Macroeconometric Modelling for Policy Making: Retrospect and Prospects

*"**Economics is a science of thinking in terms of models joined to the art of choosing models which are relevant to the contemporary world**."*

John M. Keynes

Economic models are tools for thinking about economic problems. The central problem for monetary policy is how to maintain the value of the currency - *i.e.*, price stability. There is an important prior question: why bother with models at all? Could policy judgments not simply be based on observation of current economic developments, in the light of lessons from past experience of how the economy works? That is indeed the basis for policy judgments, but making them without the aid of models would be extraordinarily difficult. The lessons of past experience are by no means immediately - if ever - clear, nor is it easy to gauge how the economy might be operating differently now from how it has done in the past. This would mean that, the alternative to using an econometric model is to work with heaps of data tables and statements.

Well-chosen models simplify and clarify economic problems by focusing on the factors judged most essential to their understanding. Importantly, models are also frameworks for empirical quantification - both of how the economy has on average behaved in the past, and of the degree to which its current or prospective behaviour might differ. For these general but practical reasons, monetary policy needs economic models. In an ever-changing economy, no single model can possibly assimilate in a comprehensible way all the factors that matter for policy. Forming judgments about those factors, and their implications for policy, is the job of the monetary policy makers, not something that can be abdicated to models or even to modelers. Nevertheless economic models are indispensable tools in that process.

Many central banks in the world are using econometric models in their decision making process. But the use of econometric models encounters growing theoretical and empirical challenges in the decision-making process. First, the present state of uncertainty in economic theory is so high that there is no consensus on key problems for central bankers such as the interaction of a causality link between money and real variables. Second, the move towards more international integration and financial deregulation since mid-1970s has provoked changes in the institutional environment by extending the sources of shocks on economic behaviours, just at a time when central banks committed to stabilisation of the nominal anchors (exchange rates, or money growth *etc*.,).

The paper is organised as follows. Section I provides a brief review of monetary models and contemporary developments in theoretical and empirical monetary economic literature. Section II provides a review of modelling efforts in the Indian context during the last fifty years. Section III provides a critical assessment of the economic models in India keeping in view the on-going structural transformation of the economy and challenges for researchers. Section IV concludes with a perspective for the future.

I. Evolution of Modelling Techniques and Guiding Principles

Economic models are useful for policy in several ways. By using an economic model, a policy maker can assess the impact of a particular economic development, and policy choice or action, on the economy without having to actually face the shock or implement the policy. More importantly, economic models impose structure and eliminate fuzzy thinking by forcing economists to formalise views that may be based largely on intuitions (Coletti and Murchison, 2002). Although, from policy perspective, judgments assume high importance, they may at times be construed as *ad hoc* decisions and thus, affect credibility of policy actions. Economic models, while providing a scientific basis to judgements, serve to enhance policy credibility.

The construction of and the analyses with an econometric model require an artful combination of the theories and the methods of economics, statistics and econometrics. Econometric modeling, which is itself directed by economic theory and by perceptions of the real economy, constitutes one of the most widely accepted means in the attempts to understand the interrelationships and interactions between economic variables. Good models require good data--that alone would be reason enough to devote effort to economic measurement. There are, of course, statistical approaches that can be implemented to deal with shortcomings in the data, but these are weak substitutes for making progress on measurement.

A macroeconometric model, like any other model, represents a compromise between reality and manageability. A model should be realistic in the sense of incorporating the main elements of the real world phenomenon and at the same time, it should be manageable so as to generate insights nor readily obtainable from direct observations of the real world. Either extreme is undesirable. The models which are highly realistic but hardly manageable are virtually useless and there is no need to develop such models in the first place. On the other hand, as indicated by Intriligator (1977), models which are overly manageable but grossly unrealistic may lead to conclusions which are totally misleading and, at times, even perilous. The essence of good modelling, thus, lies in striking the right balance between realism and manageability.

A model must be cohesive. A stack of equations, by itself, is meaningless, for what is important is that intricate inter-linkages among variables must be skillfully delineated so as to make the proposed model logical and realistic. It is in this sense that model building is as much an art as it is a science(Hendry,1995).

A macroeconometric model can serve one or more of the three basic objectives: explanation, prediction and evaluation. Macroeconometric models which are 'explanatory' in their focus, aim at structural analysis, *i.e.*, understanding the real world phenomena by quantitatively measuring, testing and validating economic relationships. In the broadest sense, such models attempt to enhance understanding of the working of the economy. 'Forecasting' type of macroeconometric models go a step beyond structural analysis and attempt to make quantitative predictions, often outside the sample period. Finally, macroeconometric models that emphasise 'policy evaluation' aim at assessing the implications of policy actions by simulating them and comparing the relevant conditional forecasts. Clearly, paucity of policy instruments may not be a serious constraint in respect of the 'explanatory' or 'forecasting' macroeconometric models, whereas in the case of the policy-oriented models, the usefulness is directly contingent upon the policy instruments embedded on the model.

At this juncture, it would be worthwhile to delineate the attributes of an ideal model. An "ideal" model should provide a complete description of the structure of the economy. The description need not be limited to the economy that is modeled but may also encompass the features of foreign economies that have the potential to feed back onto the performance of the domestic economy. The model should be linked to the observable world through accurate and timely data and would use estimation techniques capable of delivering well-identified estimates of structural parameters. It should include both sensible steady-state properties and accurate estimates of the dynamics that define short-run behavior. The model should be rich enough to embody all of the costs associated with inflation, deviations of output from potential, and with the higher moments associated with these variables. Though desirable, it is rather difficult to adhere to all the attributes of ideal economic model in practice. Some of the relevant issues that needs to be tackled, while building a model are the role of explicit expectations in models, the use of multiple models, the importance of judgmental adjustments to models, identifying model structural change, and the appropriate size and amount of detail in models. More importantly, there should be a constant endeavour to develop evidence against the model and revising the specification accordingly to improve the model.

There is no consensus as to what constitutes a monetary model. Macroeconomics literature suggests that there can be a variety of monetary models owing to different schools of thought such as classical, neo-classical new-classical, Keynesian and new-Keynesian paradigms. For monetarists with lineage to the classical tradition, monetary models are associated with money supply targeting with a fixed rule of constant money growth, quantity theory of money, *i.e.*, interest rate inelastic demand for money, absence of long run trade-off between inflation and growth, money induced long-run inflation, completely flexible prices and wages, interest elastic saving and investment, super neutrality of money with respect to real activity, monetary approach to balance of payments and exchange rate and above all non-discretionary monetary policy (Moorthy, et.al.,2000). More recent literature, however, suggests that monetary models could be envisaged without money aggregates but with monetary policy reaction function in respect of instruments such as interest rate. On the other hand, monetary models purely in the Keynesian tradition could be associated with the celebrated Phillips curve, which postulate a trade-off between inflation and unemployment or economic growth, sticky prices and wages, interest elastic demand for money, income induced saving and investment, absorption approach to balance of payment, and exchange rate, and above all an activist monetary policy for stabilisation of the economy tuned to the path of business cycle.

Real world may, however, operate quite differently from the calibration of theoretical models. In fact, following the argument of Sims(1981), it is not uncommon to find that several competing theoreies could be useful simultaneously for modelling the actual working of the economy. It is in this context that empirical economists, without any lineage to a particular school of thought, postulate monetary models, which essentially relate to monetary variables, and monetary transmission process within an interrelated instrument-indicator-target variables framework for analysing monetary policy effects on markets and the economy. Since monetary transmission entails various alternative channels pertaining to quantity of money and/or credit, interest rate, and exchange rate, and these channels also vary significantly across countries due to country specific elements characterising market structure and institutional developments, a truly monetary model should encompass all monetary variables; money aggregates, credit, the spectrum of interest rates and exchange rates. Monetary models, thus, may relate to various forms of money demand including its components, money supply process accounting for detailed sources of money, alternative policy instruments relating to interest rates, exchange rates, and cash reserves and the different policy objectives and reaction functions.

Formal models of the economy have important uses for central banks since they help ensure a consistent view of the transmission mechanism of monetary policy, identification of the shocks that have affected the economy and give a benchmark to analyse future developments and to communicate with the public (Stockton 2002, Meyer 2003). The growing literature on delayed effects of monetary policy adduced to transmission lags suggests that policy makers need to forecast the future path of the economy. Accurate forecasts, however, are only possible with a clear understanding of the structure of the economy and the shocks affecting it (Bank of England, 2000). In other words, models of the economy are valuable tools for monetary policymakers for at least two reasons (Rudebusch, 2004, Coletti and Murchison, 2002, Stockton, 2003). First, models can help central bankers to construct forecasts of the most likely evolution of the economy, particularly, the extent of future inflation, the economic growth rate, and changes in other variables which assume critical importance for forward looking policy analyses. Second, macroeconomic models can help quantify the amount of uncertainty that central banks face in making their policy choices-particularly through the use of alternative simulations and scenarios. Third, economic models can produce recommended paths for macroeconomic indicators, which approximate policy actions through changes in the instruments.

There are three broad categories of macro-economic models currently being considered for monetary policy analysis. One category contains calibrated or estimated general equilibrium (GE) models, which are closely based on a detailed theoretical structure that features explicitly optimising businesses and consumers. Focus on the empirical estimates of a structural equation is the hallmark of the second type of model used to analyse monetary policy: the structural macro-econometric model. Such structural macro-econometric models are the most common type of model used at central banks. These models, which continue a line of research over 50 years old, have been updated during the past decade or so with explicit expectations and better long-run properties. The third category of models contains those that are almost purely statistical in nature, particularly Vector Auto-Regressions (VARs).

From the standpoint of practices, and policy perspectives, central banks deploy economic models of different scope and size. Central banks use a suit of models to address a range of policy issues. As such monetary models encompass broadly three variants of large scale macroeconomic models, small macroeconomic models and single equation approaches to critical monetary variables. Large-scale and medium size macroeconomic models with monetary sector as an integral component for provide a comprehensive framework of analysis of the entire structure of an economy. These models facilitate analyses of monetary policy issues with a broader and deeper perspective. Small macro-econometric models range from the celebrated IS-LM-FB framework calibrating fundamental equilibrium and steady state conditions to time series models, in particular, vector auto-regression (VAR) models. Because of theoretical sophistications, small structural macroeconomic models based on major macroeconomic variables are considered more focused in nature and thus, are useful for a concise interpretation of the functioning of the economy. In recent years, time series models are extensively used for analysing dynamic interaction and simultaneous relationship among major economic variables. Single equation models such as demand for money, or money supply process relating to monetary aggregates and policy instruments derive justification for contextual analysis and event studies of policy actions.

As to the utility for central banks, models of the economy are valuable tools for monetary policy-makers for at least three reasons: First, such models can help produce forecasts of future inflation, output, and other variables, which are crucial for a forward-looking central banker who takes into account lags in the effects of monetary policy. Second, macro-economic models can help quantify the amount of uncertainty that central bankers face in making their policy choices - particularly through the use of alternative model simulations. Third, such models are used in a variety of "what if" scenarios and to explore the probability and consequences of risks faced by the policymakers. One of the most important attributes of a useful model is that it helps us to think clearly about the problem at hand.

The Federal Reserve Board has a long history of serious commitment to the development, improvement and use of large-scale structural macro-econometric models. The current version of the model in use at the Board is the so-called FRB/US model--a forward-looking structural model of the U.S. economy with about 60 stochastic equations and 300 identities.

A critical aspect of modelling relates to the choice between large macro-models and suite of models, the latter gaining prominence among central banks with time series approach becoming popular. In case of Fed, a great deal of modeling work takes place outside the core model, and it strongly subscribes to the "suite of models" approach. The usefulness of large-scale macroeconometric model remains, notwithstanding the significant investment of labor, both upfront and on an ongoing basis. Those costs may be worth bearing in order to have a model that can be judged against the data by rigorous measures of goodness of fit. Given the range of questions the central bankers are asked by policy makers, it is difficult to envision getting by solely on a much smaller model. Large models can be helpful in identifying shocks and dealing with structural change. Of course, there are some significant shortcomings that can be associated with the use of a large-scale structural macro-econometric models. For one, the very size and complexity that the central banker finds useful in answering the wide variety of questions they are asked to analyse and for gauging the reasonableness of model-based economic analysis, it comes with some downsides as well. There can be a thin line between the desire for completeness of the model and over-fitting the data. One hopes that tendency is curbed somewhat by the fact that those of us who use these models in the forecasting process will be around long enough to pay the penalty in terms of forecasting accuracy of that is imposed by over-fitting. But the risk is still there. If one's model leads frequently to a situation of perverse results, the benefits of transparency provided by the use a core model will be eroded.

Another problem with using a structural macro-econometric model estimated on historical data is that it seems sensible to have doubts about the usefulness of such a model in conducting analysis of policy experiments much outside the bounds of past historical experience. Despite the best efforts to separate expectational effects from costs of adjustment in FRB/US, there has been no great success for most of the analysis. For example, the current version of FRB/US model may not be of much use in predicting economic performance, say during a hyperinflation or for that matter a persistent deflation.

