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MODELLING THE CARIBBEAN MACROECONOMY FOR FORECASTING AND POLICY ANALYSIS

Problems and Solutions

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Abstract

This article looks at the various alternative approaches available for modeling the Caribbean economy and examines their potential for economic forecasting and policy simulations. The costs and benefits associated with the construction and use of the various models are considered in some detail, and special emphasis is placed on data requirements. Where they exist, illustrations of the various approaches appearing in the literature on Caribbean econometric modeling are critically analyzed.

Introduction

It is fitting to begin this paper with a lengthy quote from one of the gurus of maroeconometric modelling, Ken Wallis:

> *All economic forecasters and policy analysts use economic models. That is, they have a framework for the interpretation and analysis of economic data that allows them to proceed from assumptions about economic policy and the external environment to the prediction of the likely state of the economy. Some people, interested in only a few aspects of the economy, do this in their heads, using various rules of thumb. But as the range of questions expands, this gets more difficult. In any case these informal and intuitive methods are hard to explain and transmit to other people, who are likely to get different answers, without knowing why. Increasingly, macroeconomic forecasting and policy analysis is based on a formal, explicit macroeconometric model that, quantified with reference to historical data, provides a consistent and comprehensive account of the relevant interactions and interdependencies within the economy.* Wallis (1993), p.113.

This quote, made with specific reference to (structural) maroeconometric modelling, is valid for a host of methods that we can collectively describe as quantitative modelling of the macroeconomy. We will, in this paper, consider a selection of such methods and discuss their relative strengths and weaknesses as well as their potential for use with Caribbean economic data.

Quantitative modelling in the Caribbean began relatively humbly in the 1960s and 1970s with structural econometric models like those of Harris (1970), Carter (1970) and Manhertz (1971) for Jamaica and Persad (1975) and Gaffar (1977) for Trinidad & Tobago. They were really little more than academic exercises in the estimation of models of the open Keynesian economy (Kennedy (1966)) which, after all, was the tradition emanating from the metropolitan centres. In particular, there seemed to be no real concern about using them for forecasting and policy analysis.

In more recent times, the structural econometric approach has been developed to take greater account of Caribbean economic reality and recent advances in econometric theory. The authors also seemed to be much more concerned about their usefulness for forecasting and policy evaluation. Some examples are Hilaire *et al.* (1990), St. Cyr and Charles (1992), Watson and Clarke (1995) and Watson (1998) for Trinidad & Tobago, UNDP (1991) for Jamaica, Ganga (1990) for Guyana and Leon and Samuel (1994) for the ECCB area.

In the 1990s the so-called time series alternatives to structural modelling began to appear. Robinson (1996), Watson (1996, 1999) employ VAR models, Watson (1997a) compares VAR and ARIMA modelling, Leon (1995) and Nicholls (1995) applied GARCH models to interesting Caribbean problems while Maurin (1996) makes a strong case for the use of state-space models along the lines of those developed by Aoki (1987).

Other approaches have not yet found favour with Caribbean scholars. These include Computable General Equilibrium (CGE) models and perhaps more significantly Real Business Cycle models which Diebold (1998) refers to as the "new structural econometrics".

There is little evidence that the modelling efforts to date have influenced the decision making process in the Caribbean although some models, especially of the structural econometric genre, appear to have been explicitly built for this purpose. This is in stark contrast to the practice elsewhere, especially in the so-called developed countries, where such models are used to inform the short-term budgetary and long term planning processes.

Why this neglect in policy circles? Several possible reasons come to mind, all of which will be discussed in one way or another later in this paper. These reasons are:

- Scepticism of the policy makers vis-à-vis the validity of quantitative economic models
- Ignorance about the potential of such models
- Ignorance about the requirements for the best use of these models
- Models are too expensive to maintain
- Personnel on the ground do not have the required competence
- The data are not available and the required data will be too expensive to acquire

We pay particular attention to the needs of the decision-makers who are the principal potential clients for models. These needs are not homogenous and will vary in time and space. It is our purpose to lay bare to this clientèle the facts that will allow them to determine:

- Which modelling approach is better suited for dealing with what problem
- The costs and benefits associated with the acquisition and maintenance of such models

In the following sections we look in turn at the following approaches to econometric modelling (our main concern is with the macroeconomy):

- Structural econometric models
- Time Series Models (ARIMA models, VAR models, GARCH models and cointegration)
- Computable General equilibrium (CGE) models
- Real Business Cycle Models

It may be necessary at any one time for a particular user to apply more than one of these approaches simultaneously depending on the end requirements of the user. They should be seen as complements to each other and not necessarily as substitutes.

Structural econometric models

Structural econometric modelling became extremely popular in intellectual circles following largely upon the work of Keynes (1936) and the Cowles Commission. Caribbean scholars "followed fashion" by developing similar models and indeed continue to do so despite the barrage of criticisms levelled against this approach. See Diebold (1998). One of the most cited criticisms is the famous Lucas critique (Lucas (1976)) that the policies being evaluated will eventually result in action tending to counter such policies. Decisions and forecasts based on them are therefore flawed.

Some of the Caribbean examples of structural econometric modelling are referred to in the previous section. They have been by far the dominant feature of Caribbean economic modelling and indeed not much else has been done. It is fashionable now to speak about the failure of such models generally because of their poor forecasting performance but in the specific case of the Caribbean they were not even given that chance! They simply remained unused and nothing is really known about their performance. Non-acceptance, rather than failure, seems to be the more appropriate term to employ.

Perhaps the fate of structural econometric modelling in the Caribbean was predictable. There are some basic underlying problems with the construction and use of such models in the Caribbean contexts (and perhaps in other contexts as well). In the first place, the much vaunted failure of the large econometric models did very little to reassure Caribbean policy makers that they were missing out on a good thing. Secondly, these models make use of macroeconomic theory. A cursory glance at the literature will convince the reader that a lot of controversy surrounds the notion of a Caribbean economic theory (Célimene and Watson (1991)) and there is a strong tradition of criticism of Keynesian and other "metropolitan" theories. Many of the professionals employed in positions of authority are not only aware of the controversies but will have almost certainly been weaned on them. The crowning irony is that the national accounting systems which have been developed are all based on standard Keynesian constructs and any attempt at macroeconometric modelling would have reflected this bias.

There is, thirdly, the perennial and all pervasive problem of data or rather the absence of it. This paper is not overly concerned with the quality of economic data used in macroeconometric models in the Caribbean, nor with the related problem of the disparity between concept and measure. That economic data are of questionable quality is only too well known - see Morgenstern (1950). But as Griliches (1986) points out, it is this very deficiency that justifies the existence of econometrics as a special branch of study in the first place. In the final analysis, we must make do with what we have and stop blaming our own shortcomings on measurement errors and so on. Hendry (1980) sums up this position:

> ...Economic data are notoriously unreliable...and in an important sense econometrics is little more than an attempted solution to our acute shortage of decent data...

Data deficiency in the Caribbean, however, is not limited only to questions of data quality. Data might be, above all, deficient in quantity and it is this aspect of data deficiency - the quantity aspect - that is the principal preoccupation here. Data series required for a macroeconometric model of even the most modest size might be either non existent, or plagued by missing values, or too short, or, finally, of inappropriate frequency. At the same time, there is abundance of data in some specific areas and this is sometimes ignored by model builders.

