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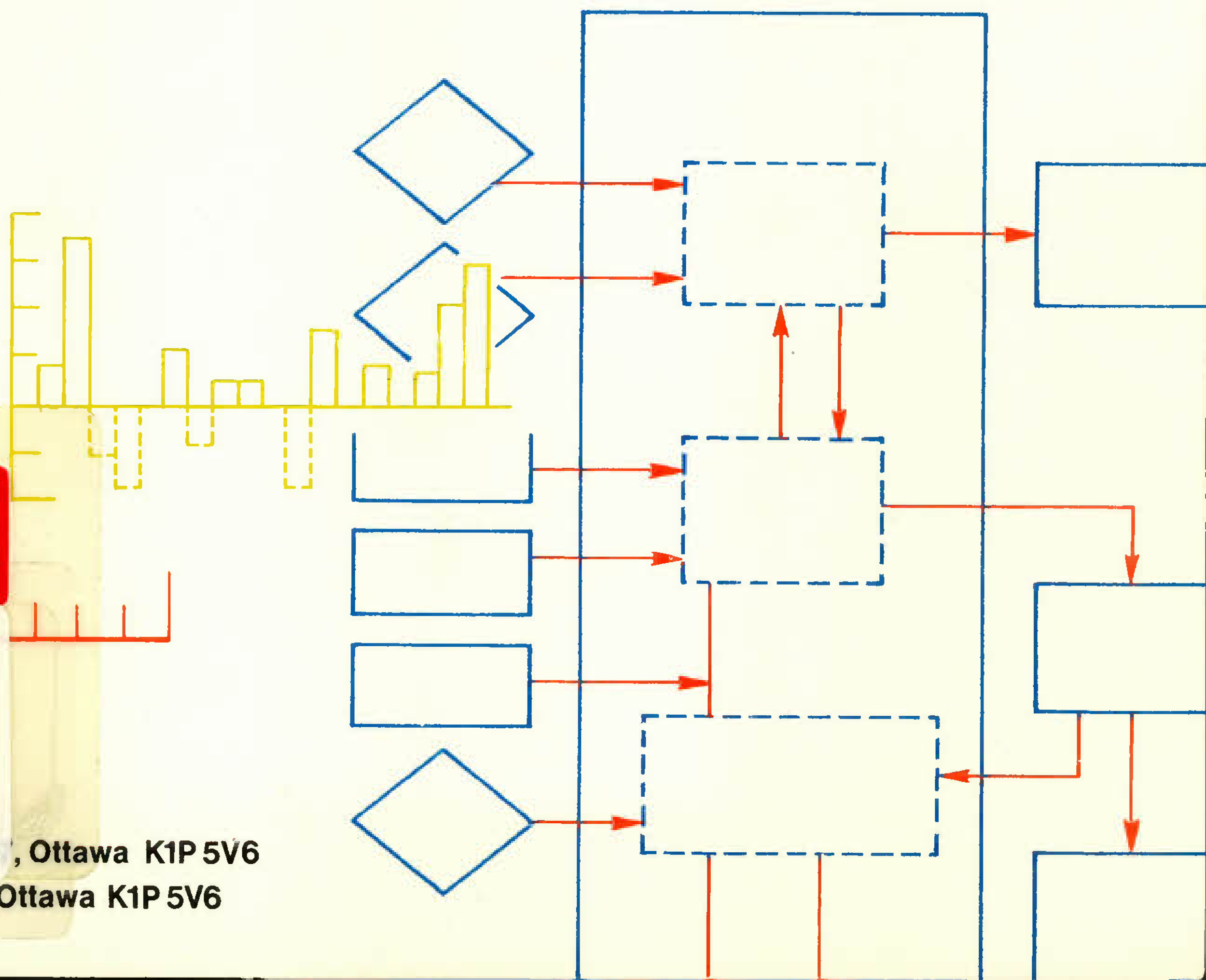

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DISCUSSION PAPER NO. 27

CANDIDE 1.1: Some Suggestions for Future Work

by Gordon Fisher

April 1975

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PREFACE

During 1974, the Economic Council obtained four critiques of its CANDIDE model. They are:

Professor J. Kmenta: "A Critical Review of CANDIDE Model 1.0", April 1974;

Professor G. R. Fisher: "Money in CANDIDE: Appraisal and Prescription for Revision", spring 1974;

Professor G. R. Fisher: "CANDIDE 1.1: Some Suggestions for Future Work", September 1974;

Woods, Gordon & Co.: "CANDIDE -- A Business User's Viewpoint", September 1974.