Sometimes small-scale econometric models, such as VARs, are used as a check on the results derived from large models. To be sure, congruence of results from the two approaches does not necessarily imply accuracy, just as difference does not necessarily signal a problem with the large model. But I think such comparisons can provide useful information about the degree of comfort one can feel with the robustness of the answers provided by large and complex models. In addition to econometric models, one can use small-calibrated models to provide guidance on some policy issues where estimated models are likely to be less useful.

What constitutes a good model will depend on the questions being asked of it. Another important use of small models at the Fed is for proto-typing specifications and structures that would be too difficult and expensive to incorporate in FRB/US without a reasonable sense that such alterations are warranted and useful. Those models often play a role in policy work long before they become formal features of the core model.

II. Macroeconometric Models in India

Macroeconometric model building is no longer a matter of esoterics in India. In the Indian context, macroeconomic models have a long tradition spanning five decades. Over the years, an increasing number of studies have resorted to quantitative analyses based on econometric techniques. As a result, macroeconometric model building has become an integral and essential part of many a research effort. With the growing influx of econometric models, stocktaking in the form of critical surveys is useful, as it provides new directions for research. Indeed, it is nearing five decades since the publication of the first Indian macroeconometric model (Narsimham 1956), and roughly three decades since Desai (1973) presented a useful survey of Indian macroeconometric models developed till the end of 1960s. Since then, model building activity has intensified. Several macroeconometric models have emerged which are not only larger in size but also more diverse, complex and technically sophisticated.

An extensive survey of all the Indian macroeconometric models in their entirety is a formidable task. The discussion here is confined to a more manageable task of surveying the monetary sector modelling in the Indian macroeconometric models, with due allowance for monetary transmission process characterising the feedbacks to and from the other sectors.

A comprehensive survey with different perspectives on a range of models is found in Jadhav(1994), Pandit(2003), and Krishnamurty (2004). On monetary modelling in the Indian context, researchers maintain bi-polar views. . In some quarters, it is argued that monetary models in India constitute a saga of frustration (Pandit, 2003). Others have viewed that monetary models for India reflects richness due to the variety of theoretical approaches and empirical anlyses.

(A) Taxonomy of Macroeconometric Models and Scope of the Survey

The survey presented here is confined only to the full-fledged simultaneous, multi-equation, multi-sector macroeconometric models. Several interesting econometric studies dealing with narrowly defined issues, such as the demand for money or the predictability of money multiplier, *etc*. within the confines of the monetary sector are ignored. Although important, these studies ought to find a place in relevant topical surveys rather than in a broader survey such as the present one[1].

The following 18 models have been selected for review in this survey.

1) Isher Ahluwalia (1979)
2) Rao D.C., Venkatachalam T.R. and Vasudevan A. (1981): RVV model
3) Madhur Srinivas, Pulin Nayak and Prannoy Roy (1982): MNR model
4) K. Krishnamurty (1984)
5) V. Pandit (1984)
6) P.K. Pani (1984)
7) T.K. Chakravarty (1987)
8) Narendra Jadhav and Balwant Singh (1990)
9) C. Rangarajan and R.R. Arif (1990): RA model
10) IEG-DSE Large scale model (1994)
11) Klien and Palanievel (1999): KP model
12) Rangarajan and Mohanty (1999): RM model
13) Bhattachraya, et.al., (1997)
14) Kaur and Kaur (1996)
15) Basu (1996)
16) Brahmananda, et.al.,(1992)
17) Ranjan and Nachane (2002)
18) Report on Currency and Finance Model (2001): RCF model

[1] In some cases one finds that the same author has more than one model to his or her credit. Krishnamurty (1964 and 1984); Pandit (1973, 1978 and 1984) are some better known examples. In such cases, only the latest version of the relevant model has been chosen for the survey.

The chosen models can be categorised broadly into two groups while taking note of structural transformation of the economy since early 1990s. Among the early models, which were developed before 1991, two of the chosen models, *viz*., Venklatachalam & Vasudevan (1981) and Madhur, Nayak & Roy (1982) are of the 'forecasting' variety; T.K. Chakavarty (1987) is 'policy-oriented', and the remaining six models are 'explanatory' in character. The explanatory models can be further classified into sub-groups, depending upon whether they are economy-wide or focused on a specific phenomenon. Among the six explanatory models, four models including Ahluwalia (1979), Krishnamurty (1984), Pani (1984), and Pandit (1984) are economy wide, whereas the remaining two [Jadhav Singh (1990) and Rangarajan Arif (1990)] focus on specific phenomena. Alternatively, the explanatory models could also be classified by their analytical foundations. Those which take a disaggregated approach to price formation, placing emphasis on 'structural' or 'institutional' factors besides the monetary factors may be termed as 'structuralist' models, whereas those which place an exclusive accent on the monetary factors in price behaviour may be regarded as falling in the so-called 'monetarist' tradition. According to this criterion, Krishnamurty (1984), Pani (1984) and Pandit (1984) may be classified as 'structuralist' models whereas Alhuwalia (1979), Jadhav-Singh (1990) and Rangarajan-Arif (1990), may be deemed to be in the 'monetarist' tradition.

During the 1990s, some major models emerged. Although these models share several common features with their earlier counterparts, they are significantly different, in particular, in the treatment of structural character of the Indian economy. In this regard, the structural economy-wide IEG-DSE (1999) model resemble to Pandit (1984) and Krishnamurty (1984). Another model which came around the same time, *i.e.,* Klein and Palanievel (1999) resembles, more or less to the structural tradition of IEG-DSE model but shares a specific character of detailed monetary block with a view to capturing the evolving financial market conditions in India. Rangarajan and Mohanty(1997) share the tradition set out by Rangarajan and Arif(1990). The RCF model is an exception for setting a new tradition, mainly, a modern monetarist model without money encompassing monetary policy reaction function and aggregate demand-aggregate supply equilibrium framework. Most other models are small in size and reflect a mix of attributes deriving from the major models.

All these models have been examined in the following sections. With a view to enhancing the readability and comparability, all models have been expressed in a standardised notation placed at the end of the chapter.

(A) Early Macroeconometric Models

The foundation of monetary modelling in India was laid by Mammen's model (1967) and G.S. Gupta's model (1973). This phase appears to have culminated in the Ahluwalia's model.

Ahluwalia's Model (1979)

Ahluwalia's model aims at analysing the behaviour of prices and outputs in the Indian economy while combining elements of structural, demand- pull, cost-push and monetary theories of inflation. Unlike the then existing models where the focus was on the components of aggregate demand, this model emphasises the disaggregation on the supply side, dealing with fluctuation in output, marketed surplus and the like.

The model has 67 equations and is estimated using annual data for the period 1950-51 to 1972-73. The monetary sector proper has three blocks: RBI, commercial banks and the non-bank public. Moreover, in addition to the real and fiscal sector, external sector is also incorporated in the model. The monetary sector of the model may be described as follows:

(i) Components of money supply

The stock of money in Ahluwalia's model is defined in terms of the narrow measure. M1 consisting of currency and demand deposits. The role of time deposits (and hence broad money M3) is incorporated separately. A distinctive feature of Ahluwalia's model is that demand functions for these components are couched in real terms, unlike Mammen's model or Gupta's wherein they are specified in nominal terms.

Demand for real currency holdings (C/P) is postulated as a positive function of real income (YR), but a negative function of the exogenously determined rate of return on short-term deposits (RS) and the expected inflation rate (π). Thus

$(C/P)=f(YR, RS, \pi)$

The demand for narrowly defined real money balances (M1/ P) has similar specification from which, the demand for demand deposits is derived residually. Thus

$(M1/P) = f(YR, Rs, \pi)$

$DD = (M1/P)-(C/P))P$

The ratio of time deposits (TD) to demand deposits (DD) is assumed to be positively related to real non-agricultural income (YNAR), and the exogenous rate of return on time deposits (RTD) but negatively related to the exogenously determined rate of return on government bonds (RG). Thus,

(TD/DD) = f (YNAR, RTD, RG

Demand for nominal time deposits (TD) is then derived simply as product of demand deposits and the ratio of TD to DD.

(ii) Portfolio of the RBI

Before discussing the portfolio of the RBI, it may be useful to briefly outline the fiscal sector in the model.

Government receipts are decomposed into direct tax revenues, from agriculture and from non-agricultural sector, indirect tax revenues from customs and other indirect tax revenues. Revenues are expressed as function of relevant sectoral outputs and the time trend excepting the customs revenues which are linked-up with the value of intermediate imports. On the expenditure side, government wages and salaries have been endogenised as a function of food prices and other revenue expenditure. Government`s capital expenditure is exogenous.

The resultant fiscal deficits feeds into the creation of reserve money. The change in reserve money(H)is modeled in the form of a recreation. Function, *i.e.*, it is assumed that the monetary authorities try to relate the change in reserve money (H) to the government's need to finance its fiscal deficit(FD), expected change in nominal income(proxied by the lagged actual) and their lagged stock of foreign assets. Thus,

$\Delta H = f(FD, \Delta YN_{-1}, RBNFA_{-1})$

The change in the RBI's holdings of foreign assets(RBNFA) is determined residually from the total change in foreign assets (NFA) generated in the external sector and exogenously determined change in holdsings of such assets by others (NFAO).

$\Delta RBNFA = \Delta NFA - \Delta NFAO$

Endogenous changes in monetary base (H) and in the RBI's holdings of net foreign assets (RBNFA) determined in Eqs. 10.6 and 10.7, when combined with the exogenously determined variations in the RBI's credit to bank (RBCB) and in the RBI's holdings of other assets (RBOA) yield the change in the net RBI credit to the government (RBCG) from the RBI's balance sheet constraint.

$\Delta RBCG = \Delta H - \Delta RBNFA - \Delta RBCB - \Delta RBOA$

(iii) Other equations

The excess of government's fiscal deficit (FD) over the exogenous capital receipts, internal as well as external, (GKR) determines the change in the banking system's credit to the government (BSCG), Thus,

$\Delta BSCG = FD - GKR$

This equation is interpreted in the model as the government budget constraint.

Given the banking system's credit to government (RBCG) emanating from the RBI's balance sheet identity equation as the commercial bank credit to the government (BCG) is determined residually. Thus, in flow terms

$\Delta BCG = \Delta BSCG - \Delta RBCG$

The balance sheet identity of the commercial banks can then be written as

Which simply states that, in flow terms, bank credit to commercial sector (BCC) is the excess of their liabilities (*i.e.*, time deposits, demand deposits and credit from the RBI) over their assets, such as bank reserves (BR), bank credit to government (BCG) and other assets (BOA).

$\Delta BCC = (\Delta TD+\Delta DD+\Delta RBCB)-(\Delta BR+\Delta BCG+\Delta BOA)$

Finally, the nominal supply of narrow money (M1) is given by the adjusted money-multiplier (m) approach:

$M1 = m\,(H - RRTD \times TD)$

where the money multiplier (m) is determined by the relevant identity.

$m= (C/DD)+1) / (C/DD)+(BR/DD)$

The nominal supply of narrow money (M1) thus obtained, when combined with the demand for real narrow money balances

$P = M1/ (M1/P)$

Which completes the monetary sector model.

(B) Macroeconometric Models of the 1980s

Having attained analytical sophistication in monetary sector modeling during the 1970s, the modeling effort in the 1980s became more diversified.

Macroeconometric models developed during this period comprise all the types discussed in the taxonomy earlier. Of the eight models chosen for review from this period, two are forecasting models [*i.e.* Rao, Venkatachalam, Vasudevan (RVV), 1981 and Madhur, Nayak and Roy (MNR), 1982], three are economy-wide structuralist models (*i.e*. Krishnamurty 1984, Pani 1984 and Pandit 1984), one is policy-oriented model (T.K. Chakravarty 1987) and the remaining two are typical monetarist Models Jadhav-Singh, 1990 and Rangarajan-Arif 1990. These models are reviewed next by groups in chronological order.

(a) Forecasting Models

Short-term forecasting models are focused, basically, on developing macroeconometric framework for forecasting macroeconomic aggregates as a useful input for policy formulation.

In the Indian context, as mentioned before, two such models can be identified:

- Rao, Venkarachalam, Vasudevan (RVV) Model and
- Madhur, Nayak, Roy (MNR) Model.

The RVV model (1981)

The RVV Model contends that "short-term monetary analysis for policy decisions must go beyond the conventional balance-sheet approach or the simple money-multiplier approach. In the balance-sheet approach, currency, bank deposits and reserve money, *etc*. are separately estimated and these estimates are not necessarily consistent with each other, except in that they conform to the balance sheet constraints" Moreover, in the money-multiplier approach, the multiplier is assumed to be constant even when, in incremental terms, it is known not to be very stable. Accordingly, the RVV model attempts to provide an alternative methodology for consistent estimation of monetary aggregates.

The RVV model is a simple 8 equation model based primarily on the portfolio behaviour of banks and the non-bank private sector.