Let us follow this up by looking in Table 1 below at a prototype macroeconometric model of Caribbean-type economies which contains six (6) interlocking blocs and 29 equations and which is intended to be the barebones of a useful working model. It is an adaptation of a larger model of the Trinidad & Tobago economy (Watson and Clarke (1995)) based on annual data. That model contains over 100 equations and, to some extent, what follows is a discussion of some of the more crucial data issues uncovered during the construction and eventual use of this larger model.

Table 1

Prototype Model of a Typical Caribbean Economy

BLOC I	$Y = C + I + X - M$	(1.1)
	$C = C_p + C_g$	(1.2)
Aggregate Expenditure Bloc	$I = I_p + I_g + I_s$	(1.3)
	$YD = Y - \frac{T}{P_y}$	(1.4)
	$C_p = f_1(YD, L, \dots)$	(1.5)
	$I_p = f_2(Y^{cap}, K, r, \dots)$	(1.6)
BLOC 2	$GDEF = C_g{*}P_g + O_g - T$	(2.1)
Public Sector Bloc	$T = g_1(Y, \dots)$	(2.2)
BLOC 3	$\frac{L}{P_y} = h_1(Y, r, \dots)$	(3.1)
Financial Sector Bloc	$\Delta XD_g = GDEF - \Delta ID_g$	(3.2)
	$\Delta XD = \Delta XD_g + \Delta XD_o$	(3.3)
	$\Delta L = \Delta R + (\Delta ID_g - \Delta NBCR_g) + \Delta CR_p + \Delta L_o$	(3.4)
	$r = \frac{(1 + r^a)}{(P_r / P_{r-1})} - 1$	(3.5)
	$\Delta R = X{*}P_e - M{*}P_m + \Delta XD + \Delta R_o$	(4.1)
BLOC 4	$X = X_1 + X_2 + X_s$	(4.2)
	$M = M_g + M_s$	(4.3)
Balance of Payments Bloc	$X_2 = k_1(GDP_w, \frac{P_e}{P_w}, \dots)$	(4.4)
	$M_g = k_2(Y, \frac{P_m}{P_r}, \dots)$	(4.5)
BLOC 5	$P_y = l_1(w, P_r, \dots)$	(5.1)
	$P_m = l_2(P_w, \dots)$	(5.2)
Wages and Prices Bloc	$P_g = l_3(w, P_r, \dots)$	(5.3)
	$P_e = l_4(w, P_r, \dots)$	(5.4)
	$P_r = l_5(w, P_m, \dots)$	(5.5)
	$w = l_6(P_r, U_R, \dots)$	(5.6)
BLOC 6	$K = I_p + I_g + (1-\gamma) K_{-1}$	(6.1)
	$UNEMP = N - EMP$	(6.2)
Output and Employment Bloc	$\frac{Y^{cap}}{Y} = m_1(EMP, K, \dots)$	(6.3)
	$N = m_2(w, POP, \dots)$	(6.4)
	$U_R = UNEMP / N$	
	$EMP = m_3(w, Y, \dots)$	(6.5)

Endogenous Variables

C = Total Consumption Expenditure (constant prices)

C_p = Private Consumption Expenditure (constant prices)

EMP = Level of Employment

GDEF = Government Overall Budget Deficit

I = Gross Capital Formation (constant prices)

I_p = Private Sector Fixed Capital Investment (constant prices)

K = *Gross Capital Stock (constant prices)*

L = Stock of Money Supply (assumed equal to demand)

M = Imports of Goods and Services (constant prices)

M_g = Imports of Goods (constant prices)

N = Total Labour Force

P_e = Exports Deflator

P_g = Government Current Expenditure Deflator

P_m = Imports Deflator

P_r = Index of Domestic (Retail) Prices

P_y = National Output Deflator

r = Real rate of Interest

R = *Stock of Foreign Assets*

T = Government Tax Receipts

UNEMP = Level of Unemployment

w = Wage Rate

X = Exports of Goods and Services (constant prices)

X_2 = Exports of Non Traditional Goods (constant prices)

Y = National Output (constant prices)

Y^{cap} = Capacity Output

YD = Total Disposable Income (constant prices)

XD = Total External Indebtedness

XD_g = External Indebtedness of Central Government

Exogenous Variables

CR = Bank Credit to the Private Sector

C_g= Government Consumption Expenditure (constant prices)

GDP_w = World Output

I_g = Public Sector Fixed Capital Investment (constant prices)

I_s = Investment in Stock (constant prices)

ID_g = Internal Indebtedness of Central Government

L_0 = Other Factors Affecting Money Supply

M_s = Imports of Services

$NBCR_g$ = Non Bank Credit to Central Government

O_g = Other Government Expenditure (Net)

POP = Size of Population

P_w = Index of World Prices

R_0 = Other Factors Affecting Foreign Assets

r^n = Nominal Interest Rate

X_t = Exports of Traditional Goods

X_s = Exports of Services

XD_o = External Indebtedness of Non Central Government Sector (including State Enterprises and Central Bank)

γ = Rate of Asset depletion

In reality, a model to be used for forecasting and policy simulations ought to be much more disaggregated than this one and, in what follows, the further problems associated with such disaggregation will be discussed. In addition, the construction of a macroeconometric model of this type, on the basis of the existing data base, will inevitably involve the use of annual data at best. A coherent set of data of shorter frequency (in particular quarterly data) to meet the requirements of this model simply does not exist. This implies that adjustments which take place over shorter time periods, for instance two to three months, cannot be adequately modelled and, as a very first step, efforts should be made to generate quarterly data to suit the needs of this model. What is remarkable, too, is that none of the economies of the Caribbean can boast of a data bank that can adequately service the requirements of even a highly aggregated model as this one even using only annual data.

The basic data requirement of any macroeconometric model is provided by the National Income and Expenditure Accounts (or the National Income and Product Accounts to use the American terminology). This *Aggregate Expenditure Bloc (Bloc 1)* is an attempt to model the principal expenditure variables appearing in these accounts and, from that point of view at least, is most dependent on the regular and timely publication of these accounts. Moreover, it is the availability of these values at constant prices (and not simply current prices) which is of crucial importance.

The story is not a joyful one for countries of the Caribbean. In all these countries, the principal activity in national income accounting consists of the calculation of total production as the sum of the "value addeds" of the various sectors of activity to give Gross Domestic Product (GDP) at current and constant prices. And although the expenditure breakdown is published for most of the territories, it is usually with some considerable time lag. At the time of writing (September 1999), these data are available at best up to 1996. Any forecast for, say, the year 2000, must inevitably be preceded by forecasts for 1997 - 1999.

Furthermore, the expenditure breakdown is usually available only at current prices. In fact, it is only in the case of Jamaica and Trinidad & Tobago that a concerted effort has been made to provide constant price values of the expenditure items. There then follows the thorny problem of choosing an appropriate deflator for the various current price items and the choice is usually between the implicit GDP deflator (a Paasche type index) or the Retail/Consumer Price Index (a Laspeyres type index), both of which are highly unsatisfactory for this purpose.