Three of these critiques were commissioned by the Economic Council of Canada, while Professor Fisher's study on "Money in CANDIDE" was funded by the Department of Finance, which has kindly consented to make it available for distribution in this series.

Although the critiques were written for internal use, the Council has obtained the consent of the authors to make them available as discussion papers. Econometric models are still black boxes to many a person involved in their use. It is our belief that these analytical tools should be regarded with a healthy dose of rational doubt, and this applies particularly to a model as large and complex as CANDIDE. In presenting the critical views of acknowledged specialists, the Council hopes to facilitate informed judgment regarding the model. It does not mean, of course, that the Economic Council or the Department of Finance endorse the views expressed by the authors.

H. Bert Waslander
Director, CANDIDE Project

Résumé

Ce document offre une analyse critique de certaines caractéristiques ainsi que des méthodes économétriques utilisées dans la construction des modèles CANDIDE. L'auteur démontre qu'un modèle conçu pour des prévisions à moyen et à long termes ne devrait pas être orienté de façon prédominante vers la demande, mais plutôt viser à expliquer l'offre comme un processus distinct de décision; les déséquilibres entre l'offre et la demande, tels qu'ils se reflètent dans les changements imprévus des stocks et des bénéfices, pourraient alors être amenés à influer sur les décisions relatives à l'offre et à la fixation des prix. La détermination de la production industrielle sur la base de coefficients fixes intersectoriels est mise en doute. L'auteur soutient que dans un modèle à moyen et à long termes, le recours à des coefficients fixes (particulièrement dans la matrice de technologie) n'est pas approprié, notamment parce que la technologie évoluera. En outre, une explication de ce changement par les variations des prix relatifs, par exemple, n'est pas seulement intéressante en elle-même, mais aussi désirable puisqu'elle anticipe l'orientation probable des événements futurs. Toutefois, vu qu'une telle explication exigerait la mise au point d'une série chronologique pour chaque coefficient intersectoriel non égal à zéro, la chose ne serait peut-être pas réalisable.

Dans le cas du mécanisme de transmission de la politique monétaire, il pourrait être avantageux d'éviter l'utilisation des taux d'intérêt et d'incorporer les effets directs du stocks

de monnaie dans les fonctions de dépense; un raisonnement semblable s'applique aussi aux équations des prix et des salaires.

Les méthodes économétriques de CANDIDE sont qualifiées de superficielles et périmées étant donné la confiance accordée aux méthodes d'estimation par les moindres carrés ordinaires et aux procédures standard de test des équations individuelles. La formulation d'importants blocs d'équations d'après le processus ARMA à variables multiples pourrait être utile en faisant ressortir les dynamiques et le besoin possible d'une respécification. Quoiqu'il en soit, il est urgent que des systèmes appropriés de méthodes d'inférence soient appliqués, sans quoi on ne pourra analyser l'importance des biais inhérents suscités par l'utilisation actuelle de méthodes inappropriées.

Summary

This paper provides a critical appraisal of some characteristics and the econometric methods employed in the construction of the CANDIDE models. It is argued that a model designed for medium- to long-term forecasting should not be predominantly demand-driven, but should seek to explain supply as a separate decision process; disequilibria between supply and demand, as reflected in unplanned inventory changes and profits, could then be made to influence supply and pricing decisions. The determination of industry output on the basis of fixed input-output coefficients is questioned. It is argued that, in a medium- to long-term model, fixed coefficients (particularly in the technology matrix) are inappropriate, since *inter alia* technology will be changing. Moreover, an explanation of such change in terms, for example, of relative prices is not only interesting in its own right but also desirable from the point of view of capturing the likely course of future events. However, since such an explanation would require the development of a time-series for every non-zero input-output coefficient, it may not be practically feasible.