The public's demand for currency is specified in incremental nominal terms (C) as a positive function of nominal income (YN), exogenous bank credit for food procurement (BCF) as a proxy for the actual expenditures incurred in the public procurement of foodgrains, the rate of change in prices in respect of sensitive commodities (PS) purported to reflect the speculative demand for currency, and the exogenously determined inflow of foreign remittances (FR), but is negatively related to the rate of return on time deposits (RTD). Thus,

$\Delta C = f(YN, \Delta BCF, PS, FR, RTD)$

The currency holdings of the public are demand determined and, in turn, given the exogenously determined reserve money or monetary base (H), the supply of bank reserves BR is determined through the reserve money identity. Thus,

$BR = (H-C-X)$

Where X = Reserves of banks other then the scheduled commercial banks and other deposits with the RBI.

The bank reserves, so determined, then determined the banks' supply of liabilities (demand and time). Specifically, banks' supply of liabilities (L) is posited as a positive function of bank reserves (BR) and time deposit-total deposit ratio but is negatively related to the incremental CR ratio (ICR) and the call money rate (RC). Thus,

$L = f(BR, ICRR, RC, (TD/D))$

In this formulation, the ratio of time deposits to total deposits reflects the stability of banks' deposit base. The higher the ratio, the less is the need to hold excess reserves as a precautionary cushion and the greater is the expansion of liabilities corresponding to a given supply of reserves. Also, since borrowing from the call money market can supplement banks' ability to create own liabilities, the call money rate appears as an argument with a negative sign.

From the supply of banks' liabilities, their aggregate deposits (D) are determined through a simple statistical equation of the form.

$D = f(L)$

Demand deposits are assumed to be demand determined. The formulation of demand for demand deposits is fairly conventional; with nominal income (YN), share of non-agricultural income to total income (YNA/YN) and the rate of return on time deposits as the arguments. Thus,

On the other hand, time deposits (TD) are supply determined, derived residually from the supply of aggregate deposits (D). Thus,

DD = f (YN, RTD, YNAN/YN)

The nominal income (YN) is assumed to be determined by supply of money (C+D) and the variables influencing the demand for money such as the real income (YR), the share of non-agricultural income in total income and the inflationary expectations. Thus, time deposits is determined as

TD = D-DD

The equilibrium between money supply and demand is assumed to manifest itself in terms of variations in nominal income. It follows, therefore, that the variables such as real income (YR) and the share of non-agricultural income in total income (YNAN/YN) which have a positive influence on money demand have a negative influence on nominal income, given the stock of money, and the opposite is true in respect of the inflationary expectations.

Finally, the general price level (P) is determined simply by the identity:

P = (YN / YR)

Which completes the model.

The MNR Model

The MNR Model, in a similar vein, aims at developing a framework for short-term macroeconomic forecasting and policy formulation. General macroeconometric models, it is argued, are "couched in a framework which is not readily amenable to analysing the implications of the annual Central Government budget or for short-term forecasting purposes" . The MNR model accordingly presents a methodology for systematically analysing the effect of the budget on certain key macro variables, such as money, credit and inflation.

(1) Money supply

The broad money stock (M3) is determined by the so called proximate determinants of the money multiplier and the unborroweed reserve money (H*). Thus, M3 = (1+k)/ (k + r-q)

Where k = currency deposit ratio (C/D), r = bank reserves-deposits ratio (BR/D), q = borrowed bank reserve deposit ratio (RBCB/D), H*= unborrowed reserve money.

This, of course, is the familiar money-multiplier approach. Unlike the conventional formulation, however, the money multiplier is not treated as a constant but varies depending on the values of three asset ratio (k, r, and q). The variations in the asset ratios, in turn, reflect the behavioural responses of the relevant economic agents to identified policy variables.

The currency-deposit ratio, k, basically a decision variable of the public, is posited as a negative function of the number of bank branches (NB), their spread as measured by the proportion of rural branches in the total (NRB/NB) and the rate of return on deposits (RTD). Thus,

k = F(NB,RTD, NRB/NB)

The bank reserve-deposit ratio, r, which is essentially a decision variable of banks, is assume to be positively related to the cash reserve ratio in the absolute terms (CRR) and in incremental terms (ICRR) as well as the bank rate (RB), but negatively related to the rate of return on the competing assets such as the loan rate (RL) and the rate of return on government securities (RG). Thus,

r = f (CRR, ICRR, RB, RL, RG)

The remaining asset ratio, *i.e.*, the banks' borrowed reserves ti deposit ratio (q), is postulated as a positive function of the cash reserve ratios (CRR and ICRR), the rates of return on bank lendings to the commercial sector (RL) and on government securities (RG), but a negative function of their cost of borrowings *i.e.*, the bank rate(RB). Thus,

q = f (CRR, ICRR, RB, RL, RG)

(2) Asset and liabilities of banks

Aggregate deposits (D), which are liabilities of commercial banks, are determined in a manner similar to the determination of broad money stock. Specifically,

D = (1/ (k+r-q))H

Where k, r and q are the asset ratios defined above.

The counter part of deposit on the asset side of banks' balance sheet is the aggregate bank credit (BC), which comprises the bank credit to the commercial sector (BCC) and to the government sector (BCG). The aggregate bank credit (BC) is assumed to be determined by a simple `statistical' function:

BC=F(D)

Once the aggregate bank credit is determined, its allocation between the commercial sector (BCC) and the government sector (BCG) is posited as a portfolio choice problem, modeled as

(BCC/BCG) = f (RL-RG, RB)

Thus, bank credit to the commercial sector as a ratio of bank credit to the government sector is postulated as a positive function of the differential between the banks' lending rate (RL) and the rate of return on government securities (RG) as well as the cost of bank's borrowing from the RBI.

Thus, given the unborrowed reserve money (H*), the endogenous asset ratios k, r and q determine the stock of money, aggregate bank credit and its allocation between the commercial sector and the government sector.

(iii) Assets and Liabilities of the RBI

The unborrowed reserve money (H*) may be defined, from the liability side as:

H = C+BR-RBCB

i.e., the reserve money (C + BR) minus the borrowed reserve, *i.e.*, banks' borrowings from the RBI (RBCB).

Alternatively, from the asset side, it may be defined as

H = RBCG+RBCC+RBNFA-RBNNML

Where RBCG is net RBI credit to the government, RBCC - RBI credit to the commercial sector, RBNFA - net foreign assets held by the RBI and RBNML- RBI's net non-monetary liabilities.

In the MNR model, RBNML is assumed to be exogenous while the RBCC is deemed to be a policy variable. On the other hand, RBNFA is endogenous and its variations are determined in the external sector. The remaining and the most important variable, RBCG is determined in the fiscal sector. The link equation takes the following form:

$$\Delta RBCG = f\ (FD)$$

It may, however, be noted that the fiscal deficit (FD*) as defined in the model is quite different from the conventional formulations. With short-term policy as the primary aim, ex ante intentions of the government as revealed in the budget are translated into more plausible numbers on the basis of the past deviations in the budget estimates and the corresponding actuals. For this purpose, a simple methodology has been proposed to purge the relevant non-random deviations. Having `corrected' the fiscal deficit of the Central Government, the combined fiscal deficit of the Centre, States and Union Territories is derived by simple `blow-up' factors, which then feeds into Eq. to determined the Net RBI Credit to government, thus providing the crucial link between the fiscal and monetary sectors.

(b) Structuralist Models

Structuralist Models, as mentioned before, take a disaggregated approach to price formation and avoid exclusive reliance on the monetary imbalance in explaining price movements. In these models, generally, `structural' or `institutional (*i.e.* country-specific) factors are incorporated in the price equations, either supplanting the monetary factors or augmenting them as deemed appropriate.

In the Indian context, several studies based on this approach are available. Given the eclectic nature of this survey, attention has been focused on those models in this group, which are of a more recent vintage and therefore, broadly reflect the salient features of the earlier models as well. With this criterion, the discussion here is confined to the following three models:

- Krishnamurty's Model (1984),
- Pandit's Model (1984) and,
- Pani's Model (1984)

Krishnamurthy's Model

Krishnamurthy's Model comprising of 77 equations and relating to the period 1960-61 through 1979- 80 is deemed to be suitable for "studying the pattern and tempo of growth and other long-run movements in the economy". It emphasises the critical role played by agriculture, the growth-inflation trade-off, the secular relationship between money, output and prices and the productivity changes in the economy.

The monetary sector sub-model is relatively small with 13 equations. Moreover among the structural models its price formation equations are closer to the quantity theory of money, though structural features do play an important role in the model. The model may de described as follows:

Money stock, narrowly defined (M1), is treated as a positive function of the reserve money (H) and lagged money stock. Thus,

M1= f(H, LAGS)

The reserve money (H) is derived as an identity from the asset side of the RBI's balance sheet. It thus comprises the sum total of net RBI credit to government (RBCG), government's currency liability to the public (CLG), RBI credit to commercial sector (RBCC) and RBI's holdings of net foreign assets (RBNFA), in excess of RBI's net non-monetary liabilities (RBNML). Thus,

H = RBCG+CLG+RBCC+RBNFA-RBNML

As far as the components of the reserve money are concerned, RBNFA and RBNML are assumed to be exogenous; the former because there is no external sector in the model, and the latter being a residual item. The RBI credit to the commercial sector (RBCC) is simply related to its own lagged value. Thus,

$RBCC = f(RBCC_{-1})$

The remaining two components, ***i.e.***, net RBI credit to government (RBCG) and government's currency liability to the public (CLG) reflect to the monetary sector's integral link with the fiscal sector, are modeled as under.

The resource gap arising out of the government's fiscal operations ***i.e.***, the fiscal deficit (FD) is financed by borrowings from the RBI, other borrowings (domestic and external) or by enlarging its currency liability to the public. The external borrowings (FB) are assumed to be exogenous. The domestic borrowings outside the RBI (DB), on the other hand, are endogenised by relating them simply to the resource gap in excess of foreign borrowings. Thus,

DB = f(FD-FB)

The resource gap uncovered by these borrowings is termed the `high powered deficit' (HPD). Thus,

HPD=FD-DB-FB

By the balance sheet constraint, then, the high powered deficit brings about an equivalent change in the net RBI credit to government (RBCG) and government's currency liability to the public (CLG). Thus,

$RBCG+CLG = HPD+RBCG_{-1}+CLG_{-1}$

Which feeds into the money stocks through reserve money.

As mentioned earlier, a distinguishing feature of the structuralist models is their elaborate and disaggregated treatment of prices. In Krishnamurthy's Model, prices are modeled as under.

The general price level (P), as measured by the GDP deflator is posited as a positive function of money / real GDP ratio and the lagged price level in the partial adjustment framework. Thus,

$P = f(M/YR, P_{-1})$

The wholesale price index (WPI) is disaggregated into four components: food (PF), non-food agricultural products of raw materials (PR), manufacturing and mining products (PM) and energy items, such as fuel, power, light and lubricants (PE). The WPI is derived simply as a weighted combination of these four sectoral prices with weights assigned as in the official index. Thus,

WPI=0.298PF+0.106PR+0.511PM+0.085PE

Among the sectoral prices, all except the energy prices (PE) have money-GDP ratio as an argument. Thus,

PF=f(M/YR,..)

PR=f(M/YR,..)

PM=f(M/YR,..)

Additionally, per capita availability and per capita real income appear as explanatory variables in PF and PR. In the latter case, exogenous `other agro-based import prices' has also been included as an additional raw material prices (PR), wage rate and imported raw material prices have been incorporated as additional explanatory variables.

On the other hand, energy prices (PE) are assumed to be regulated by the government and are adjusted with a lag to the general price situation and the prices of imported fuels. Thus,

$PE=f(WPI_{-1},..)$

Finally the consumer price index (CPI) is assumed to adjust to the variation in the (WPI). Thus,

$CPI=f(\Delta WPI,WPI_{-1},..)$

which completes the monetary sector model.

Pandit's Model (1984)

Unlike the Krishnamurty's model with its emphasis on long-run movements in the economy, Pandit's model is focused on the short and medium-term problems. Accordingly, it emphasises causes and consequences of inflation, monetary and fiscal policy issues, the saving-investment equilibrium and impulses from the external sector. This model has 60 equations and covers a relatively longer sample period, 1950-51 through 1977-78.

Here again the monetary sector sub-model is somewhat small with 13 equations. A move towards the `structural' factors in preference to the monetary factors in explaining the price variations, however, is distinctly discernible.

(i) Money Supply and Related Aggregates

Demand for real currency holdings (C/P) is postulated as a positive function of real income (YR) but a negative function of short0term interest rate (Rs) and expected inflation rate (p) in the partial adjustment framework. Thus,

$(C/P) = f\ (YR, RS, \pi, (C/P_{-1})$

Demand for demand deposits has a similar specification with the real income (YR) replaced by non-agricultural real income (YNAR). Thus,

$(DD/P) = f\ (YNAR, RS, \pi, (DD/P_{-1})$

Nominal money supply, narrowly defined (M1), on the other hand, is specified as a positive function of the monetary base (H) and the lending rate (RL). Thus,

$$M1 = f(H, RL)$$

The equilibrium in the money market is assumed to be achieved with the short-term interest rate (Rs) and / or the expected inflation rate (p) acting as equilibrating devices. However, as can be seen below, the inflationary expectations have no bearing on the actual inflation rate.