It is only in the Jamaican case that an attempt is made to measure private consumption expenditure directly. For Trinidad & Tobago, and for all the other countries, it is obtained as a residual. The current price values of the various expenditure components, including private consumption expenditure, are then deflated by appropriately constructed deflators. But the sum of the constant price values does not add up to the constant price value of GDP obtained by the "value added" approach. A statistical discrepancy is then introduced to account for the difference which can amount to as much as ± 10% of GDP.

Most of the countries that publish current price expenditure items distinguish between investment in fixed capital and investment in stock (but some do not, Guyana for instance). Many, however, do not disaggregate this total into (at least) public sector and private sector investment so that it is impossible to fit a private investment function like (1.6). This is a major shortcoming given the current emphasis throughout the Caribbean region on the importance that the private sector must play in its economic transformation.

It is not unreasonable to ask this bloc to provide us with much more detailed analysis than is now available in the prototype model shown above. For instance, the consumption function can be disaggregated to deal with the demand for more specific items like food, consumer durables and so on where behaviour is likely to be much different. Also fixed capital investment (private) can be disaggregated by sector of activity or even by type of good (or both). Disposable income can be broken up into personal and non personal income which would have implications for the measurement of private and, in particular, household savings. It would then be possible to calculate the domestic resource gap and so on. Disaggregation of the variables explained in this bloc will almost certainly imply the existence in disaggregated form of the explanatory variables such as the stock of capital and capacity output (to be taken up again below). Unfortunately, most of the data required to achieve these objectives, even of the most questionable quality, are simply not available.

The *Public Sector Bloc (Bloc 2)* presents a much less bleak picture than the previous one. To a large extent, one of the most important tasks of the data collecting agencies in the Caribbean is the collection of data that can be used in this bloc. It is therefore not surprising that the required data are generally readily available although they may be scattered over several publications.

In fact, data are available to allow for easy disaggregation and extension of this bloc provided that efforts are put into consistency checks on data drawn from different sources. Indeed, if there is a problem in acquiring data for this bloc of the model, it is to assure the consistency of the data across several publications, especially when the fiscal year does not coincide with the calendar year. Fairly detailed tax data of all kinds exist: personal income taxes, corporate taxes, indirect taxes (including, in some countries, the recently introduced Value Added Tax) and others. On the expenditure side, data are available on subsidies, transfers, debt interest and so on. The reader is referred to Watson and Clarke (1995) for a fairly elaborate treatment of this bloc in the Trinidad & Tobago case and which illustrates the richness of the data available.

The *Financial Sector Bloc (Bloc 3)* suffers from an embarrassment of riches as far as data are concerned. The task of collecting (most of) the data relevant to this bloc usually falls to the Central Banks who publish them on a monthly, quarterly and annual basis right across the Caribbean (including in the non English speaking territories). This is a very fortunate circumstance since the monetary authorities in these countries play a major role in policy making and implementation. Nevertheless, with one major exception (Watson and Clarke (1995)), models of Caribbean economies have generally failed to take advantage of this situation. They have tended instead to either ignore the financial sector altogether (the U.N.D.P (1991) model of the Jamaican economy) or give it only passing consideration where the instruments of monetary policy are more or less absent (Hilaire *et al.*'s (1990) model of the Trinidad & Tobago economy).

The principal reason for this lack of consideration might be that, despite the abundance of data, they do not "hang together" in an obviously coherent manner in the various publications and, in particular, the identities shown in bloc 3 are not immediately verifiable from the published data. But with some patience, an even more elaborate system of identities can be established as shown in Watson and Clarke (1995) for the Trinidad and Tobago case.

Nobody can deny the importance of what goes on in the *Balance of Payments Bloc (Bloc 4)* to the typical Caribbean type economy. Most of the countries recognise this and regularly (more than once per year) publish data on trade (import/export of goods). A coherent statement on the Balance of Payments, however, appears at best annually and, even then, frequently with some considerable lag. Furthermore, only the aggregate values (M and X) which appear also as items in the expenditure breakdown of the National Accounts are expressed in constant price values and then again only for those countries where these expenditure items are expressed in constant price values. To effect a conversion to constant price values, then, the model builder must employ the highly unsatisfactory Average Unit Values.

In the case of Trinidad & Tobago and some of the other countries, a detailed breakdown of imports and exports of goods by S.I.T.C. sections is usually given but it is not impossible to find alternative breakdowns for imports which distinguish between capital, intermediate and consumer goods. There is thus room for further disaggregation of the import function.

More and more emphasis is being placed in Caribbean countries on the export of non traditional goods which must compete for a place on the world market. The blanket statement that "exports are exogenous" therefore cannot apply to this category. It is a straightforward step to include the exchange rate as a policy variable in the case of countries with fixed rates and as an endogenous (possibly target) variable for those countries where it is floating. Furthermore, it is possible that service oriented economies like the Bahamas and Antigua will be more interested in the export of non traditional services for which it may be necessary to set up a separate equation. These and other changes in orientation will put additional demands on the data requirements of an econometric model.

An immediate implication of the widespread absence of constant price data is the non availability in many of the measures associated with the prices in the *Wages and Prices Bloc (Bloc 5)*. Most of the countries, however, are up to date with P_y (the implicit GDP deflator) and P_r (the Retail/Consumer Price Index). In fact, the latter is published monthly with some short time lag although for some countries (notably Guyana) there is some considerable lag (close to three years in the case of Guyana).

There is an immediate need for up to date and relevant price indices, which may be of the "hedonic" variety to reflect changes in quality as well.

The most important missing element in the *Output and Employment Bloc (Bloc 6)*is a series on capital stock which enters directly into the production function to determine capacity output as well as (possibly) into the private investment equation in bloc 1. If, too, it should be considered desirable to establish specific (key) sectoral production functions in order to determine capacity output there, then measures of the capital stock must be available by sector of economic activity. Watson (1997b) measures the capital stock for Trinidad & Tobago at the end of 1991 by sector and by type of asset which can be used as a starting point to generate a longer series for that country, but a similar measure exists for no other country.

It would also be interesting to be able to determine how the output of a sector is distributed between sectors and even how the output of each sector is distributed in final consumption. See Klein (1980). For this to be done within the framework of a macroeconometric model, we would require the kind of detailed information normally available in Input-Output tables (to be discussed below). This is likely to be a particularly heavy demand on the statistical resources of all the countries as such tables do not now exist in any of them.

Data on population, employment and labour force are generally easily available, sometimes even by economic sector, and it is more the quality of the data that may be in question. The population data to be used in this bloc (POP) may be based on updates of population censuses. These can be as much as ten years old and in some cases even more and few of the countries conduct surveys of the labour force and, relatedly, employment, on an ongoing basis.

Finally, there are the problems related to *econometric estimation*. A lot of the early work on econometric modelling by the Cowles Commission was devoted to the development of appropriate estimation methods like Two Stage Least Squares. Unfortunately, even in situations where data are more abundantly available than in the Caribbean, the practice has been to employ the theoretically inferior Ordinary Least Squares (OLS) method in preference to these more fanciful procedures precisely because the data series are inadequate.