In respect of the transmission mechanism of monetary policy, it is suggested there may be a practical advantage in avoiding the use of interest rates and incorporating direct money stock effects into expenditure functions; a similar argument applies also to price and wage equations.

The econometrics of CANDIDE are termed "trivial and outdated" in view of the reliance on ordinary least squares estimation methods and standard single equation test procedures. Formulation of important blocks of equations in terms of a multivariate ARMA process might be valuable in bringing to light inter-related dynamics and the possible need for re-specification. In any case, it is urgent that proper systems methods of inference now be applied, for otherwise there can be no appraisal of the significance of inherent biasses caused by the present use of inappropriate procedures.

1. Supply Considerations

CANDIDE 1.1 is a demand determined model. Its causal structure may be caricatured as follows. The various categories of final demand by ultimate use are first determined and these are then converted, *via* a large rectangular input-output system (and simple statistical bridge models), into a set of real domestic products by industry. The implicit, but fundamental, assumption underlying this conversion is that what is demanded will be supplied. Moreover, to be consistent, the same assumption is mirrored in the build up of employment, wages and the distribution of income. For, given the labour supply (which is essentially a demographic phenomenon), employment is determined according to what is required, in terms of labour input, to produce the industry outputs; industry prices, which are essentially based upon unit costs, are used (with import prices) to build up the prices of the commodities which comprise final demand, by application of the input-output system in the reverse direction to that used for industry output determination; and final demand prices in the form of the consumer price index, along with the unemployment rate and various (U.S.) exogenous factors, determine wage rates. Thus with employment and wage rates determined, labour income is also determined and thereby property income as well, from the appropriate accounting identity. What then needs to be added to complete the picture are two submodels: one which determines the demographic basis of the model, in particular the determination of the labour supply, and another which determines interest rates (to be used in the determination of e.g. certain categories of final demand) and key financial flows (which play a role in determining interest rates and the position of international reserves).

Demand determined models are traditional in econometrics and they work fairly well. Moreover, they have the important practical advantage of being essentially simple in their structure, which makes for easy understanding and straightforward estimation and inference. Yet these advantages are bought at the price of a sacrifice in structural realism, and may account for the fact that the performance of such models within the sample period of observations is not matched by performance in medium- or long-term forecasting and simulation. Even in short-term forecasting, such models are effective only to the extent that they are subjected to considerable *ad hoc* adjustment and practical experimentation.

In a model designed for medium- to long-term forecasting, it would seem to me that a sound structural basis is important, for otherwise we would anticipate the need for continual *ad hoc* adjustment to produce realistic and convincing forecasts. From a fundamental viewpoint, I would argue that the structure of CANDIDE is deficient to the extent that it is demand determined. No one surely believes that industry has such an easy task as to supply what is demanded. Output, and the pricing of output, must be based upon individual estimates of what can be sold at what price, and what to produce to service inventory. In this process, mistakes are bound to be made. Moreover, it is precisely these mistakes - that is the disequilibrium between supply and demand - that will affect behaviour at a later stage. The structure of the model should, in my opinion, seek to explain supply as a separate decision process from that determining demand.

In considering supply decisions, it is important to distinguish what is planned and anticipated, from what actually happens. One method of handling this is to concentrate, in the first instance, on planned inventories, and to regard inventory holders as absorbing all the unplanned activity in the economy. This identification of disequilibria with unplanned inventory changes would promote the inventory equations from something of comparatively minor importance, to something more like a central role in the model. For if inventories absorb the unplanned activity - the differences between supply and demand - then it follows that unplanned changes in inventories are an indicator of the incompatibility between supply and demand - and hence a crucial element in determining the adjustments to be made.