The reserve money (H) is endogenously determined as a function of the exogenously determined net RBI credit to the government (current and lagged) and the RBI's holding of the net foreign assets which is determined in the external sector. Thus,

$$\Delta H = f[(\Delta RBCG+\Delta RBCG\bullet\ \bullet\ ), (\Delta RBNFA+\Delta RBNFA_{-1})]$$

Other components of the reserve money are simply ignored. Further, bank credit to the commercial sector (BCC) is specified in incremental terms as a positive function of the changes in reserve money (DH) current and lagged, as well as the interest rate differential between the banks' as well as the interest rate differential between the banks' lending and borrowing rate (RL• -RB•). Thus,

$$\Delta BCC = f[(\Delta H, \Delta H_{-1}, (RL-RB)]$$

affected by monetary factors because money supply growth rate (M) appears, among others, as an explanatory variable. The impact is indirect in respect of manufactures since (PR) is included in the inflation rate equation for textile products and the rate of expansion of bank credit to the commercial sector is included as an explanatory variable in the equation for (non-textile) manufactures. Other explanatory variables include supply constraints (in respect of PF and PE), import price changes (in respect of PM), besides the relevant lagged dependent variables. Thus,

$$PF = f(M1,..)$$

$$PR = f(M1,..)$$

$$PT = f(PR,..)$$

$$PT = f(BCC,..)$$

The wholesale price index (WPI) is then determined as a weighted combination of these sectoral prices, with weights based on the official formulae. Thus,

$$WPI = 0.431PF+0.106PR+0.255PM+0.110PT+0.085PE+0.013PMN$$

The sectoral price indices also determine the overall agricultural and non-agricultural price indices. In particular, the implicit deflator for GDP in agriculture (PA) is specified as a function of prices of food and raw materials. Thus,

PA = f(PF,PR)

and the implicit deflator for GDP outside agriculture (PNA) is specified as a function of prices of textiles, other manufactures and the money wage rate. Thus,

PNA=f(PT,PN,W)

Finally, the general price level as measured by the GDP deflator (P) is derived as a weighted combination of relevant deflators for agricultural and non-agricultural sectors. Thus,

P= f[(YAR/YR)PA+(YNAR/YR)PNA]

which completes the model.

Pani's Model

Among the models reviewed in this survey, Pani's model is the largest one in size with as many as 79 equations but is applied to an exceedingly short sample period -- from 1969 70 through 1981-82. According to the author, the distinguishing feature of other model is that "compared to some existing descriptions, the theoretical foundations underlying the economic relations in the study are based on considerable subjective evaluation …"

As compared to the other structural models, the monetary sector is also relatively more elaborate with 17 equations. The monetary sector of Pani's model is set out below:

(i) Components of Money Supply

Change in nominal stock of currency with the public (C) is specified as a positive function of the fiscal deficit (FD) and change in RBI's net foreign assets (RBNFA), but is negatively related to government's total borrowings outside the RBI (B). Thus,

$\Delta C=f(\Delta FD, RBNFA, B)$

The stock of currency with the public (C) is given by the simple identity:

$C=\Delta C+C_{-1})$

Outstanding bank deposits (D) of all banks are derived as a statistical function of scheduled commercial banks' deposits (DS) which in turn, are determined by the deposit base ***i.e.***, ban0 reserves (BR) net of exogenous impounded deposits *DI) and the stock of net foreign exchange assets of the RBI (RBNFA). Thus,

D=f(DS)

DS=f[(BR-DI),RBNFA]

The stock of broad money (M_3) is then given by the definitional identity:

M3=C+D+OD

Where OD refers to other deposits with the RBI.

(ii) Other Monetary Variables

Link bank deposits, reserves of all commercial banks (BR) are derived as a statistical function of reserves of the scheduled commercial banks (BRS). Thus,

BR=f(BRS)

Scheduled commercial banks' reserves (BRS), in turn, are assumed to be positively related to the stock of currency (C), "used both as proxy for government deficit and demand for currency holdings by the public", and net foreign exchange assets of the RBI but is negatively related to the bank rate (RB) which reflects the tightness of the monetary policy (***i.e.***, supply of reserves to the banking system). Thus,

BRS=f(C,RBNFA,RB)

Among the other assets in the portfolio of banks, their combined investment in government securities (BCG) and in other approved securities (BOS) is determined by their deposit base and the exogenous Statutory Liquidity Ratio (SLR). Thus,

BCG+BOS = (SLR)df + BECS)

Where BECS is banks' excess investment in government and other approved securities.

Bank credit to the commercial sector (BCC) is determined not through the relevant balance-sheet identity, but as a statistical function with positive coefficients for liabilities like deposits (D) and the exogenous bank borrowings from the RBI (RBCB) and a negative coefficient fora group of assets comprising reserves (BR) and their investment in government securities (BCG) and in other approved securities (BOS). Thus, BCC=f[D,RBCB,(BR+BCG+BOS)]

(iii) Fiscal Feedbacks

Central government's revenue receipts as well as its revenue expenditure is specified as a function of nominal income in the partial adjustment framework. On the other hand, capital expenditure is bifurcated into `current and capital' transfers, and other capital expenditure; the former is treated as an exogenous variable whereas the latter is linked up with the exogenous government investment in real terms. The fiscal deficit, thus derived, feeds into the currency equation Eq.

Financing the government deficit involves, among other things, borrowings from domestic as well as foreign sources. Net domestic borrowing of the government (outside the RBI) denoted by DB is postulated as positive function of nominal household savings (HSS) but negatively to the inflation rate (P). Thus,

DB=f(HSS,P)

These borrowings, combined with exogenous foreign borrowings (FB) determine the government's total borrowings outside the RBI. Thus,

B=DB+FB

Which also feeds into the monetary sector through the currency equation. Separate equations have also been provided for the Centre and State Governments combined. The combined fiscal deficit (CFD), thus derived, is financed either by borrowings outside the RBI (B) (domestic and foreign) or else by expanding the net RBI credit to government. Thus,

ΔRBCG=CFD-B

(iv) Prices

In this model, WPI is divided into three sub-groups, food (PF), raw materials (PR) and manufactures (PM), with the first one acting as the prime mover.

The ratio of broad money to agriculture and manufactured output (YR*) appears as an explanatory variable in the food-prices equation along with supply of foodgrains (current and lagged) output outside the agriculture sector, and non-food agricultural output. In turn, the food prices (PF) determine the prices of raw materials (PR) along with other explanatory variables such as the sector's output (current and lagged) and the output of the manufacturing sector. The two sectoral prices PF and PR, then, determine the prices of manufactures, with import prices acting as an additional influence. Thus,

PF=f(M3/YR,..)

PR = f(PF,..)

PM = f(PF, PR,..)

The WPI is derived not as a weighted combination of the sectoral prices but through a behavioural equation postulating WPI as a positive function of money-real income ratio, food prices (PF) and a specially constructed index (PAD) reflecting potential impact of changes in administered prices. Thus,

WPI=f(M3/YR, PF, PAD)

Finally, the general price level as measured by the overall deflator (P) is specified as a positive function of money-nominal income ratio, food prices (PF), raw material prices (PR), and the administered prices (PAD). Thu

P = f(M3/YN, PF, PR, PAD)

(c) A Policy-oriented Model of the 1980s

Among the models developed during the 1980s, apart from the MNR Model (1982) which is a forecasting model, the only other model that is purported to be "suitable for policy analysis" is the one by T.K. Chakravarty (1987). This model has been termed as a minimod (***i.e.***, a mini macromodel) which, besides restraining the overall size to 32 equations, also aims at incorporating `institutional features' of the economy. The monetary sector of this model is described as follows:

(i) Components of Money Supply:

Demand for currency is specified in real terms as a function of change in real income and its own lagged level. Thus,

(C/P)=f(ΔYR,LAG)

Similarly, demand for bank deposits, also in real terms, has been posited as a function of real income (YR), exogenous time despite rate (RTD) and the own lagged value. Thus,

(D/P)=f(ΔYR,RTD,LAG)

Together, these two constitute demand for real money balances.

On the supply side, money stock in nominal terms, is determined simply by the stock of reserve money (H). Thus,

M3=f(H)

The reserve money (H) is determined through the conventional identity.

H=RBCG+RBCC+RBNFA-RBNML)

where, excepting the net RBI credit to the government (RBCG) which is determined in the fiscal sector, all others are exogenous.

In the fiscal sector, nominal revenue receipts are postulated as a positive function of nominal income and exogenous effective tax rate in the partial adjustment framework. On the expenditure side, nominal revenue expenditure is specified as a function of nominal income and the own lagged value. Capital expenditure is decomposed into gross fixed capital formation and the rest; the former is linked to exogenous government investment whereas the latter is treated as an exogenous variable.

The fiscal deficit thus derived is financed, in part, by government's domestic market borrowings (DBM) which are specified as a positive function of nominal deposits (D) in the partial adjustment framework. Thus,

DBM=f(D,LAG)

Government's reliance on the RBI credit is then derived residually as

ΔRBCG=FD-DBM-DBNM-FB

where net non-market borrowing (DBNM) as well as the net foreign borrowings (FB) are deemed to be exogenous. The stock of net RBI credit to government is given by the identity:

RBCG=ΔRBCG+RBCG• •

which feeds into the reserve money identity Eq.

Finally, the general price level (P) is stipulated as a positive function on money stock (M3), effective excise tax rate (ETR) and inflationary expectations proxied by the lagged price level but a negative function of real income (YR). Thus,

P=f(M3,ETR,YR,π)

which completes the monetary sector model in which the only two policy instruments are the interest rate on one year time deposits and the RBI credit to the commercial sector.

(d) Topical Macroeconomic models

The latest modeling effort in India seems to bring into sharper focus single central relationship. In these cases, the overall structure of the model is geared towards analysing various dimensions and inter-sectoral linkages that have a bearing on the chosen central relationship. This class of models has been referred to here as the topical macromodels.

In this regard, the following two models have been chosen for the review:

(a) Jadhav-Singh Model (1990) and

(b) Rangarajan-Arif Model (1990).

Both of these deemed to be in the monetarist tradition. The former attempts to capture the dynamic nexus between government deficit, money supply and inflation, whereas the latter presents "the framework of a model of the Indian economy that emphasises the determination of money supply and its impact on both output and prices". As will be shown later, the two models have a fair degree of overlapping, notwithstanding important modeling differences.

Jadhav-singh Model (1990)

The model has 14 equations and is applied to the period 1970-71 through 1987-88. The structure of this model may be described as follows:

Given the primary focus of the study, accent of the model is on e the fiscal sector which is disaggregated. In respect of government receipts, a distinction is made between tax and non-tax sources, whereas government expenditure is decomposed into development expenditure, interest payments and other non-development expenditure.

On the receipts side, both, nominal tax receipts (TXR) and non-tax receipts (NTR), and on the expenditure side, non-development expenditure excluding interest payments (NINDE) are specified as positive functions of real GDP and price level in the partial adjustment framework. Thus,

TXR=f(YR,P,LAG)

NTR=f(YR,P,LAG)

NINDE=f(YR,P,LAG)

Of the remaining components, nominal development expenditure (DEVE) is treated as an exogenous policy variable while interest payments (INT) are related to the lagged outstanding domestic debt held outside the RBI (DEBT). Thus,

$INT=f(DEBT_{-1})$

The fiscal deficit emanating from these components is given by

$FD=(DEVE+NINDE+INT)-(TXR+NTR)$

To the extent that fiscal deficit is financed by net RBI credit to government, it leads to monetary expansion. With the partial adjustment process, money stock (M3) is, thus, related to the fiscal deficit, *i.e.*

$M3=f(FD,LAG)$

Additionally, financing fiscal deficit involves enlargement of the outstanding stock of domestic debt held outside the RBI (DEBT). Thus,

$\Delta DEBT=f(FD)$

The incremental domestic debt adds on to the previously outstanding domestic debt which, after a lag, raise interest payments Eq. Thus feeding back to the fiscal sector.

The fiscal sector transmits a positive impulse to the real sector through real development expenditure which augments the production capacity with a lag. Thus, capacity output (YR) is assumed to be related to the lagged real development expenditure in the partial adjustment framework, *i.e.*,

$YR=f[(DEVE/P)_{-1}, LAG)]$

Enhanced productive capacity has a bearing on real GDP. Specifically, the incremental real GDP is determined as a positive function of (a) the excess of current period's capacity output over the actual output of the previous period, and (b) the exogenous measure of capacity utilisation (CUTL). Thus,

$YR=f[(\Delta YR,CUTL)]$

Finally, the price equation is derived as an inverted money demand function in the conventional manner. Thus,

$P=f(M3,YR,\pi)$

where the expected inflation rate (π^{e}) is proxied by the previous year's actual.