Recent developments in *econometric modeling methodology* have placed greater emphasis on things like unit root testing, General-to-Specific (GS) modelling, Vector Autoregressive (VAR) models (to be discussed later) as well as on the related area of cointegration analysis. The successful application of all these methods requires the application of a barrage of tests of models which involve the use of (sometimes relatively lengthy) lags. Moreover the tests, such as the Unit Root tests, are invariably more powerful in longer time series while all Caribbean countries do not have a coherent data set that stretch back beyond the 1970s (and most the 1980s). Furthermore, the introduction of lags results in even greater data loss. See Watson (1998) for an attempt at modelling within the cointegration freamework.

This chronic deficiency in the length of the time series available therefore impacts directly on the choice of econometric methodology available and, at best, allows us to use the modern methods in a framework that militates against implementing the associated testing procedures in an efficient manner. Unfortunately, there is very little that can be done about this state of affairs at present except to ensure that, in the future, short time series will not present the same problems as they do today.

Data deficiency is a serious constraint in any macroeconometric modeling exercise in Caribbean countries. Except for the Public and Financial sectors, where data are plentiful but possibly scattered over several publications, the other sectors, including the all important Aggregate Expenditure Sector, suffer from serious data shortage. Moreover, even where the data available, a coherent set is only available if annual data are employed and then again it is short.

This might suggest that sector rather than economy wide models be constructed and used, especially in those for which quarterly data are available. But clearly this would be a serious limitation if the impact of public sector and financial variables on real variables could not be established. There must be some interest in filling the data gaps from now.

Time Series Models

ARIMA Models

ARIMA modelling is an important area of time series modelling. They appear to be natural alternatives to modelling economic variables when there is not a well articulated economic theory and when the task at hand requires forecasts in the context of unchanged economic policy (so that the Lucas critique is not relevant). These models appear to be nothing more than one or more stochastic difference equations which can be interpreted as part of the reduced form of the structural econometric models. See Enders (1995).

ARIMA models became an integral part of the econometric landscape following the work of Box and Jenkins (1970). They are single-equation stochastic difference equations where the behaviour of a variable is explained by its own past and random shocks. The "best" representation is chosen on the basis of the well known Box-Jenkins cycle of identification-estimation-diagnostic checking and forecasts are made without recourse to unknown "exogenous" variables. The literature is replete with arguments that the forecasts from these models outperform those from the larger and more expensive structural models. See for instance King et Bessler (1985), McNees (1986), Makridakis (1986) and Wallis (1989).

These models have not been widely used by Caribbean modellers. The only known example is Watson (1997a) in which the author compares the forecasting performance of ARIMA with VAR models. There is probably good reason for this and once again the answer is to be found in the absence of data for key macroeconomic variables (like national income variables) of appropriate frequency and length.

ARIMA modelling is not suitable for use with annual data. In the first place, existing series are usually quite short while these models require data covering fairly lengthy periods. Secondly, the forecasts, to be useful, must be available in sufficiently good time for use by policy makers. We would suggest that data in quarterly are a minimum requirement and higher frequency data may be even better.

It is true that some of the more cited variables are not available in at least quarterly format. But many important macroeconomic variables are. These include monetary variables (including deposits, interest rates and others), trade variables, retail price indices, stock market indices, exchange rates, some fiscal variables, unemployment, labour force and others. There is no reason why these cannot form the basis of useful ARIMA models. Watson (1997a) uses ARIMA models to forecast some useful variables from the monetary and real sectors. Such models require the use of very little resources and, given today's readily available computational power, there should be no great inconvenience to constructing and using such models where the relevant data are available.

The simplicity and apparent power of ARIMA models for making unconditional forecasts is a strong argument for the development of a national income quarterly data base for Caribbean countries.

VAR modelling

Vector autoregressions (VARs) are another form of time series modelling. It was forcefully advocated in econometrics by Sims (1980) as a less restrictive alternative to structural models. Sims deplored basically two methodological weaknesses of the latter

- the "incredible restrictions" associated with such models where variables were arbitrarily labelled "endogenous" and "exogenous" (in a VAR, all variables are endogenous)
- they are subject to the Lucas critique in relation to the unchanging behaviour of economic agents in the face of policy decisions

The VAR approach seeks to isolate a small number of variables considered to be of fundamental importance and models a host of possible interactions among them. In many respects, a VAR is a natural extension of the univariate ARIMA models and can be viewed as the mutlivariate counterpart. In the standard form of the model, each variable in the system is regressed on past values of itself and past values of every other variable in the system. These models are consistently estimated by Ordinary Least Squares and can be used to generate forecasts with the same ease as ARIMA models and, in particular, without the bother of unknown "exogenous" variables. They have also found widespread application in the study of causality among variables.

The VAR approach, however, has also attracted criticism and has obvious limitations:

- even though it provides a better forum for incorporation of expectations, the Lucas critique still applies.
- The values of the estimated reduced form parameters and the residuals do not have an obvious economic interpretation. Standard form VARs are therefore not suitable for policy analysis.
- The model is over parameterised even though only a few variables may be involved. A lot of these parameters prove to be insignificant. Forecasts obtained are therefore influenced by the number of lags retained.

Econometricians have attempted to deal with these criticisms by proposing various variants of VAR models. Litterman (1984) suggests a Bayesian approach to deal with the over parameterisation issue and introduces *a priori* knowledge into the model in the form of a probability distribution. He proposes that the coefficients are pairwise independent and are normally distributed with zero mean and small variance. The main idea behind this approach is to ensure that the more recent lags have more influence than those that go further into the past, largely because of the larger variances attached to the coefficients of the latter. It results effectively in a trade-off between over parameterisation (too many non significant coefficients) and a possible under parameterisation (zero type restrictions imposed on certain variables or lag lengths).

To deal with the problem associated with the estimation of the standard (reduced form) VARs, Structural VARs were introduced. They differ from the standard form VARs by the presence of contemporaneous values among the regressors and this introduces some complications for estimation. In fact, the coefficients of the structural VAR cannot be estimated directly because its disturbances are correlated with the contemporaneous values. Coefficients of the reduced form, which has the appearance of a standard form, can however be estimated. In order to identify the coefficients of the structural form, restrictions must be imposed. To accomplish this, several techniques have been proposed which take into account the instantaneous correlations between the variables and the covariance matrix of the structural innovations. These include the work of Sims (1986) which is based on the Choleski decomposition, as well as those of Blanchard and Quah (1989) and Bernanke (1986). More recently, a generalised impulse function was introduced by Pesaran and Shin (1998) and this is used in Watson (1999).

The estimation of the structural VAR can be carried out by the standard methods applicable to simultaneous equation models since it is a system of simultaneous equations.

If the standard form VAR models cannot be used for policy analysis, the introduction of the constraints makes it suitable for this purpose. These make use of impulse response functions and forecast error variance decompositions which allow dynamic simulation.

For all these reasons, VAR models can be seen as useful alternatives to the large structural models for policy analysis. Paradoxically, they have not found great favour in Caribbean economic circles. There have been three serious attempts (Robinson (1996) and Watson (1996, 1999)) at using VAR models for economic analysis. In two others, Watson (1997a) and Maurin and Montauban (1997), they are used it for their forecasting ability.