For example, consider the relations between domestic supply, prices and inventories. If demand is incorrectly estimated by suppliers, then the effect will be felt through inventory changes. On the other side, if costs have been incorrectly assessed (because of circumstances extraneous to suppliers), then the initial impact will be detected in profits. In disequilibrium, four possible cases may be considered. First, when profits are unexpectedly large and unplanned inventories positive: this would seem to imply that the current output/price combination is such that prices and/or output are 'too high' and hence that either or both should be reduced. Second, if profits are higher than expected and unplanned inventories are negative, then prices are 'too low' and/or output is 'too low'. Thus an increase in prices and/or output is called for. Third, let profits be lower than expected and unplanned inventories negative. In this case, clearly prices would be expected to increase, since this permits inventory to be replenished, at a lower planned level, and profits to be increased. Finally, let profits be lower than expected and unplanned inventories positive. Here we would expect output to be decreased, since this preserves the relation between unit costs and revenues, while getting rid of excess inventories.

What this crude example suggests is that changes in supply will depend on changes in the difference between observed and expected profits and the changes in unplanned inventories, and that reactions will vary according as the two are positive or negative in different combinations. Of course, we should also expect capacity restraints to play a part as well, since if output cannot be increased, then the adjustment must take place on prices. Moreover, there must also be a corresponding equation explaining prices, for as I have indicated, the two are jointly dependent.

Note carefully that if separate considerations were given to the determination of supply in the manner indicated, this would not reduce the role of the input-output system. This would still be vital, since the information it now provides would obviously be required to determine market disequilibria at the level of industrial output. However, there are difficulties in finding operational methods that are capable of capturing the notion of planned behaviour in both profits and inventories (for a recent example see Caton and Higgins, 1974).

2. Industry Output Determination

The question of separate supply equations, as suggested, involves a fundamental change in the CANDIDE structure, perhaps too fundamental to be feasible with the resources available. The second area on which I wish to comment is not fundamental to the structure, but it might involve a switch in emphasis and approach. This concerns industry output determination. The methodology of this sector is based upon a constant adjustment at a base year (1961) level together with the application of linear transformations defined in terms of 1961 market shares, technology, etc. to convert final demand in 166 categories to real value added per industry for a contracted set of 63 industries. These are then compared with the observed values by regression methods so as to provide a statistical device, called a bridge model, for improving accuracy. If f_t is the vector of final demands in year t, and y_t^* is the corresponding vector of estimated industry (value added) outputs, then the first step is represented by

$$(1) \quad y_t^* = F_o f_t + c_o$$

where the matrix F_o and the vector c_o are determined in the base year. If y_t is the observed value corresponding to the estimate y_t^*, the second step involves

$$(2) \quad M(L)(y_t - y_t^*) = Qx_t + H(L)\varepsilon_t$$

where M(L) and H(L) are diagonal matrices whose elements are finite polynomials in the lag operator L, $x_t^T = [1 \ t]$, Q is an appropriate matrix of coefficients and ε_t is a residual error. Over time the coefficients of the industry technology matrix, the market shares matrix and the expenditure matrix (which combine together to form F_o) will change, because of technological change, compositional changes, changes in tastes and relative prices. Hence at time t, $y_t = F_t f_t + c_t$ and the estimate y_t^* is incorrect to the extent that $F_t \neq F_o$ and $c_t \neq c_o$. Rather than estimate new values of F_t for each t, the estimates y_t^* are adjusted by applying regression methods to (2). Note carefully that combining (1) and (2) we have

$$(3) \quad M(L)\{(F_t - F_o)f_t\} = Qx_t + H(L)\varepsilon_t$$

if the difference between c_o and c_t is zero. Thus while equation (3) is designed to explain how the F matrix has changed, it actually takes account also of changes in f_t (since M(L) applies to the whole of the expression in { }).

I should note, in passing, that I find this a very impressive sector, in terms of methodology and results. Nevertheless there are two comments worth making. First, equations (2) and (3) represent an ARMA process around a linear trend and statistical methods are available for evaluating such equations, particularly to aid the selection of the most appropriate forms of M(L) and H(L), given that ε_t is a zero mean, constant variance serially independent error. See Section 3 below. Presumably there are also restrictions on the sum of the elements y_t, yet these do not seem to have been applied to y_t^*. Second, methods are available for evaluating a time series of F_t, given that additional bench marks to F_o are available. Such methods would, of course, involve massive computations, but one is led to ask if it is not time for a more up-to-date evaluation of F to be obtained and applied. Actually, the most interesting and crucial element contained in F is the technology matrix (the B matrix in the CANDIDE literature). An evaluation of a time-series of this matrix would be of considerable interest in its own right and much work has been done in developing methods to handle this problem in recent years: for example, the RAS method or the trend evaluation method which is essentially based upon judgement. Moreover, both the implicit adjustment equations (3) (based upon B rather than F) together with the various zero and other restrictions upon B would make a time-series estimation of B possible, in principle. The advantage of such information would be the possibility of exploring time series of the elements of B in terms of technological change (time) and relative prices, and this would provide an economically meaningful explanation for the observed changes. Extensions of this principle to the other matrices (D and E in the CANDIDE literature) would seem to be feasible.