Rangarajan-Arif (RA) Model (1990)

This model has 20 equations and is applied to the period 1961-62 through 1984-85. The structure of this model is set out as follows:

The model describes the money stock determination through the money-multiplier approach. The broad money stock (M3) is specified as a positive function of reserve money (H) which, in turn, is defined by the usual identity; all components of reserve money other than the net RBI credit to government are treated as exogenous variables. Thus,

$M_3 = f(H)$

H=RBCG+RBCC+RBNFA+GCL-RBNML

The broad money stock so derived then determines bank deposits (D) through a statistical function specified in incremental terms. Thus,

$\Delta D=f(\Delta M3)$

In the fiscal sector, revenue expenditure (GRE) is determined in real terms according to the partial adjustment process related to real income (YR). Real capital expenditure (GKE/P) is assumed to be a policy determined exogenous variable. On the other hand, nominal revenue receipts (GR) of the government are related to nominal income (YN) according to the partial adjustment mechanism. These formulations, which are largely conventional, yield government's fiscal deficit (FD). Thus,

(GRE/P)=f(YR,LAG)

GRR=f(YN,LAG)

FD=f[(GRE/P)+(GKE/P)]P-GRR

The fiscal deficit is financed either by government's capital receipts (GKR) or else by extending net RBI credit to the government. Government's capital receipts (GKR) are decomposed into credit to government by banks (BCG), by non-bank financial institutions (NBCG), domestic non-market borrowings (DBMN) and foreign borrowings (FB). The non-bank financial institutions' credit to government and foreign borrowings are treated as exogenous variables. Thus,

GKR=BCG+NBCG+DBNM+FB

The bank credit to government is constrained by the banks' deposit resources and the Statutory Liquidity Ratio (SLR), and is modeled simply as:

$\Delta BCG=f(\Delta D)$

On the other hand, government's non-market borrowings (DBNM) constitute a part of the household saving and are, therefore, specified as a positive function of nominal income (YN). Thus,

$DBNM=f(YN)$

The government's capital receipts (GKR) thus determined, given the fiscal deficit, indicate the necessary change in net RBI credit to government residually. Thus,

$\Delta RBCG=FD-GKR$

which feeds into the monetary sectors (Equations RA 10) and RA 10.2) . The fiscal sector also has a feedback into the real sector in the form of a stimulus to growth. Government's real capital expenditure enhances its capital stock which, in turn, fosters the capital formation in the private sector. Addition to the overall real capital stock (KR), being a factor of production, promotes real output. The monetary sector also contributes to output with real money balances acting as an additional argument in the aggregate production function. Both variables are assumed to affect output with a one year lag. Thus,

$KR=f[(GKE)/P),...)$

$YR=f[KR_{-1},(M3/P)_{-1})$

Here again, the general price level (P) is specified as an inverted money demand function with positive influence from monetary expansion and higher inflationary expectations (proxied by the lagged price level) but dampening impact of larger output. Thus,

$P=f(M3,YR,\pi)$

Which completes the model.

C. Macroeconomic Modeling in the 1990s and Thereafter

IEG-DSE Model

Pandit and Krishnamurthy (2001), widely recognised for their pioneering contribution to macro-econometric modeling in the Indian context, were first to provide a serious treatment of monetary sector of the Indian economy. Their large scale macroeconomic model is founded on eight blocks or sub-models in respect of production, investment and capital stock, price behaviour, public finance, money and banking, trade and balance of payment, private consumption, and private saving. The gigantic model included as many as 347 structural equations comprising 136 stochastic relationships and 211 identities.

The monetary sector accounted for twenty-one stochastic relations besides five identities for characterising monetary equilibrium. The monetary block of the model is designed with primary focus on the impact of liberal monetary policy on economic activity, prices, and external balances. Accordingly, interest rates and capital formation serves as intermediate targets in their analysis.

Money supply is endogenous to the system, and determined by using the money-multiplier-high powered money formulation. The policy instruments such as bank rate and cash reserve ratio have direct effects on money multiplier, which coupled with reserve money determine broad money supply. Thus, the model specifies

M3 = mH

m=f[C/DD, TD/DD, BR/DD+TD,CRR)

H=RBCG+RBCC+CLG+RBNFA-RBNML)

The money multiplier is determined stochastically in terms of proximate determinants such as currency-demand deposit ratio(C/DD), demand deposits-time deposits ratio(DD/TD), banks cash and borrowed reserves to aggregate deposit ratio(BR/AD) and weighted cash reserve ratio(CRR). Reserve money is specified as a lateral sum of its sources. The various sources of reserve money indicators are stochastically determined while providing separate stochastic specifications for Reserve Bank credit to commercial banks and cooperative banks including NABARD under refinancing facilities(RBCB),Reserve bank credit to commercial sector(RBCC) including development banks, government's currency liability to public(CLG) and Reserve Bank's non-monetary liabilities(NNML).

RBCB=f(BC,RB,LAG)

RBCC=f(YRAN,TIME)

CLG=f(C,TIME)

RBNML=f(TIME,YNANLAG)

Money demand is modeled in terms of its major components such as currency with the public, demand deposits, and time deposits with other deposits exogenously given. In general, money demand components are determined by personal consumption, interest rate either in the form of deposit rates, or average of deposit rates and mutual funds (UTI) dividend yield as alternative source of savings, expected inflation rate (five-year moving average of annual inflation rates) and nominal output of the non-agricultural sector.

$C = f(PC, R, YNAN/YN)$

$DD = f(YNAN, R, \pi^e)$

$TD = f(YNAN,(R-R^{UTI}, \pi^e)$

The model achieves monetary equilibrium between money demand and money supply since money demand components such as currency with public, and deposits directly affect the money multiplier, which coupled with reserve money affect aggregate money supply.

Recognising the prominent role of banks and development financial institutions in the financial intermediation process in the economy, the model provides structural determination of commercial banks' food credit, non-food credit and investment in government securities, and aggregate sanctions and disbursements from development financial institutions. In order to provide a complete stochastic formulation of the entire portfolio of commercial banks, the model also provides structural formulation of banks cash holdings and actual reserve balance with the central bank.

$BCF=f(IPFG, R^{SBI}, lag)$

$BCNF=f(D, R^{SBI} , BCG, GDCF, lag)$

$BCG= f[(D_{-1}, SLR^{w}, RG^{W}/R^{SBI}),$

$BCGOS=f((BCG+BOS))$

$BCASH=f(D_{-1}, CRR-BCC, RB)$

$TSAI=f(GDCF,RL^{PLR}, lag)$

$TDAI=f(TSAI,YRAN, lag)$

Interest rates are modeled across the spectrum of maturity, various forms of savings, credit and investment as reflected in separate specifications for commercial banks' deposit rates, prime lending rate of state bank of India- the major commercial bank, average prime lending rates of all India development financial institutions, dividend yield of mutual funds, and weighted average on government's market borrowing. The spectrum of interest rates together reflects the effects of bank rate-the policy instrument, level of funds (aggregate deposits) available with the banking sector, fiscal policy induced government market borrowing, and expected inflation rate.

$RTD = f(TD, RG^{W}, \pi^{e}, R^{UTI})$

$R^{SBI} = f(D, BCG, RB)$

$R^{PLR} = f(RB, \pi^{e}, LAG)$

$R^{UTI} = f(RTD, \pi^{e}, LAG)$

Monetary transmission entails direct and indirect effects of quantity of money and/or credit as well as interest rate channels ensuing from the modulation in policy instruments such as CRR and the bank rate. The policy impulses are transmitted to money and credit aggregates-the intermediate target, which in turn affect price level, investment, aggregate demand and consequently, real output:

$\Delta K^{AG} = f(YR_{-1}^{AG}\}, \Delta K\_{G}^{AG}\}, BCC^{F}, WPI^{AG}/ WPI^{mnf})$

$\Delta K^{MNF} = f(YR_{-1}^{mnf}, \Delta K_{G}^{INF}/\Delta K^{MNF}, (BCC^{NF} + TDAI)/\Delta K^{MNF}, K_{-1}^{MNF})$

$\Delta K^{srv} = f(YR_{-1}^{srv}, \Delta K_{G}^{INF}/\Delta K^{srv}, (BCC^{NF} + TDAI)/\Delta K^{srv}, K_{-1}^{srv})$

$YR^{AG} = f(AREA, RAIN, WPI^{AG}/WPI^{MNF}, BCC^{F}, ICOR^{AG})$

$YR^{mnf} = f(BCC^{F}, \Delta K_{G}^{INF}, IMPORT/YN, ICOR^{mnf})$

$YR^{srv} = f(ICOR^{srv}, \Delta K_{G}^{INF})$

$WPI^{AG} = f(M3, YR^{AG}, PCP)$

$WPI^{MNF} = f(M3, YR)$

$WPI = \theta\ WPI^{AG} + (1-\theta)\ WPI^{MNF}$

$PDFL_{J} = f(WPI_{J})$

Klein and Palanievel's Model

Klein and Palanivel (1999) developed a large-scale macroeconometric model similar to that of IEG-DSE albeit with more disaggregating nature and special emphasis on monetary sector of the Indian economy. The monetary block of their model comprised as many as forty structural equations broadly, grouped into money demand, money supply, interest rates, bank credit, bank investments, and cash flows of banks. The model, thus, in a broader perspective, resembles more or less to a financial sector model.

Money demand block comprised specification of components including currency with the public, demand deposits, and time deposits.

$C=f(PC,R,((YNAN)/(YN)))$

$DD = f\ (YNAN, R, \pi^{e}\}$

$TD = f\ (YNAN,(R/RG),\pi^{e}\}$

$OD = f\ (M3^{D})$

$M3^{D} = C+DD+TD+OD$

The approach to modelling money supply process encompasses the underlying principle of high-powered money such that aggregate money supply is determined by central bank's reserve money times the money multiplier.

$M3^{S}=mH$

The reserve money aggregate is specified as an identity comprising the sources variables including Reserve Bank's net credit to government, commercial sector, commercial and cooperative banks under refinancing facilities, and non-monetary liabilities and government's currency liability to public. All the sources of reserve money are separately specified as structural equations.

H=RBCG+RBCB+RBCS+RBNFA+CLG-RBNML

RBCG=f(FD,LAG)

RBCB=f(BCG,RB,LAG)

RBCS=f(LAG)

CGL=f(LAG)

RBNML=f(LAG)

On the other hand, money multiplier is determined proximate determinants, ***i.e.***, cash reserve ratios (CRR)-the policy instrument of monetary control, currency-demand deposit ratio, and currency-time deposits ratio, capturing the behavioural component pertaining to public choice of currency and deposits (or savings) and bank's credit-aggregate deposit ratio.

$m=f[(C/(DD),(TD/DD),(BR/(DD+TD)),CRR)$

A striking feature of the model is that it characterises monetary equilibrium, in a characteristic fashion similar to product market equilibrium in which prices clear the market. Accordingly, the model achieves equilibrium in the monetary sector such that call money interest rate (which is postulated to capture the opportunity cost of money as well as price effect of financial portfolio of leading participants, the commercial banks) is determined by excess demand for money, the gap between money demand and money supply estimates. However, the specification does not exactly estimate interest rate using excess demand for money, rather money demand and money supply enter separately as explanatory variables.

$RS^{CALL} = f(M3^{D}, M3^{S}, LAG)$

Taking note of increasing significance of financial markets and the fact that monetary policy in the Indian context works through a mix of direct and indirect instruments of monetary control, and policy impulses are transmitted in the first instance through the financial markets, the KP model incorporated the interest rates block proving structural specification for a range of interest rates representing the spectrum of short and long-maturities across different instruments and financial products including deposits, credits, government securities and mutual funds. Accordingly, there are as many as 13 interest rate variables in the model, which include 91-day treasury bills, commercial banks' deposit rate for 1 to 3 year maturity, bank's minimum lending rate, lending rate for procurement of food grains, prime lending rates of major financial institutions such as, industrial development bank, industrial finance corporation of India, ICICI, and state finance corporations providing long-term financing to corporates, and mutual funds-dividend rate of UTI, which provide an alternative source of savings to households.

$RG^{TBILL}=f(\pi^{e},LAG)$

$RD=f(YR,RG^{e}\pi^{e},RL,R^{UTI},LAG)$

$RL^{SCB}=f(D,BCG,RL^{FI},BR)$

$RL^{FOOD}=f(YR^{AG},RD,\pi^{e},LAG)$

$RL^{FI}=f(RL^{SCB},TSAI,RB,LAG)$

$RL^{UTI}=f(RD,\pi^{e},LAG)$

$RG^{S}=f(FD/YN,LAG)$

$RG^{M}=f(FD/YN,\pi^{e},E,RG_{e}^{M}LAG)$

$RG^{L}=f(FD/YN,\pi^{e},E,RG_{e}^{M},LAG)$

Keeping in view the prominent role of quantity channel of money in economic development, the model accorded space to commercial banks and major long-term financial institutions in the Indian financial system in allocation of resources to productive sectors. The model provides separately structural explanations of food credit, which assumes considerable significance for growth of agriculture sector, and non-food credit, which meets short-term working capital and investment requirements of the manufacturing and services sectors, and sanctions and disbursement of loans from major financial institutions, the major source of long-term finance for investment activities of producing sectors.

$BCC^{F} = f\ (YR^{AG}, CRFP,$

$BCC^{NF} = f\ (YR^{NAG}, D, BCG, RL^{SCB}\}$

$BCG=f\ (SLR^{W}, RG^{W}, RL^{SCB}, LAG$

$BR=f(CRR, RB)$

$TSAI=f(YR^{NAG}, RL^{FI}, LAG$

$TDAI=f(TSAI)$

From monetary transmission perspective, the model is broadly calibrated to capture money, credit and interest rate channels in the classical tradition.