The relative unpopularity may once again be due to the absence of data. In the first place, they require relatively long data series because of the need to impose lag structures of reasonable length. A model having, say, 6 variables with 4 lags would involve the estimation of 24 coefficients in each (reduced form) equation. This alone means that VARs are ruled out of court for use with annual data. It is also true that if, say, four lags are imposed in an annual model, this would imply an adjustment period of four years (and economic agents are likely to respond much faster than this). VARs are therefore more suitable for models using data of higher frequency, at least quarterly in most cases. Even then, it is impractical to use VARs for situations involving more than just a few variables (4 or 5) and/or lengthy lags (the optimum lag length must be determined) since the degrees of freedom for estimation may be rapidly exhausted otherwise.

The availability of the key national accounting variables in only annual format is a serious drawback to the use of VARs in the Caribbean and is yet another reason why these data should be a priority of the statistical agencies. VAR models are not expensive to maintain and their utilisation is almost mechanistic. In the meantime they can be used for forecasting other variables available in the required form as well as for policy analysis involving these variables (a non exhaustive list was given above).

GARCH Models

Models of volatility dynamics, which permit volatility forecasting, are likely to become more and more applicable to the Caribbean, especially with the advent of stock markets and currency liberalisation. Leon (1995) employed GARCH models to examine the relationship between stock prices and other macroeconomic variables in Jamaica. Nicholls (1995) examined risk-return profiles on the Trinidad & Tobago Stock Exchange and tested for volatility in the returns.

GARCH models are ideally suited to high frequency data, in particular financial data. Such data abound in most countries of the Caribbean. They are easy to set up and easy to use and there is no reason why they should not be routinely employed by decision makers.

Cointegration

The cointegration approach to the econometric modelling of time series looms large in modern practice. It is closely related to the concept of the VAR and to the error correction mechanism made famous by the Davidson et al. (1978) article and which itself is a benchmark of the General-to-Specific modelling methodology. In many respects cointegration is the bridge between the structural modelling of the past and modern time-series analysis. The famous Granger 2-step approach depends a lot on economic theory although the more popular Johansen method is more in the time-series tradition. Johansen (1988) shows how a VAR model can be transformed into one which is characterised by error correction (called by some a Vector Autoregression ECM or VECM).

Caribbean modellers have applied the cointegration methodology widely to time series data. One of the main concerns is how to use it in the estimation of structural econometric models. Hsiao (1997a), (1997b) argues, among other things, that in the structural modelling approach it is the standard concerns of identification and estimation (and not integration and cointegration) which are fundamental. He shows that, when the variables are I(1) and cointegrated, OLS is not consistent but that the Two and Three Stage Least Squares estimators are. Furthermore, he shows how the structural form can be transformed into an error correction model which emphasizes the implied long run and short run relations between the variables.

Hsiao's results are very useful but, as with VAR models, we are still left in the lurch when the number of variables is relatively large or when non-linearities are present: the consistent procedures still cannot be applied. Watson (1998) proposes an heuristic solution to the problem which he applies to a medium-size structural econometric model of the Trinidad & Tobago economy.

Computable General Equilibrium (CGE) Models

The first generation of CGE models appeared in the 1950s (around the same time as structural econometric models) and were a follow up to the work of Leontieff (1951, 1966). They were based on detailed specification of the interdependence of economic activity à la Walras but fell short of a full general equilibrium model since they lacked a regulatory price system.

The second generation of CGE models appeared in the 1970s and their original contribution was the introduction of a price system which assured market equilibrium. The conditions for the existence of such equilibrium were based on the work of Arrow and Debreu (). The Golden Age of CGE modelling was the 1970s and 1980s following Scarf's (1967) important discovery of an algorithm allowing for computer based solutions. In the wave of work that followed, we can distinguish five (5) distinct approaches to CGE modelling:

- *The Johansen (1960) approach*
- The approach due to Haberger (1962), Scarf (1967) and Shoven and Walley (1984)
- The World Bank approach (for special application to developing countries)
- Jorgenson's (1984) econometric approach
- The approach of Ginsburgh and Waelbroeck (1981)

Schubert (1993) presents a very useful review of these approaches.

CGE models range from the very simple to the most sophisticated and may incorporate dynamic economic behaviour as well as expectations. They have been used in the sphere of economic planning, in modelling sectoral features (notably of the agricultural and energy sectors), international trade, the environment and government's fiscal activity. In general, they have found widespread application in areas where the concern is for the impact of economic activity on the overall economy since they lend themselves naturally to modelling interdependencies and feedback among economic variables.

Worldwide, CGE models have been more widely used than any other type of model and this irrespective of country or economic system. Why then have they found so little application in the Caribbean? These models, after all, have been often used in cases where there is a dearth of statistical data so characteristic of many Caribbean countries. Could it be that the general equilibrium framework is not relevant to the functioning of Caribbean markets? We will consider certain possible theoretical and technical limitations and will conclude that they are not binding.

Theoretical considerations

In the Walrasian tradition, general equilibrium theory analyses the economy within a context of pure and perfect competition. Economic agents maximize utility and profits under revenue and cost constraints respectively. There are constant returns to scale and externalities are non existent. In such a system, prices play a decisive role: they are in a state of continuos adjustment in order to ensure equilibrium between supply and demand in all markets, including the labour market. The equilibrium prices and quantities resulting from solution of the model determine the allocation of resources and the distribution of income.

Little interest has been shown to date in the application of such neoclassical models in the analysis of the small island economies of the Caribbean. However, the preeminence of Keynesian analysis has been also criticized and arguments made in favour of "supply side" models since these countries are limited more by supply and production constraints. According to such arguments, any policy measure seeking to achieve economic recovery through demand stimulation will result inevitably in significant increase in imports and chronic balance of payments deficits. Increased production is limited by shortfalls in factors of production like capital, specialized skills and intermediate goods (usually imported).

For sure, the theoretical framework of general equilibrium may appear too constraining and even unrealistic for applied work. But one of the main advantages of the CGE approach is that it offers a flexibility which allows it to go beyond the Walrasian framework through the incorporation of more realistic assumptions. Indeed, the vast majority of recent applications are not subject to the Lucas critique. They allow for the analysis of the reaction of economic agents to a change in economic policy since choices are modelled explicitly as a function of the goals that they set themselves and the constraints that they must respect. More generally, the behaviour of economic agents is modelled in a framework of optimisation over time.

Some authors have adapted CGE models to the peculiarities of developing countries principally by setting aside some of the Walrasian assumptions and incorporating blocs which model the socio-institutional characteristics of these countries. One example of this is the work of Tokarick (1995) which is one of the rare attempts of the application of CGE modelling to the Caribbean, in this case Trinidad & Tobago. He set up a model to study the effects of shocks, resulting from the introduction of trade liberalization measures and changes in terms of trade, on the real exchange rate, trade flows and the fiscal position of the economy.

