroeconometric modelling both in developed and developing countries. In addition, this study briefly discusses criticisms of macroeconometric modelling for policy analysis. In order to have a fair and balanced discussion, the responses of some of the leading model-builders to these criticisms have also been discussed.

A cursory look at the history of macroeconometric modelling in the period from the late 1940s to the 1960s shows that this field has contributed to the expanding knowledge of both economists and econometricians. However, from the early 1970s, several issues invalidated MEMs. These issues are: theoretical contrasts with rational expectations theory, structural instability, the arbitrary division of endo-exogenous

variables of the model, the existence of the problem of unit roots (spurious regressions) and insufficient amount of econometric "know-how".

Macroeconometric modelling in developing countries has been subject to criticisms on a greater scale because of the presence of an additional adverse factor of data unreliability. Apart from data problems which are inevitable, however, there are some specific modifications which should be implemented in constructing a MEM for each individual developing country to capture its specific structural peculiarities.

The criticism or failure of some MEMs has motivated econometricians to devise alternative methodologies. In this respect, three famous methodologies have been proposed by Sims, Leamer and Hendry. These new approaches have been briefly reviewed in this paper. It is argued that each one of them has some shortcomings.

Nevertheless, macroeconometric modelling can still be a unique tool, especially for policy formulations provided that a wide variety of investigations, particularly in relation to model selection, diagnostic tests and time series properties of the data, are undertaken. It seems that, with the advancement of econometric "know-how", the disparity of opinions between advocates and critics of macroeconometric modelling can be narrowed.

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