$YR^{AG}=f\ (RAIN, AREA, \Delta K^{AG}, BCC^{F})$

$YR^{MNF}=f(\Delta K^{MNF}, YR^{INFR}\})$

$YR^{SERV}\}=f(\Delta K^{SERV}, YR^{INFR}\})$

$\Delta K^{AG}=f[YR_{J}^{AG}, \Delta K_{G}^{AG}, PDFL^{AG}/PDFL^{MNF}{}_{j}]$

$\Delta K^{MNF}\}=f[YR_{-j}^{MNF}, BCC^{NF}/PDFL^{MNF}, \Delta K_{G}^{INFR}, TDAI)/PDFL^{MNF}{}_{J}]$

$\Delta K^{SERV} = f\ [YR_{-}j^{SERV}, BCC^{NF}/PDFL^{MNF}, \Delta K_{G}^{INFR}, TDAI/PDFL^{MNF}{}_{j}]$

$WPI^{AG} = f[M3/2YR, IP^{AG}, PCP, P^{ADMN}, P^{IMPORT}\}$

$WPI^{MNF} = f[M3/2YR, PA, P^{IMPORT}\}$

$WPI = \theta WPI^{AG} + (1-\theta)WPI^{MNF}\}$

$PDFL_{J} = f\ (WPI_{J})$

Aggregate money supply determines aggregate prices level, which percolates down to sectoral prices in order to transform real variables to nominal terms. Interest rates have no direct effect on investment activities including that of the private sector. Indirectly, however, the effect of interest rates ensues from the impact of lending rates on short-term bank credit and long-term finances by DFIs, which in real terms deflated by prices deflators pertaining to investment, affect real fixed investment in the manufacturing sector, thus, characterising the credit channel of monetary transmission. Inventory accumulation is determined by the level of fixed investment and investment price deflators, which in turn are affected by money and credit through their effect on aggregate price level. Thus, interest rates have direct effect on inventory choice of the producing sectors.

Rangarajan and Mohanty's Model

Rangarajan and Mohanty (1997) developed a medium-size macroeconomic model comprising about thirty estimated structural equations with the express objective of characterising the interaction among fiscal, monetary and external sectors in the Indian context. Their model provided space for the monetary sector in terms of structural equations in respect of inverted money demand, aggregate money supply underlying high-powered money hypothesis, deposit rate of interest rate, commercial bank deposits and credit to government. The striking features of RM's work relate to fiscal dominance and monetary targeting. This is reflected in the reserve money being specified in the form an identity equating the sum of sources of high power money and all the sources of reserve money, except bank credit to government, are exogenous to the system.

$M3=f(RM)$

$RM=RBCG+RBCS+RBNFA+CLG-RNML$

$RBCG=FD-\Delta BCG-\Delta FICG-DNMB-EB-MISCR+RBCG\bullet\ \bullet$

$FD=GXP-TR$

$BC=M3-RBCG-BCG-RBNFA-OBFA-CLG+RNML$

$BCG=\Delta BCG+BCG\bullet\ \bullet$

$\Delta BCG=f(\Delta D,SLR^{W}\})$

$\Delta D=f(\Delta M3)$

$RTD=f(YR,M3_{-1},\pi)$

$WPI=f(YR,M3,LAG)$

P^{DFL}=f(WPI)

$YR=f(RAIN,AREA,Y^{ABSP}\},M3\bullet\ \bullet\ ,K)$

$\Delta K=GDCF=f(YR_{-J}, \Delta BC+CAPB, RL^{W})$

The most distinguishing feature of the model pertains to aggregate money supply determination. Unlike other models, this model estimates money supply as a statistical function of reserve money as the explanatory variable. Both broad money and reserve money are used in their level form; thus money multiplier is constant on incremental basis. The average money multiplier, however, is not constant; it varies with the level of reserve money over time. Such characterisation of money multiplier does not incorporate the effect of proximate determinants such as currency to deposit ratio, cash-reserve ratio, and also interest rate, which affect the proximate determinants. Monetarist tradition impinges on the characterisation of money demand, which is postulated entirely in the form of classical quantity theory of money; money demand is determined by output and price level but not the interest rate. Thus, in the inverted form, price level depends on aggregate money and real output.

The model determines bank deposits endogenously as function of aggregate money and the lagged-dependent term referring to previous period's level of deposits.

Deposit rate of interest is determined by aggregate liquidity (broad money), real output, and inflation rate. The real lending rate of interest is determined in the form of an identity such that it is equal to the sum of deposit rate, and bank's operating cost less inflation rate.

The monetary transmission process of the model entails that the quantity of money supply and bank credit have direct effect on investment and real output besides the indirect effect through changes in aggregate price level-the inflation rate, deposit and lending rates which also affect investment and thus, capital stock and output, particularly in the non-agricultural sector. Interestingly, Rangarajan and Mohanty(1999) did not assign any role to policy instruments such as cash reserve ratio, and bank rate in the monetary transmission process.

Bhattacharya, Barman and Nag(1994)

Bhattacharya, et.al.,(1994) formulated a medium size macro-econometric model with focus on stabilisation policy options. Monetary sector accounted for six structural equations with three stochastic specifications --one each for broad money supply, base money, and commercial bank lending rate and three identities in respect reserve money excluding Reserve Bank's non-monetary liabilities, reserve bank's credit to government, and foreign exchange assets.

Broad money supply was estimated using reserve money, cash reserve ratio, and differential interest rate (between lending rate and bank rate) while base money statistically adjusted to reserve money excluding non-monetary liabilities, and lending rate responded to bank rate, cash reserve ratio and exogenously given commercial bank credit. Although there was no standard money demand function in the model, the stochastic specification of price behaviour in response to broad money, and output along with import prices reflected the inverted money demand function. The model relies on monetary targeting as money supply is determined in line with high-powered money hypothesis, albeit with a difference that high power money corresponds to autonomous component.

$M3=f(H^A)$

$H^A = RBCG+RBNFA-RBNML$

RBNFA=RBNFA• • +CAB+CAPB

RL = (RB, CRR, BCC)

WPI=f(M3,PQ,YR,LAG)

P^{DFL}=f(WPI)

YR = f(K• • ,RAIN,XQ,ΔGEXP)

$\Delta K = f(YR,RL,GEXP^K,LAG)$

From the perspective of monetary transmission, bank rate had a direct effect on commercial bank's lending rate, which in turn had direct effect on private investment, and thus, capital stock and real output. The bank rate also had direct effect on money supply, which in turn affected general price level. On the other hand, the policy instrument, the effect of cash reserve ratio percolated through its effect on commercial bank lending rate to real investment and real output. At the same time, cash reserve ratio through its effect on lending rate as well as money supply affected the general price level.

Kaur and Kaur (1994)

Kaur and Kaur (1994) developed a small monetary model of the Indian economy. Their model incorporated monetary sector equilibrium, with demand for money equated to money supply. The demand for money is modeled in terms of two principal components, currency held by the public and aggregate deposits which in turn are determined by income, and long-term interest rate on government securities.

C=f(YN,RG,)

D=f(YN,RG,)

$M3^D = C+D$

Money supply is modeled as a function of reserve money, and long-term interest rate on government securities.

$M3^S = f(H,RG)$

Short-term and long-term interest rates are endogenous to the system. Short-term interest rate is determined by its one period lag level and one period lag level of long term interest rate, thus, in some way, characterises the term structure of interest rates. Long-term interest rate is modeled along the principles of macroeconomic fundamentals, as determined by aggregate liquidity (money) and aggregate supply (income/output).

$RS=f(RG,LAG)$

$RG=f(YN,M3_j)$

Monetary and real sector linkage is established through interest rate effect on private investment.

$\Delta K = f(Y, \Delta K^G, RG)$

$Y=PC+GC+\Delta K+X-M$

Basu (1997)

Basu(1997) developed a small macroeconomic model within the framework of an adaptive control model in order to characterise the dynamics of monetary policy in the Indian context. The model comprised altogether sixteen structural equations including ten stochastic relations and six identities while using fourteen exogenous variables. As formulated in the adaptive expectation framework, most variables appear in lagged form in the stochastic formulation. The monetary block of the model had seven endogenous monetary and interest rate variables, *i.e.*, currency deposit ratio, banks reserve deposits ratio, Reserve bank's foreign exchange assets, and net domestic assets, aggregate money supply, bank rate, and money market interest rate. There were eight structural equations for the monetary block; two stochastic specifications devoted to proximate determinants of money multiplier, *i.e.*, currency deposits ratio and reserves-deposit ratio, a stochastic equation for aggregate money demand being determined by output and interest rate, an equation for money market interest rate, and one deterministic form equation for aggregate money supply determined by money multiplier times reserve money supply, and three identities in respect of reserve bank's foreign exchange reserves, net domestic assets, the equilibrium between money demand and money supply.

$M3^D=M3^S$

$M3^S=(1+k)/(k+r)H$

$k=f(RS_{-J}, YN_{-J}, TREND,LAG)$

$r=f(RS_{-J},YN_{-J},TREND,LAG)$

$M3^D=f(RS_{-J},YN_{-J},LAG)$

$YN = f(YN_{-J}^{A}, RS_{-J}, E)$

$CPI = f(YN_{-J}^{A}, P^{M}, LAG)$

The underlying monetary transmission process entailed interest rate channel while embracing Keynesian IS-LM framework. In particular, the quantity money as well as the interest rate affected money influenced domestic absorption and subsequently, domestic absorption affecting the output and price level.

Rao and Singh (1997)

Rao and Singh (1997) worked out a financial programming and growth oriented adjustment type macroeconomic model. Their model calibrated a consistent macroeconomic accounting and equilibrium framework with monetary approach to balance of payments and foreign exchange reserve accretion setting the core of theoretical analysis. As such, the model had real money balance function of real output and interest rate while money supply was specified as an identity equating the sum of domestic credit and foreign reserves.

Price level adjusts to excess demand for money; the gap between money supply and money demand. From monetary policy consideration, the model could set monetary supply targets; changes in money supply targets would affect foreign exchange reserve accretion, inflation, and exchange rate, which in turn would be channelised to affect savings, investment and economic growth.

Ranjan and Nachane (2002)

Ranjan and Nachane (2002) developed a macroeconomic model with focus on the current and capital accounts of balance of payment of the Indian economy in order to account for a detailed analysis of fiscal and monetary policy shocks on the external sector. Their model comprises five blocks in respect of balance of payment, external debt, output and price, money and credit, and fiscal sectors. Several macroeconomic models as discussed in the above have a guiding influence on this model in regard to functional form specification of economic variables. Of particular interest, monetary sector block has two behavioural equations in respect of broad money and bank credit. Broad money is stochastically related to reserve money and policy instruments such as CRR and bank rate. Reserve money is set out in terms of an identity linking to BOP through net foreign exchange assets. Bank Credit is linked to money supply and government borrowing which in turn is linked to fiscal block. Money has direct effect on prices but indirect effect on output through the direct effect of bank credit on investment and real activity.

The RCF Model Model : Models without Money

In the last about two decades, monetary policy analyses have witnessed several developments adducing to new theoretical insights, new empirical regularities as observed in monetary aggregates and evolving market conditions, in particular, rapid changes in the financial market environment. A succinct review of developments in theoretical macroeconomics literature is provided by IMF(2004) as set out in **Box I**. Of particular interest, the rational expectation and monetary policy rules such as Taylor type interest rate rule at theoretical level and instability in demand for money reported by several empirical research studies have had a deep impact on monetary analyses. Keeping in line with these developments, many central banks have abandoned intermediate monetary targets while switching from direct instruments of monetary control such as cash reserves requirements (CRR) to interest rates, usually, short-term central bank refinancing rate as policy instrument for modulating macroeconomic aggregates and inflation expectations in an increasingly competitive market environment. Several central banks are also increasingly tilting in favour of single objective of price stability; some have explicitly adopted inflation targets while others have been less upfront in this endeavour. Another major factor, which has facilitated the contemporary monetary policy analysis, relates to gradual waning of fiscal dominance on monetary policy. Money financing of government deficits, which prevailed upon intermediate monetary targeting regime, has given way to increasing bond financing of government deficits through market route. Accordingly, monetary transmission mechanism has undergone changes; policy induced changes in interest rates are, in the first stage, transmitted to financial markets to affect various other market interest rates and then, in the second stage, such changes in financial markets induce changes in savings, investment and thus, aggregate demand, real activity and inflation conditions. For modulation of policy instrument, several central banks are tilting in favour of policy rules such as interest rate rule for mapping policy actions as reflected in changes in short-term interest rate with output gap and inflation gap connoting for excess demand and inflation expectations.

Monetary policy analyses of several central banks have embraced macroeconomic models, which belong to the class of models without monetary aggregates. In the Indian context, the RCF model assumes first mover advantage in this endeavour. The RCF model embraces several contemporary issues and developments in monetary policy analysis. The model is medium size, comprising five blocks of real, monetary, fiscal, financial, and external sectors and twenty endogenous equations besides a set of identities in respect of government budget constraint, balance of payments and various other national accounts and statistical relations. The salient features of the model are the following.