Tokarick's model is constructed in the tradition of CGE models applied to small open economies in the spirit of Dervis, de Melo and Robinson (1982) and Shoven and Walley (1984). It is static and based on three sectors: the export sector (mainly petroleum products), the imports sector (largely labour intensive manufacturing activities) and a non-traded sector (services and construction activities). The terms of trade are exogenous and prices in the non-traded sector are determined local demand and supply. The model contains about 30 equations including the accounting identities of the SAM and supply and demand functions for the different sectors. Tokarick argues that his model is "sufficiently general to be applied to other small, open economies" and that the CGE model is "especially appropriate in analyzing the effects of changes in commercial policy and terms-of-trade shocks because of its ability to capture directly the important relative-price effects of various shocks".

Tokarick compares the CGE approach with that of structural econometric modelling which has found more favour in the Caribbean. He argues that these models (and other types of modelling) "do not usually capture resource constraints, material balance constraints such as market clearing, and other elements grounded in general equilibrium microeconomic theory". We may add to that the observation that macroeconometric modelling requires the existence of time series data which, even in the best of Caribbean cases (Barbados, Trinidad & Tobago, Jamaica), remain insufficient. It is easier to envisage the construction of a CGE model for every Caribbean case which require data spanning no more than one year in most instances. The theoretical foundations of such models may have a common basic structure which may incorporate non Walrasian specificities that take into account the characteristics of small open island economies (segmented labour markets, price rigidities etc.).

Technical considerations

The transition from a theoretical to an applied CGE model, quantified and set up to evaluate results emanating from alternative economic policies, involves two fundamental steps. Firstly, data must be collected to set up the Social Accounting Matrix (SAM). Secondly, the coefficients of the model must be estimated. The method of "calibration" is normally used in this second step.

Step 1: Social Accounting Matrices

An Input-Output table provides us with a description of the exchanges between the productive sectors of the economy. The SAM, on the other hand, traces out the flow of exchanges between the various agents in the economic circuit and is in fact a generalization of the Input-Output table. It takes the form of a square matrix that matches row and column entries to each economic category defined by the user. Each row traces out the origin of a resource associated with an economic category and each column accounts for the utilization of these resources. Row and column totals are therefore necessarily equal. The overall set of accounts described by the corresponding rows and columns can be as disaggregated as the data allow. So Firms can be grouped into sector of economic activity, households into socio-economic categories and so on. In the end we have a (more or less) detailed description of the relationship between the structure of production and the distribution of income. It may show as well the financial transactions between the domestic economy and the rest of the world.

The simplified SAM shown in Table 2 below is an adaptation from Dervis et al. (1982), p. 412.

Table 2
Simplified SAM

	Activities	Commodities	Factors	Enterprises	Households	State	Capital account	Rest of the World	Total
Activities		Domestic Sales				Export subsidy	Investment	Exports	Total sales
Commodities	Intermediate inputs				Private consumption	Government consumption			Total demand
Factors	Wages Rentals								Value added
Enterprises			Capital income			Transfers		Net private flows	Enterprise income
Households			Labour income	Distributed profits		Transfers		Net factor income	Household income
State	Indirect taxes	Tariffs		Direct taxes	Direct taxes			Net public flows	Government income
Capital account				Retained earnings	Private saving	Government saving		Reserve decumulation	Saving
Rest of the World		Imports							Imports
Total	Total costs	Total absorption	Value added	Enterprise expenditure	Household expenditure	Government expenditure	Investment	Foreign exchange reserves	

The Main features of any SAM are displayed in this illustration. It regroups three principal accounts:

- Production account
- Institutions account
- Rest of the World account

The Production account is further disaggregated into

- an "Activities" account the production process and, in particular, incorporates the Input-Output table
- a "Commodities" account which highlights the equality between global supply and demand
- a "Factors" account which shows how factor income is distributed among economic actors

The Institutions account is made up of

- a current account for each agent (firms, households and the government) and showing the resources of each and expenditure (private and government consumption, investment and exports)
- a capital account which highlights the saving-investment equality

The Rest of the World account is nothing other than the standard Balance of Payments account.

A SAM can be articulated using data drawn from one year or based on the average of two or more years (see below for a discussion of "calibration"). Several problems may be encountered in the this process, the most notable of which are:

- The consistency of the data set seeing that the data sources are as diverse as the national income accounts, company balance sheets, household surveys, monetary and financial data, trade data and so on. When data are inconsistent, they have to be adjusted to ensure accounting balance in the SAM.
- The choice of the base year: we must find a year for which macroeconmic equilibrium is verified. One solution is to use an average of the data spanning several years which (hopefully) smoothes out cyclical fluctuations.
- The level of disaggregation: as is the case for structural models, there has to be a compromise between constructing a model as detailed as possible so as to be a better reflection of reality and the limitations imposed by cost, data availability and other such considerations.

Notwithstanding these difficulties, SAMs have enjoyed tremendous success in situations where the time-series data base is inadequate. It is interesting to note that CGE modelling has found more applications for developing than for developed countries. In the particular case of the Caribbean there have been serious though limited efforts in this direction like those of Tokarick (1995). There is some evidence that others have actually been employed by institutions which have a direct impact on policy making. One such is the work of Dalrymple et al. (1996) which was developed within the context of the introduction of a Value Added Tax in Barbados.

Dalrymple et al. construct a model which, in their own words, "is a hybrid, i.e. it lies between the national accounts approach and a comprehensive model inasmuch as it utilizes a SAM but is not as detailed as the comprehensive model". The model is made up of a SAM "which distinguishes sales and purchases between twenty-four sectors which embrace all of the legal economic activity in Barbados. Each of these sectors has entries on a column and a row in the matrix. The column for each sector shows purchases by the sectors, purchases of imports and purchases of goods and services from domestic sectors. Each of the twenty-four column totals therefore represents intermediate expenses for the relevant sector. The row for each sector shows sales of goods or services by the sector. Each row total therefore represents gross output of the relevant sector". From a purely technical standpoint, the model is set up in a Spreadsheet and structured around a set of linked spreadsheets, each one representing a partial SAM for the Barbados economy in 1994.

Dalrymple et al. make the following important observation:

> .... Based on the information from the Statistical Department, data from the Customs Department on imports, exports and the relevant tax liabilities, and the wider knowledge of the Statistical Department (and others) of the Barbados economy, it was possible to assemble a form of SAM for Barbados which, while rough and subject to uncertainty in many areas, would nevertheless be sufficiently accurate and detailed to provide a basis for a much more comprehensive VAT impact assessment than has been available so far.

It appears as though this model is used to guide the formulation of tax policy in Barbados and this is very encouraging.

Step 2: Estimation and solution

"Calibration" methods are the most widely used procedures for estimating the values of structural parameters of CGE models. The objective is to determine parameter values that are consistent with the data used in the SAM. A sketch of the procedure follows.

Let the CGE be represented by the following set of equations:

$$Y = F(X, \beta, \gamma) \qquad (1)$$

where Y an X denote, respectively, the vector of endogenous and exogenous variables. F is a non linear function (multivariate), β the vector of calibrated parameters and γ a vector containing the other parameters.