3. Estimation

In my earlier report on the monetary sector of CANDIDE, I expressed the view (*inter alia*) that greater attention should be given to the modeling of price expectations effects stemming from developments in the monetary sector. I also expressed some surprise that more appropriate systems methods of estimation had not been applied. The first of these points has important implications (at least in principle) for the dynamics of the behaviour of the system, and this, together with the second point about estimation, should be a reminder that appropriate estimation methods should, in principle, be capable of handling *both* dynamic considerations *and* the more traditional difficulties that arise with simultaneous equations and interdependence. I now turn to some methods that could be exploited in estimating CANDIDE 1.1.

Let me emphasise at the outset that, in a large system, the most appropriate methods of estimation and inference may be computationally difficult (or impossible) to implement. In these circumstances, it seems appropriate to proceed first to a sector by sector evaluation, using *ad hoc* instrumental variable methods. This will help in the refining of existing hypotheses and perhaps the introduction of new ones. Once this stage has been completed, it would then seem appropriate to exploit any block recursivity in the system, and proceed to apply more general and more efficient methods of estimation. In both of these steps, it would seem important to point out that the treatment of equation errors is, at the moment, simplistic to the extent that only first-order autoregressive errors are applied, where appropriate. I believe that a more general approach is required. Indeed, the econometrics of CANDIDE are, frankly, trivial and outdated. On various points connected with this view, e.g. non-linearities and treatment of lags, the reader is referred to my earlier report (Fisher, 1974) and the literature cited there.

The usual dynamic linear simultaneous equation model may be expressed in general multiple time-series form. There are m endogenous variables contained in the m×l vector y and k exogenous variables x. Let m+k = p, whence the stochastic error ε is a p×l vector, partitioned into ε_1 (m×l) and ε_2 (k×l). To account for the dynamic structure, the p×p matrices A(L) and D(L) are introduced. These have elements which are finite polynomials in the lag operator L. By appropriate partitioning of A(L) and D(L) we have, for t = 1,2,...,n:

$$(4) \quad \begin{bmatrix} A_{11}(L) & A_{12}(L) \\ A_{21}(L) & A_{22}(L) \end{bmatrix} \begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} D_{11}(L) & D_{12}(L) \\ D_{21}(L) & D_{22}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$$

These equations are in ARMA form and postulate that the joint ARMA process of the variables, endogenous *and* exogenous, are compatible with a joint stochastic process for the set of random variables ε. It should be noted that equations are included in (4) to explain the exogenous variables as well as the endogenous variables. In this sense the system is more general than the traditional complete econometric model. Nevertheless, as it stands, the model does not make a great deal of sense, since the exogenous variables are made to appear as interdependent as the endogenous variables. It is therefore appropriate to introduce the following restrictions:

$$A_{21}(L) = 0,\ D_{12}(L) = 0,\ D_{21}(L) = 0\ ;$$

and the assumption that the elements of ε_t have zero mean, constant variance and are uncorrelated both across equations and through time (t). Equations (4) then become:

$$(5)\quad A_{11}(L)y_t + A_{12}(L)x_t = D_{11}(L)\varepsilon_{1t}\ ,$$

$$(6)\quad A_{22}(L)x_t = D_{22}(L)\varepsilon_{2t}\ .$$

Thus the current and lagged elements of ε_{1t} have no effect upon the current and lagged elements of x_t, and the current and lagged elements of ε_{2t} affect the current and lagged elements of y_t only to the extent of their influence on the current and lagged elements of x_t. In effect the restrictions and the assumption imply a general definition of exogeneity in terms of the linear independence of the processes in ε_{1t} and ε_{2t}, and the exogenous variables are thereby treated as random variables. Traditionally speaking, equations (5) above represent a complete linear structure.