Unlike other macroeconomic models in India, the RCF model is constructed with certain established counter-cyclical properties to facilitate policy analysis in a dynamic equilibrium framework. This has been possible due to characterisation of consumption and investment demand using Samuelson's multiplier-accelerator mechanism, which provides an inbuilt mechanism for the economy to move dynamically in response to exogenous shocks. It is for the first time, a macroeconomic model in the Indian context uses aggregate supply function based on production function, a la, neo-classical Cobb-Douglass function, to capture the effect of productivity shock, and changes in technology on the economy. The production function is linked to the macroeconomic model in the off-model framework, so as to characterise the state of supply constraint, which could be changed with endogenous capital accumulation, exogenous changes in labour supply, and advances in the state of technology. Thus, aggregate demand and aggregate supply interact dynamically to determine excess demand or structural output gap, which is linked to interest rate characterising the monetary policy rule.

Inflation target is exogenous through a stipulated threshold rate, which is determined in the off-model framework in order to characterise inflation target while allowing flexibility of policy preference to suit to evolving socio-economic conditions. The policy rule, calibrated as a Taylor type interest rate rule, is endogenous to the system since it is linked to structural output gap and inflations gap. From the stand point of monetary transmission, policy induced changes through bank rate are transmitted to the financial market through adjustments in deposit and lending rates to affect consumption and investment activities.

From the fiscal policy perspective, the model recognises government spending in terms of consumption and investment spending, the later again classified into productive infrastructure services and non-infrastructure services. Government's aggregate revenue is endogenous to the system while expenditure is exogenous. Such characterisation of fiscal sector along with the budget constraint enables an assessment of fiscal restructuring on aggregate demand as well as aggregate supply. A summary form of the model specification is as follows.

Aggregate Supply Func

$YR^{AS} = f(Labour, KS)$

Private Consumption

$PC = f(YR, R^{DRT}, LAG)$

Investment (Private)

$GDCF_{private,\ j} = f(YR_j, R^{LRT}, GDCF_{public,}^{services}, LAG)$

Capital Stock

$K = K_{-1} + GDCF$

Export demand

$Export = f(YR^{world}, P^{foreign}/P^{domestic}, LAG)$

Import demand

$Import = f(YR^{world}, P^{foreign}/P^{domestic}, LAG)$

Government Revenue

$TR = f(YR, P, LAG, tax\ rate)$

Monetary Policy Rule(Interest rate)

$R^{policy} = f\{(\pi - \pi^{treshold}, YR^{gap}, LAG)$

Inflation

$\pi - \pi^{treshold} = f(YR^{gap}, Z^{fuel}, Z^{AG}, LAG)$

Price Level

$WPI = WPI_{-1}(1+\pi)$

GDP Deflators

$P^{DFL} = f(WPI)$

Financial Market (Deposit and Lending rates)

$R^{Market} = f(R^{policy}, LAG)$

Aggregate Demand

$Y^{AD} = PC + GC + GDCF + Export - Import$

Output Gap

$YR^{gap} = Y^{AD} - Y^{AS}$

III. Analytical Assessment of the Macroeconometric Models in India

Macroeconometric modeling has come a long way in India. Over the years, macroeconometric models of the Indian economy have acquired technical sophistication as well as diversity while broadening their structural basis. The evolution of monetary sector modeling in India appears to have been characterised by three distinct phases <footnote>In some quarters, somewhat more fine classification of modeling phases is available; Krishnamurty(2003) recognises five phases.</footnote>

The early models constructed during the 1960-s and 1970s, which constitute the first phase, made pioneering contributions towards putting economy-wide models together with general objectives. The second phase, which began in the early 1980s, one the other hand, has been marked by specificity of objectives. In the third phase, macroeconomic models have endeavoured at providing detailed structural analysis of supply side, and demand side factors of real activity and prices, and more disaggregated treatment of fiscal sector, monetary sector and financial intermediation for policy evaluation. Macroeconometric models have increasingly sharpened their focus, leading to a greater variety and diversification.

Model building is essentially a process of `learning by doing'. Not surprisingly, therefore, one finds with the benefit of hindsight, a certain amount of rough edges and loose ends in the early models. For example, the Mammen Model (1967) does not have the government budget constraint. Moreover, it has a simple foreign sector but its feedback to the monetary sector is missing. Similarly, in the G.S. Gupta Model (1973), Reserve Bank has been treated as a apart of the government, which obscures the fiscal-monetary linkages.

Since the early models were adapted from similar models of the developed countries, some incongruities with the Indian economic structure are also evident. For example, in most early macro models, interest rates have been endogenised. This does not conform to the institutional reality of most interest rates being administratively determined in the years for which data were used in the models.

The foundation phase of macroeconometric modeling in India seems to have culminated in the Ahluwalia Model (1979) which presents a neat analytical formulation of the monetary sector in India. Portfolio behaviour of relevant sectors has been neatly encapsulated in a set of behavioural equations, balance-sheet identities and equilibrium conditions. In that sense, it could be regarded as a bench-mark macroeconometric model of the Indian economy.

Having attained analytical sophistication during the first phase, the modeling effort in the second phase became more purposeful and task-oriented, guided as they are by specific rather than general objectives.

First, there were the short-term forecasting models developed by Rao, Venkatachalam & Vasudevan (RVV) and by and by Madhur, Nayak and Roy (MNR). These models essentially focused on developing macroeconometric framework for forecasting macroeconomic aggregates as a useful input into policy formulation.

The RVV Model (1981) has convincing established the need for an econometric model for consistent forecasting of monetary aggregates. The published version of the model, however, has reported only the `interim' results./ The `interim' version, however, does not adequately capture the interaction either between the monetary and real sector, or between the monetary and fiscal sector. Explicit specification of the real sector is non-existent; instead real income is simply taken to the an exogenous variable. The fiscal sub-model is also absent. As a result, the critical link between fiscal deficit, net RBI credit to the government and the reserve money has been left unexplored.

The more elegant MNR Model (1981) seems to have gone beyond a mere forecasting of monetary aggregates and has made a maiden attempt to develop a methodology of forecasting the impact of government budget on key macroeconomic aggregates. Here again, the published version has reported only `work-in-progress'. The interim version does not report sub-models for the real sector as well as for the external sector. This incompleteness has seriously undermined the usefulness of the model, as the promising line of investigation has not been pursued fully.

Another interesting development during the 1980s was the emergence of a different class of the so-called `structuralist' model, which adopted a disaggregated approach to price formation, placing emphasis on `structural' or `institutional' factors besides the monetary factors. Krishnamurty (1984), Pandit (1984) and Pani (1984) are prime examples of such models.

These models have been characterized by a marked degree of heterogeneity which, in the absence of relevant justifications, amounts to arbitrariness. In the structuralist models of the Indian economy, this phenomenon is evident in the way as well as the form in which money is introduced.

The Krishnamurty model introduces money in the equations for all the sectoral prices (except for energy) as well as in the GDP deflator. The Pandit model introduces money in food and raw materials prices which, in turn, determine other sectoral prices (except energy prices) as well as the GDP deflator. In the Pani model, money enters only in the equation for food price which acts as the prime mover in f\influencing other sectoral prices. The overall price level (WPI) in the Pani model, however, is determined not as a weighted combination of sectoral prices as in the Pandit model, but through a behavioural equation with money as an argument along with food prices.

There is no uniformity even in respect of the form in which money is incorporated. For example, Krishnamurty prefers money per unit of aggregate output (as a proxy for the "excess demand pressure") while Pani confines it to money as a ratio of output in agriculture and manufacturing. On the other hand, Pandit opts for the rate of monetary expansion as an argument in price equations.

At times, there is asymmetric treatment even within the same model. For example, in the WPI equation, Pani e\uses the ratio of money to output in agriculture and manufacturing. When it comes to the equation for GDP deflator, however, the ratio of money to nominal GDP is deployed.

There is certain degree of ambivalence even in respect of the macroeconomic role of the money market. The excess demand for money spills over to the commodity market and any disequilibrium in the money market leads to changes in the general price level. By contrast, in the structuralist view, the ,money market does not determine the general price level and, hence disequilibrium in the money market must reflect somewhere else say in the determination of some other price such as the interest rate.

In the Krishnamurty model, monetary disequilibrium manifests itself in the general price level as in the monetarist tradition. In the Pandit model, the money market determines one of the short-term interest rates in the economy, namely the bazaar bill rate. In the earlier version of the Pani Model (1977), the money market determined a wide range of interest rates including the time deposit rate, the call money rate and the banks' price lending rate. In the later version of the model (1984), this position has been reversed and the monetarist stance has been adopted.

In spite of these limitations, there is no doubt that the structuralist models have drawn a pointed attention to `structural' factors that have a bearing on inflation and have warned against excessive reliance on monetary factors alone. A lot more research however, is required before a cohesive and full-fledged paradigm becomes available.

In the meantime, macroeconometric modeling on the conventional line has continued through the 1980s, with a sharper focus Jadhav-Singh Model (1990) and Rangarajan-Arif Model (1990) are some latest efforts in that direction.

These two models focus on the interactions between the monetary, fiscal and real sectors in a closed economy framework with the inverted money demand function at its core as the price equation. The two models are broadly congruent; both demonstrate that the government expenditure adjusts more rapidly than receipts to a given change in price level. As a result, inflation tends to widen the fiscal deficit, leading to larger money supply exacerbating inflation further. Both the models have an attempt to capture the self-perpetuating cycle of a deficit-induced inflation followed by an inflation-induced deficit.

There are important differences in the modeling strategy though. The Rangarajan-Arif model follows the budgetary classification revenue and capital, expenditure and receipts which allows endogenisation of bank credit to government and government's non-market borrowings. On the other hand, the Jadhav-Singh model follows the distinction between development and non-development expenditure which paves the way for capturing the self-enforcing tendency of fiscal deficits -- the large deficit leading to higher domestic debt (outside the RBI), which raises the interest burden with a lag, thereby aggravating deficits in the next period.

During the 1990s, although most Indian macroeconomic models have inherited the tradition set out in the 1980s, they have been shown interest in structural transformation adducing to the new economic regime. The IEG-DSE model, which owe to Krishnamurthy and Pandit, and the KP model follow the same tradition with regard to monetary transmission process, in particular, monetary effect on prices. The difference between the 1980s and the 1990s pertain to highly disaggregated treatment of supply side of the economy, and monetary and financial sectors. Monetary variables have direct effect on prices and other nominal variables including interest rates and exchange rate, while interest rates, despite significant change in the financial restructuring, have indirect effect on investment and real output. Similarly, the RM model resembles to RA model; fiscal dominance and monetary targeting remaining at the core of analysis. Other models, in particular, the medium size models of Basu(1997), and Kaur(1996), are typically driven by an IS-LM type analysis with both credit and interest rates directly affecting consumption, investment, and output.

IV. Future Perspective

Since 1991, the Indian economy has undergone a phenomenal structural transformation in the wake of economic reforms, liberalisation, globalisation and rapid advances in information technology. The economy is becoming increasingly competitive.

The structure of the economy has changed remarkably with services sector accounting for about half of the country's GDP. The underlying structural transformation might have had a perceptible change relating to the inter-linkages among macroeconomic aggregates reflecting the remarkable change in economic agents 'behaviour toward consumption, saving, investment, and expectation formation. From the supply side, the production frontier accompanied by industrial restructuring, and development of information technology has changed as it is reflected in the potential growth continuously improving over the years. From financial market perspectives, there have been qualitative change in institution building process amidst deregulation, and increasing market orientation of the financial sector. From monetary policy point of view, intermediate monetary targeting has ceased to be relevant with the emphasis shifting from direct instruments to indirect instruments of monetary control such as interest rates. Saving and investment instruments have widened with increase in depth of financial markets. In this context, there are several challenges to the existing macroeconomic models.

First, most macroeconomic models developed in the 1990s are estimated using data-base pertain to the period of either before 1970s or the period from 1970s to early 1990s. In this context, there are concerns over the usefulness of these existing econometric models for policy analysis due the considerations of parameter stability and uncertainty. Second, for meaningful analyses, models must relate to contemporary theoretical and empirical literature, which have perceptible influence on the policy making. Several new developments in macroeconomic literature, particularly, increasing recognition of rational expectations, open economy macroeconomic analysis-market determined exchange rate regimes with liberalised current account and greater openness of capital account, fiscal policy with bond financing, rule based monetary policy reaction functions, inflation targeting and forward looking monetary and financial policies are yet to be recognised by macroeconomic models.

Third, there is also increasing recognition of demographic changes and their influence on long-run sustainability of economic growth. Most models in the Indian context suffer from the limitation of neglecting demographic trends.

Fourth, several models suffer from serious functional form mis-specification. Of particular interest, modelling of high-powered money and money demand functions are inconsistent with theoretical models.