The calibration process involves the solution of the equation

$$\beta = G(Y_0, X_0, \gamma) = g(\gamma)$$

obtained from

$$Y_0 = F(X_0, \beta, \gamma)$$

where Y_0 and X_0 are initial equilibrium conditions observed for the base year.

It should be no surprise that the techniques used for the quantification of the CGE models have attracted criticism both about the validity of the model as well as its ability to reproduce the past. In particular, the values chosen for the γ vector have a great influence on the final values obtained for the β parameters. Furthermore, as opposed to the case of econometric estimation, calibration does not lend itself easily to statistical inference and the determination of the level of uncertainty to be attached to parameter values.

Following the estimation and verification stages comes the solution phase that also allows for simulating the effects of policy shocks. This is easily done using a computer program adapted for the numerical solution of problems involving maximization under constraint. Analysis of policy shocks is thus a classic case of multiplier analysis similar to the kind employed in the case of structural econometric models where the equilibrium resulting form the shock is compared with the base equilibrium solution.

In the case of SAMs, multipliers are obtained following a procedure similar to the one used in Leontief-type systems. Let Ω be a SAM of dimension $n \times n$. The first k rows correspond to the endogenous sectors while the remaining n-k sectors refer to the exogenous sectors. Let Σ be the diagonal matrix made up of the column totals of Ω. There are two stages in the calculation of the multipliers:

- Calculation of the matrix $\Pi = \Omega\Sigma^{-1}$
- Determination of the accounting multiplier matrix

Let Π_1 be a k x k sub-matrix extracted from Π and corresponding to the endogenous accounts. Let y be the $k \times 1$ vector containing the totals of the endogenous accounts and let x be the $k \times 1$ vector whose i^{th} element is defined by

$$x_i = \sum_{j=k+1}^{n} \Pi_{ij} .$$

y and x verify:

$$y = \Pi_1 y + x \qquad (2)$$

or:

$$y = (I - \Pi_1)^{-1} x \qquad (3)$$

The matrix $G = (I - \Pi_1)^{-1}$ is the accounting multiplier matrix of the SAM Ω. It is similar to the Leontief inverse matrix.

The above procedure was followed by Dalrymple et al. (1996) when they studied the impact of the VAT on the Barbadian economy. Their impulse analysis is based on the assumption that the endogenous accounts respond to exogenous shocks linearly and prices are fixed or excluded from the explanatory variables. We may, of course, go beyond such restrictive assumptions. To do this we must move from the SAM to the CGE. This becomes possible with the endogenisation of prices and the addition of behavioural equations to the accounting identities of the SAM.

The precise steps in the solution of a CGE are as follows:

- The model is calibrated and the β parameters are obtained from the observations on Y_0 and X_0 and the given values of the γ parameters.
- The values in the X matrix are modified to take into account the proposed policy measures. The Y values are obtained as a new equilibrium[1].
- The multipliers are calculated as percentage deviations from the base solution.

It is our view that the rich literature on the functioning of Caribbean-type economies allow for specification of a CGE model. Secondly, the data required to use such a model are in large part already available or can be obtained in a relatively short period without much difficulty. There seems to be no major obstacle to using these models in the preparation of economic policy as the work of Dalrymple et al. (1996) amply demonstrate.

Real Business Cycle Models

The Real Business Cycle (RBC) school came into being in the 1980s. Compared to the CGE approach that is centred on a stationary state with the economy growing at a constant rate, the RBC school proposes a modelling approach based on the irregular and cyclical nature of economic activity. Indeed, the proponents of the school believe that the evolution of economic variables provides evidence of cyclical movements that originate from exogenous shocks consequent to disturbances in the real sector as well as from random disturbances. Monetary variables are ascribed no fundamental role in the cycle and only real phenomena like climatic changes, ecological disasters, war, technological innovation and so on that have any effect on productive activity. Indeed these are the very cause of economic cycles.

The objective of RBC models is to account for these kinds of behaviours in variables. The original models of Kydland and Prescott (1982) and Long and Plosser (1983) have their theoretical roots in the neoclassical framework. Their main assumptions and properties have similarities with those of a Solow-type capital accumulation model. The economic system under consideration is an amalgam of entities and operations that are part of a process of interaction between a host of consumers who also engage in business activity. There is thus an aggregation of different behaviours that the RBC school attempts to resolve by introducing the notion of the "representative agent".

[1] The non linear system of equations is solved using techniques such as those proposed by Johansen (1960), Shoven and Whalley (1972) and Ginsburgh and Waelbrock (1981).

The representative household expresses its interests through a utility function (u) containing two elements: consumption (C_t) and leisure (L_t) available now and in the future. The trade-off between the present and the future is expressed through a discount factor (β). In each period the consumer is confronted with two decisions: how to allocate total time available between work and leisure and how to dispose of his income between investment (I_t) and consumption goods. New capital acquisitions add to the existing capital stock that is depreciating at a rate of δ.

The representative firm produces the single good in the economy (Y_t) which may be either consumed or invested. The productive process is summed up by an aggregate production function (F) with constant returns to scale. It incorporates two factors, capital (K_t) and labour (L_{th}) and a deterministic technical progress term ($X_{H,t}$) which is a representation of the growth in labour productivity. This function also contains an exogenous technical progress term to take into account overall factor productivity and random technological shocks.

In such an economy, it is these technological shocks that explain the appearance of cycles. Indeed the rational behaviour of agents make the economic system react optimally to variations in the economic environment. These shocks cause the agents to make changes in plans about consumption and the allocation of time between leisure and work. These changes manifest themselves through intertemporal substitution effects between current and future consumption and between leisure and labour supply. They therefore impact on production and employment and form the basis then of cyclical fluctuations.

The following is the canonical form of the Real Business Cycle model:

$$\underset{C_t, I_t}{\text{Max}}\, E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, I_t)$$

subject to:

$$C_t + I_t \leq A_t F(K_t, H_t, X_{H,t})$$

$$L_t + H_t \leq 1$$

$$K_{t+1} = (1+\delta)K_t + I_t$$

This programme is solved to obtain equilibrium (optimal) quantities and prices over time. The work of Kydland and Prescott (1982) and Long and Plosser (1983) was followed by an enormous literature that modified and enriched this canonical form. The theoretical contributions can be placed squarely within either the neoclassical framework (with a multitude of assumptions concerning the form of the equations) or within a non Walrasian framework integrating market imperfections, notably disequilibria in the labour market.

In their specification, RBC models are like CGE models in an uncertain universe and made up of only a few equations. The operationalisation of an RBC model is done in two phases:

i. Measuring the cycle

ii. Calibration and simulation of the RBC through random shocks

Measuring the Cycle

Macroeconomists have always had differing opinions on how to interpret the evolution of a variable in terms of its long-term path (growth) and its short-term dynamics (fluctuations). See Abraham-Frois (1991).

RBC modelling is yet another attempt to confront economic theorising with the stylized facts. In the first instance, the variables whose movement over time is of primary interest to us are selected. The trend is measured using an appropriate method and the cycle is then obtained using the gap between the observation and the estimated trend.