Equations (5) may be used to derive the reduced form and the final form of the structure. The reduced form expresses (apart from the stochastic error) the current values of the endogenous variables in terms of the lagged values of the same variables and the current and lagged values of the exogenous variables. To assist in this development, I shall write for i,j = 1,2:

$$A_{ij}(L) = A_{ijo} + A_{ij1}L + A_{ij2}L^2 \ldots + A_{ijr}L^r\ ,$$

r being the maximum order of the polynomial functions contained in $A_{ij}(L)$. Thus $A_{ij\ell}L^{\ell}$ contains only those parts of the polynomial functions in L comprising the elements of $A_{ij}(L)$ that are terms in L^{ℓ}, $o \leq \ell \leq r$. With this notation, we have the reduced form

$$(7) \quad y_t = -\Sigma_{\ell=1}^{\ell=r} A_{110}^{-1} A_{11\ell} L^{\ell} y_t - A_{110}^{-1} A_{12}(L)x_t + A_{110}^{-1} D_{11}(L) \varepsilon_{1t}$$

assuming that A_{110} is of rank m. Thus the reduced form (7) is a system of m stochastic difference equations.

The final form of (5) is given by

$$(8) \quad y_t = -A_{11}^{-1}(L) A_{12}(L)x_t + A_{11}^{-1}(L) D_{11}(L)\varepsilon_{1t}$$

provided $A_{11}(L)$ is invertible i.e. the roots of det $A_{11}(L) = 0$ must lie outside the unit circle. Alternatively (8) may be written as

$$(9) \quad \det A_{11}(L)y_t = -A_{11}^{*}(L) A_{12}(L)x_t + A_{11}^{*}(L) D_{11}(L)\varepsilon_{1t}$$

where $A_{11}^{*}(L)$ is the adjoint matrix associated with $A_{11}(L)$. The final form expresses each of the current values of the endogenous variables in terms of current and lagged values of the exogenous variables and the current and lagged values of ε_{1t} .

The following points are of interest:

(i) As equation (9) indicates, every endogenous variable has an autoregressive part of the same order and with identical parameters. Statistical (ARMA) methods are available for checking the properties of these equations. Once the degree of det $A_{11}(L)$ and the order of the moving average errors have been ascertained, the equations may be estimated, since they are in the form of 'seemingly unrelated' regressions with moving average errors. Typically the estimation must be restricted by the implied over-identifying information.

(ii) Equation (5) is generally necessary for structural analysis which implies that: (a) we have sufficient data available on all variables; (b) we can distinguish between endogenous and exogenous variables; (c) the structural coefficients may be identified; (d) the dynamic properties of the structural equations have been ascertained. Nevertheless, the lag structures in (5) have implications for the (8) and (9). Hence (9), for example, may be very important as a means of gathering useful information about the structure.

(iii) Equations (7), (8) and (9) can be used for prediction and control, but not for structural analysis, unless $A_{110} \equiv I$, or $A_{11}(L) \equiv I$.

(iv) If sufficient data are not available on some of the endogenous variables, it will not, in general, be possible to make use of the reduced form (7). It will, however, be possible to use the transfer functions (9) for those endogenous variables for which data are available. This is clearly important for we often wish, in effect, to build part of a system, leaving some endogenous variables unexplained, or we are simply short of appropriate data.

(v) It should be emphasised that the requirements under (ii) above are rather severe. Insofar as they are too severe, it may be better to approximate and work with a more easily manageable system in place of (5), even though the applications of such a system would be more limited.

For further details on the matters discussed in this Section, including an empirical example, the reader is referred to Zellner and Palm (1974). My feeling is that the approach discussed is valuable in bringing to light how lag structures impinge on simultaneous systems, and how the basic structure may be re-formulated to aid estimation and inference. Moreover, methods are available to exploit these advantages.