Fifth, macroeconomic models serve as an important tool for policy analysis. In general, economic policies could be used for two broad objectives; stabilisation purpose or counter-cyclical purpose and forward looking purpose, ***i.e.***, for maintaining long run stability. From stabilisation perspective, macroeconomic models should satisfy some countercyclical properties. Models should be dynamic and capable of achieving the adjustment to equilibrium in the face of policy shocks. At a theoretical level, such characterisation of models could be envisaged in various ways, including the consumption-investment dynamics a la Samuelson type multiplier-accelerator mechanism characterising the momentum of the economy. From forward looking perspective, models should incorporate relevant optimisation problem such as consumption smoothing, and capacity augmenting investment activities to sustain long-run growth. In the context of price stability or inflation targeting, a robust forecasting process for inflation coupled with a robust monetary policy reaction function assumes critical importance. similarly from the perspective of long-run sustainability of growth, underlying demographic changes as reflected in the labour supply, skill formation and productivity should influence supply side in production function framework.

In the Indian context, most models miss on these perspectives. Although the RCF model, takes note a few perspective, it is incomplete in various ways. From the supply side, although the supply of labour and labour productivity determine long run growth path, the economy-wide production framework seriously faults on the structural side which could be improved with production function separately estimated for various broad sectors of the economy. The monetary policy reaction function need to be calibrated in an open economy framework while taking care of exchange rate and external sector developments. This is particularly relevant in the context of globalisation and increasing internationalisation of economic policies including monetary policy (Mohan, 2004). In the RCF model, the external sector of the economy is seriously missing on evolving structural change in regard to capital flows and current account dynamics.

Sixth, according to an eminent statistician David Hendry, economic models should be all encompassing in nature with the scope for alternative formulations in order to validate robustness of model . Most macro models appear to be having lineage to some particular schools of thought. Thus, models are subject to the criticism of 'incredible theory" owing to Christopher Sims. In retrospect, what then could be identified as promising areas for future modeling effort? In the conventional as well as the structuralist models, the causation typically runs from the monetary and non-monetary factors to prices, whereas the impulses transmitted from prices to other macro-variables are generally not incorporated. Such attempts, as in Jadhav-Singh or Rangarajan-Arif model, are limited in scope, which however need to be generalised and enlarged for a better capturing of the transmissions to other macro-variables. In the formulation of price formation, the conventional and structuralist models are seen as mutually exclusive alternatives. This need not necessarily be the case. Indeed, one could think in terms of combining the desirable features of both types while eliminating the deficiencies of either. In any case, bringing about cohesiveness in the structuralist models is undoubtedly called for. Moreover, the early effort at developing forecasting models which was inexplicably aborted could be taken up again. Most importantly, it must be recognised that even after three decades of modeling effort, a reasonable policy-oriented model is still conspicuous by its absence. In sum, trite as it may sound, one could say that while much has been done, much nonetheless remains to be done.

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Notation

Money and banking aggregates
C : currency held by public
H : High powered money
H* : Unborrowed reserve money
BR : bank reserves
RR : required reserves
ER : excess reserves
CLG: currency liability of government
RBCG: RBI credit central government
RBCB : RBI credit to commercial banks
RBCC: RBI to Commercial sector
RBNFA : RBI holdings of foreign exchange assets
RBNML: RBI's net non-monetary liability
RBOA: RBI's other assets
OD : Other deposits
M1 : narrow money
M3 : broad Money
DD : demand deposits
TD: time deposits
D : total deposits
DS: deposits of scheduled commercial banks
DI : impounded deposits
DL: demand liabilities
TL: time liabilities
L: banks' aggregate liabilities
BC: total bank credit
BCG: banks' credit to government
BCC: bank credit to commercial sector
BCF: banks' food credit
BOS: banks' investment in other approved securities
BECS: bank's excess investment in government and other approved securities
X : Reserves of banks other than scheduled commercial banks with RBI
BOA : banks' other assets
BOA: Banks' other assets (variously computed)
BSCG: Banking system's credit to government
CRR: Cash reserve ratio
ICRR: Incremental cash reserve ratio
SLR: Statutory liquidity ratio
NB: Number of bank branches
NRB: Number of rural bank offices
k: Currency-deposit ratio (C/D)
r: Bank reserve-deposit ratio (BR/D)
q: borrowed reserves-deposit ratio (RBCB/D)
m : Money multiplier
TSAI: total sanctions of finance by all-India financial institutions (IDBI, ICCI, *etc*)
TDAI: total disbursement of finance by all-India financial institutions(IDBI, ICCI, *etc*)
Rates of Return

Rs: Short-term rate of return (variously computed)
RTD : Rates of interest on time deposits
RL: Loan rate (variously computed)
RL^{Food}: Loan rate for food credit
RB: Bank rate
RC: Call money rate
RG: Rate of return on government securities
RIS: Rate of return on industrial securities
R : Deposit rate
RL^{UTI} : UTI mutual funds return
RG : weighted government bond yield
RG^{S} : short-term government bond yield
RG^{M}: medium-term government bond yield
RG^{L} : long-term government bond yield
R^{SBI}: SBI lending Rate
R^{IDBI} : IDBI rate
R^{IFCI} : IFCI rate
R^{ICCI}: ICCI rate
RL^{FI} : Average of financial institutions lending Rate
RL^{SCB}: average of Scheduled Commercial bank lending rates
R^{policy}: monetary policy rate (RB)
RL^{market}: market interest rate (RD, RL, *etc*.,)

Fiscal variables
GEXP : Government total expenditure
GRR: Government's revenue receipts, nominal
TXR: Tax receipts, nominal
NTR: Non-tax receipts, nominal
GKR: Government's capital receipts, nominal
GRE: Government's revenue expenditure, nominal
GKE: Government's capital expenditure, nominal
DEVE: Development expenditure, nominal
INT: Interest payments on government debt
NINDE: Non-interest, non-development expenditure, nominal
FD: Fiscal deficit of the Central Government
CFD: Combined fiscal deficit of Centre and States
HPD: High powered deficit
GCC: Government credit to the commercial sector
GS: Government securities outstanding
GSP: Government securities held by non-bank public
NBCG: Non-bank financial institutions' credit to government
DEBT: Government's outstanding debt held outside the RBI
B : Government's total borrowings outside the RBI
DB : Government's domestic borrowings outside the RBI
FB : Government's foreign borrowings
DBM : Government's domestic market borrowings
DBNM : Government's domestic non-market borrowings
OSF : Other sources of financing government deficit
ETR : Effective excise tax rate

Output and Income

PC: real personal consumption expenditure
GC: real government's consumption expenditure
GDCF: real gross domestic capital formation
Export: real exports
Import: real imports
YN : Nominal income
YNA : Nominal agricultural income
YNAN: Nominal non-agricultural income
YR: Real income
YAR: Real agricultural income
YNAR: Real non-agricultural income
YR^{C} : Capacity (trend) output
YR^{AG}: real agriculture output index
YR^{MNF}: real agriculture output index
YR^{SERV}: real agriculture output index
Y^{AD}: aggregate demand
Y^{AS}: aggregate supply
YR^{gap} : aggregate real output (GDP) gap
YR^{world} : A measure of real activity (world)

Prices

P = General price level (GDP deflator)
WPI = Wholesale price index
WPI^{AG} = Wholesale price index (agriculture)
WPI^{MNF} = Wholesale price index (non agriculture)
CPI = Consumer price index
PS = Price index for `sensitive' commodities
PA = Deflator for agricultural output
PNA = Deflator for non-agricultural output
PF = Price index for foodgrains
PR = Price index for raw materials
PM = price index for manufacturers
PT = Price index for textiles
PE = price index for energy items (fuel, power, light and lubricants)
DFL : GDP deflator
DFL^{J}: deflator for sectors, AG, MNF, SERV
π : inflation rate
π^{e} : expected inflation rate
π^{th} : threshold inflation rate
$P^{Foreign}$: Foreign price
$P^{domestic}$: domestic price (WPI, P, DFL, *etc*.,)

Miscellaneous Variables

Δ : difference (change) operator
e : expectation subscript
K: capital stock
t = Time
NFA = Net Foreign Assets
NFAO = Net foreign assets held outside the RBI
FR = Foreign remittances

CC = Total credit to the commercial sector
PRF = Profits
KR = real capital stock
K^{J} : capital stock for sectors (AG, MNF, SERV)
W = Money wages
HSS = Household sector's nominal savings
CUTL = Capacity utilisation ratio

Annexure I

There are three broad classes of models:

(i) Single Equation Regression Models

Regression analysis was applied to estimate economic relations in the 1930s. Outstanding examples are the study of business cycles by Tinbergen (1939), and the study of demand for agricultural products by Schultz (1938)[2]. Within single equation framework,

- The variable under study is explained by a single function of a number of explanatory variables; and
- Several assumptions are involved in the classical linear regression model. These are: no multicolinearity among independent variables, no heteroscedasticity in error variance, no autocorrelation, no correlation between an error term and an independent variable *etc*.

Single equation methods are sometimes called `limited information methods' because they only utilize knowledge of the restrictions in the particular equation being estimated. Examples of these are: Ordinary Least Squares (OLS), Indirect Least Squares (ILS), Instrumental Variables (IV), Two-Stage Least Squares (2SLS) and Limited Information Maximum Likelihood (LIML) methods.

(ii) Multi-equation Simulation Models

It was the monumental 1943 work of Trygve Haavelmo (who received the Nobel Prize in 1989), which broke new ground in econometric method departing from traditional regression analysis in statistics that brought structural models to the centre stage. Until the 1970s, the simultaneous equation approach advocated by the Cowles Commission dominated the empirical research in econometrics. The Cowles tradition set out the following:

- The variable to be studied is a function of several explanatory variables, in turn related to each other as well as to the variable under study -- a set of individual relationships -- simulation is the process of solving them over some range in time.
- Systems estimating procedure estimate all the structural equations together as a set instead of estimating the structural parameters of each individual equation separately. These systems methods are also called `full information' methods

[2] For his contribution to econometrics, Tinbergen received one of the first two Nobel Prizes for Economic Science in 1969.

because they utilise the knowledge of all restrictions and as such have smaller variance-covariance matrix than single equations. By the same token if the model is misspecified, all the structural parameters will be affected as against particular parameters in the single equation estimation.

- Two major systems methods are: Three-Stage Least Squares (3SLS) and Full Information Maximum Likelihood (FIML).
- Interaction among variables is also captured, so it contains more information than the sum of individual regression equations.
- They involve assumptions about movement of future behaviour of exogenous variables.

(iii) Time Series Models

The initial optimism about the potential of the simultaneous equation model was not fulfilled and the inability of large-scale macro-models to compete with `atheoretic' Box-Jenkins ARIMA models on predictive grounds has led to an increased adoption of time series techniques in the 1980s. Simultaneous equation models were criticised mainly on two grounds; first, forecasts obtained from them were often unreasonable and second, restrictions placed on a simultaneous equation model for identification are not `credible' because in a general equilibrium analysis all variables will affect all other variables, which implies that all variables are endogenous. Seminal papers by Sims (1980), Engle and Granger (1987) and Johansen (1988) prepared the ground for the ultimate success of Vector Auto-Regression (VAR) in econometrics. Forecasts from these models served as a useful benchmark for comparison purposes vis-à-vis proper econometric models and these forecasts were combined with other forecasts to produce improved forecasts. However, as argued forcefully by Cooley and Le Roy (1985), VAR has the status of a `reduced form' and thus merely summarises the dynamic properties of the data. Without referring to a specific economic structure such a reduced form is difficult to understand. As long as such parameters are not related to structural parameters characterising technologies, optimisation behaviour *etc.*, the parameters do not have an economic meaning and subject to the so-called `Lucas Critique'. These criticisms have led to the emergence of Structural VAR as a dominant methodology for empirical work in macroeconomics and monetary policy analysis. While it fits nicely to some recent macroeconomic developments including the theory of rational expectations and the Real Business Cycle agenda, it also takes advantage of VAR approach and co-integration.

As of the rationale of the time series approach, nearly all simultaneous equations models used in macroeconomics and financial economics are dynamic in the sense that some of the pre-determined variables are lagged endogenous variables, while the remaining are exogenous variables. A simple example is a first-order auto-regression. Ever since Trygve Haavelmo's work, economic time series is viewed as realisation of a stochastic process and this allows the model builder to use statistical inference in constructing and testing equations that characterise relationships between economic variables.

Up to the early 1980s, the statistical theory applied to model building and testing large-scale simultaneous equations was based on the assumption that variables in these models were covariance-stationary. Beginning with the influential paper of Engle and Granger (1987), models with unit roots have become more popular. It has been shown that macro-economic models containing non-stationary variables can be constructed in such a way that results are both statistically sound and economically meaningful. Granger achieved this by introducing the concept of co-integrated variables, which has radically changed the way econometric modeling is carried out. Time series models including ARMA, ARIMA, VAR, Co-integrated VAR, Structural VAR are popular for the following characteristics:

- No a priori causal relationships that affect the variable we are trying to forecast;
- Past behaviour of a time series to infer something about its behaviour; and
- Adopted when little is known about determinants of the variable being studied and useful for short-term forecasting.

The general principle here is that the choice of the model type involves tradeoff between time, cost, energy and desired forecast precision. Given some information about the process involved, it may be useful to construct the types of models and compare their relative performance.