The method of choice is the one proposed by Hodrick and Prescott (1980) which involves the minimisation of a weighted sum of two terms. The first term corresponds to the variation in the cyclical component represented by the difference between the raw series (x_t) and the trend (T_t) and the second the variation of the growth rate from the trend. In formal terms, the programme to be solved is:

$$Min\{Var(x_t - T_t) + \lambda Var(\Delta T_t - \Delta T_{t-1})\} \quad (1)$$

which is equivalent to:

$$Min\left\{\sum_{t=1}^{n}(x_t - T_t)^2 + \lambda\sum_{t=3}^{n}\left[(T_t - T_{t-1}) - (T_{t-1} - T_{t-2})\right]^2\right\} \quad (2)$$

The parameter λ is a weight expressing the importance of the second term relative to the first. It can be interpreted as an opportunity cost related to the introduction of fluctuations in the trend. If $\lambda=0$ is the solution to (2) then $T_t=x_t$: the trend coincides with the raw series. As λ tends to infinity, (2) is equivalent to

$$Min\left\{\sum_{t=3}^{n}\left[(T_t - T_{t-1}) - (T_{t-1} - T_{t-2})\right]^2\right\}$$

and the minimum is obtained for $\Delta T_t = T_t - T_{t-1}$ = constant (the trend is linear). For $\lambda \in (0, \infty)$, this "filter" has a modulating effect on the cyclical component as can be seen if we denote σ_1 and σ_2, respectively, the standard errors of T_t and $(x_t - T_t)$. Equation (2) may then be re-written as:

$$Min\left\{\sigma_1^{-2}\sum_{t=1}^{n}(x_t - T_t)^2 + \sigma_2^{-2}\sum_{t=3}^{n}\left[(\Delta^2 T_t\right]^2\right\} \text{with } \lambda = \frac{\sigma_2^2}{\sigma_1^2}$$

Here λ is clearly shown as dividing the total fluctuations into long term and short term fluctuations. Its value will be determined by the observed fluctuations. Hodrick and Prescott establish a value of $\lambda=1600$ for the USA.

Some more recent works have alluded to deficiencies in the Hodrick-Prescott filter, notably those of Harvey and Jaeger (1993) and Cogley and Nason (1995). They note the tendency of this filter to deform the dynamic properties of the data by introducing spurious cycles. They propose instead alternative filters which they claim better identify the stylized facts of the cycle.

The procedure proposed by Baxter and King (1995) is in this tradition and is probably the "industry standard" today. They propose "a band-pass filter of finite order K which is a moving-average approximation of an ideal band-pass filter, i.e. with trend-reducing properties and symmetric weights, which ensure that there is no phase shift in the filter output". Let x_t and y_t be, respectively, the original and filtered series. They are related by

$$y_t = \sum_{i=-K}^{K} a_i L^i x_t \qquad (3)$$

where L is the lag operator. The weights a_i, i= 1, 2, …, K are determined by applying to 3 a Fourier transform $\alpha(\omega)$. Their values are determined through solving:

$$\underset{a_n}{\text{Min}}\ Q = \int_{-\pi}^{\pi} \left|\beta(\omega) - \alpha(\omega)\right|^2 d\omega \qquad (4)$$

$\beta(\omega)$ denotes "the ideal filter gain with cut off frequencies ω_1 and ω_2, so $\beta(\omega) - \alpha(\omega)$ is the discrepancy arising from approximation at frequency ω". The solution is given by:

$a_i = b_i + \theta$, $i = 0, \pm 1, \pm 2, \ldots, \pm K$

$$b_i = \begin{cases} \dfrac{\omega_2 - \omega_1}{\pi} & \text{if } i = 0 \\ \dfrac{1}{\pi_i}(\sin \omega_2 i - \sin \omega_1 i) & \text{if } i = 0, \pm 1, \pm 2, \ldots, \pm K \end{cases} \qquad (5)$$

$$\theta = \frac{-\sum_{-K}^{K} b_i}{2K + 1}$$

Woitek (1998) shows that although this filter outperforms the Hodrick-Prescott filter, it too suffers from some basic defects linked to the fact that the ideal filter, which is a discontinuous function of ω, may be approximated by finite Fourier series. He proposes instead a non optimal (but acceptable) filter in which the a and b weights are defined by:

$$b_i^* = b_i \frac{\sin((2\pi i)/(2K+1))}{(2\pi i)/(2K+1)}; i = \pm 1, \ldots, \pm K$$
$$a_i^* = b_i^* + \theta;\ i = 0, \pm 1, \ldots, \pm K; \qquad (6)$$

Calibration and Simulation

As with the CGE models, it is possible to estimate the unknown values of an RBC model by calibration methods. But these have not been very successful, especially when it came to the reproduction of the stylized facts of an economic cycle. This has resulted in a passionate debate which opposes the "calibrationists" and the econometricians (those who are partial to econometric estimation). Fair (1992) makes this contribution to the debate:

> Take the simple RMSE procedure. This procedure would compute a prediction error for a given variable for each period and then calculate the RMSE from these prediction errors. This RMSE might then be compared to the RMSE from another structural model or from an autoregressive or vector autoregressive model. I have never seen this type of comparison done for a RBC model.

The latest generation of RBC models appears to have been influenced by the debate and have employed the Generalised Method of Moments (GMM), introduced into the literature by Christiano and Eichenbaum (1992), to estimate the unknown coefficients. It is based on the principle of "matching the moments" which involves the comparison of cross-correlations and autocorrelations of the generated and actual series. The method is applied to the Euler equations that result from the first order conditions of the intertemporal optimisation problem. Estimation of the parameters involves choosing parameters that minimise a weighted quadratic function.

The undoubted contribution of the GMM approach is that we are able to apply standard inferential procedures. However, the micro-foundations at the base of the calibration methods are largely ignored in deference to the use of aggregate macroeconomic time series data.

There are several methods available for the simulation of RBC models which all seek to determine the optimal trajectory paths calculated by the model. Some of the techniques seek to solve directly the Euler equations but there are others like the Fair-Taylor procedure which is widely used for solving large models based on rational expectations. Solution is obtained after the model is subjected to random shocks. Taylor (1990) applies different methods to the same problem and showed that the results obtained differ substantially. Indeed, it is fair to say that these numerical methods of solution have not to this date provided satisfactory results about the optimal paths.

Conclusion

Many developed and even some developed countries routinely use quantitative models as a tool in decision making and in the preparation of economic policy. It might very well be true that Caribbean economists and decision-makers more generally understand the potential usefulness of these models, official practice proves otherwise.

It is our belief that quantitative economic models are a necessity. The use of such models lends credence to governmental agencies negotiating with International Lending Agencies like the World Bank and the IMF. Policy alternatives may be evaluated by simple model simulations, and the effects of proposed measures "determined" before they are actually implemented.

Models of various types may also be used in the process of economic forecasting which itself feeds into the decision making process.

The most binding constraint seems to be the data requirements of the various models. Some, like the structural econometric models, require elaborate and coherent time series data which may not exist. Some are less demanding in terms of time seriesdata, like the CGE models , but do require detailed data for one or two years. Some require data of higher frequency than might now exist (quarterly or monthly as oppoed to annual). The question is: does construction and use of such models justify the data collection exercise? We have no doubt that it does.

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