In my view, it is now an urgent matter to attempt a re-estimation of CANDIDE along the lines described, that is, paying especial attention to interdependence, dynamics and error structures. Clearly, in the initial stages, 2SLS methods applied to (5) must play an important role, and I emphasise in this the evaluation of $D_{11}(L)$. Diagnostic checks may then be performed with natural blocks of interdependent equations.

4. Specific Comments on Details

In Fisher (1974) I made a number of comments and recommendations about the monetary sector of CANDIDE and some of these had implications for other sectors of the model, in view of the emphasis in that paper on the channels of monetary policy. The first of these was directed at wealth and price expectations effects and these had implications for consumption. I should like to re-emphaise these remarks in this paper. The second was a suggestion that, since rates of return are difficult to measure and explain, and the link between interest rates and investment is weak and sluggish, it may be better to consider the link between e.g. money stocks and investment directly. Indeed, there was a general plea in Fisher (1974) for the consideration of direct money stock effects in most expenditure functions, following Preston (1972). I took this view - and I still hold it - because of the difficulty of modeling interest rate behaviour in an annual model. An alternative approach is treat the short-term interest rate equation as a portfolio balance equation, and with additional research, continue to emphasise rates of interest as the main channel of monetary activity. If this is to be the decision, then clearly it would make sense also to 'expand' the role of interest rates by giving them more detailed treatment. Thus in connection with residential construction, it would be logical to attempt more detailed explanation of the mortgage market. However, I am frankly doubtful of the viability of this approach in an annual model, and would argue for greater emphasis on money stocks; moreover, I would also press for their consideration elsewhere, e.g. in the prices and wages sector. Given the similarities between the form and the development of CANDIDE and the Wharton Annual Industry and Forecasting Model, I am surprised that there has not been greater emphasis in the former on monetary stocks.

A third recommendation in Fisher (1974) was that there should be a disaggregation between the Federal and the Provincial Governments. I am pleased that this work has been undertaken in CANDIDE 1.1, even if for different reasons than the ones I put forward.

The import equations in CANDIDE 1.1 are, as I understand the matter, treated as traditional demand equations and the explanatory variables reflect domestic (including cyclical) activity and relative prices. It should be clear that, in principle, import equations are neither demand equations, nor supply equations: importing is essentially an activity of distribution. For this reason, we should ask what causes variation in importing activity? If the import is non-competing (not domestically produced) then importing is just like domestic supply (Section 1 above). If the import is competing, then we should expect imports to change accordingly as there is (i) variation in excess demand, (ii) variation in relative prices and (iii) variation in capacity usage. Given my points about the importance of home supply equations, it would seem logical to pursue the role of excess demand (at least) in the process determining imports. I have, of course, already emphasised the importance of home supply and excess demand in price formation, and hence in explaining the various aspects of inflation within the Canadian economy.

5. Summary and Recommendations

I have examined a number of points in regard to the development of CANDIDE 1.1, some specific and some general. My recommendations are summarized below.

(i) Urgent attention should be given to the estimation of CANDIDE 1.1 as an econometric system, using methods which properly account for simultaneity, the dynamic interdependence of variables and general forms of serial correlation in the errors.

(ii) Updating of the industry output determination transformations seems called for at this stage, with the prospect of at least some checking of the movements in individual coefficients in the period since 1961.

(iii) Corresponding to (ii), is the updating and re-estimation of bridge models by more appropriate means (i.e. ARMA methods). Since such development of methods is envisaged under (i) above, this proposal is in the nature of spin-off.

(iv) The basis of the determination of supply in CANDIDE 1.1 should be reconsidered in the light of my remarks in Section 1 and of recent literature in the field.

(v) Should (iv) be explored, this should be done simultaneously with an exploration of the implications - particularly in respect of the price - wage sector, the import sector and, of course, inventories.

(vi) More general consideration should also be given to the role of money stocks and hence to the position and role of the monetary sector. If CANDIDE 1.1 is to make broad use of money stocks, then the monetary sector need not be substantially expanded. If, on the contrary, it is decided to confine attention to interest rate effects, then considerable expansion of the monetary sector would seem logical, particularly in respect of the mortgage market.

(vii) Further recommendations are contained in Fisher (1974).

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