Economic Council of Canada
Conseil économique du Canada

Post Office Box 527, Ottawa K1P 5V6
Case Postale 527, Ottawa K1P 5V6

DISCUSSION PAPER NO. 25

A Critical Review of CANDIDE Model 1.0

by J. Kmenta

March 1975

"Un examen critique du modèle CANDIDE 1.0"

Résumé

Le but de ce document est de présenter une évaluation critique des divers aspects de la première version du modèle CANDIDE (appelé le modèle CANDIDE 1.0). Nous y examinons la méthodologie de la construction, de la formulation et de l'évaluation d'un grand modèle. Nous abordons également la question des coûts et des bénéfices inhérents à un très vaste modèle économétrique, de la compréhension du modèle, et des différences entre plusieurs modèles d'une même économie. Nous y recommandons que les auteurs de CANDIDE étudient la possibilité de produire une version miniature de leur modèle qui en retiendrait les principales caractéristiques tout en évitant sa complexité. La principale critique quant à la spécification du modèle CANDIDE 1.0, concerne les ajustements arbitraires de certaines des constantes de régression dans les équations des investissements des entreprises et de la formation de capital des gouvernements. En outre, il faudra que de nouveaux travaux soient entrepris pour améliorer le mécanisme prix-salaires, pour renforcer les liens entre les secteurs monétaire et réel et pour incorporer un mécanisme permettant la substitution des facteurs dans les secteurs de la production. Le document traite également de problèmes d'estimation statistique et contient certaines propositions au sujet de modifications et de travaux ultérieurs.

"A Critical Review of CANDIDE Model 1.0"

Summary

The purpose of the paper is to make a critical assessment of various aspects of the first version of the CANDIDE model (known as "CANDIDE Model 1.0"). The aspects considered are those of strategy of large-scale model building, and of its formulation and estimation. Consideration is given to questions of benefits vs. costs of having a very large econometric model, of understanding the model, and of the differences between several models of the same economy. It is recommended that the authors of CANDIDE consider the possibility of producing a mini-version of their model that would retain its main features but would not be burdened by its complexity. As for the specification of CANDIDE Model 1.0, the major criticism concerns the arbitrary adjustments of some of the regression constants in the equations of business investment and government capital formation. Further, it is noted that additional work is needed to improve the wage-price mechanism, to develop stronger links between the monetary and the real sectors, and to incorporate a mechanism for input substitution in the production sectors. The paper also deals with problems of statistical estimation and contains some suggestions for changes and further work.

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

The good man is the builder, if he build what is good.
I will show you the things that are now being done,
And some of the things that were long ago done,
That you may take heart. Make perfect your will.
Let me show you the work of the humble. Listen.

T. S. Eliot, The Rock

Table of Contents

	Page
Resumé	II
Summary	III
1. Introductory Remarks	1
2. Specification of the Model	5
3. Econometric Problems	16
4. Comments on the Size of the Model	21
5. Other Comments	22

1. INTRODUCTORY REMARKS

The CANDIDE model of the Canadian economy represents an ambitious and awe inspiring project. There is clearly nothing like that in the entire world. Even the existing "super" models of the U.S. economy, such as the SSRC-Brookings Quarterly econometric model[1/], pale in comparison with the CANDIDE model. No reviewer could help but be impressed by the sheer fact that such a giant model could actually be constructed and brought into a working condition. It is, indeed, a great achievement to have been able to specify some 1,600 equations in such a way that they form a internally consistent system and are in a reasonable agreement with the Canadian historical experience of the postwar years.

One of the main difficulties in dealing with econometric models of substantial size is the matter of comprehension. Since virtually nobody can get a clear picture of what is being modeled by looking over a set of several hundred equations, an explanation of the model and a judicious guidance through the main building blocks is very important. Indeed, one of the major criticisms of the large econometric models of the United States has been the complaint that they cannot be understood.[2/]

1/ J. S. Duesenberry, G. Fromm, L. R. Klein, and E. Kuh (eds.), The Brookings Quarterly Econometric Model of the United States (Chicago: Rand McNally, 1965).

2/ See, e.g., E. Mosback, "Review of the First Brookings Volume," Econometrica 36 (January, 1968), pp. 194-196, or K. Brunner (ed.) Problems and Issues in Current Econometric Practice (Columbus: Ohio State University, 1972), p. 268.

The authors of the CANDIDE model have gone some way toward assuaging their critics on this count by a careful organization of their model into a manageable number of blocks. The guidance provided by the simplified, nontechnical description of the model by R. G. Bodkin[3/] is very clear and informative, and is bound to be greatly appreciated by all who have to deal in any way with the model.

In assessing a model that has involved a great amount of effort and whose development has commanded the employment of substantial resources, the question of its worth is highly pertinent. Whether the benefits from having a huge model on hand outweigh the costs or not depends on the use to which the model is to be put and the alternatives available for such a use. If the construction of the model were to be regarded largely as an academic exercise with the ostensible purpose of carrying out "the analysis of business cycle problems and stabilization policies"[4/] as was the case with the SSRC-Brookings model, then such a large undertaking is probably not worth the cost. For instance, it is very doubtful that our knowledge of economics in the area of business cycles and stabilization policies has been markedly advanced by the existence of the large econometric models of the United States constructed in the last few years. Certainly it is difficult

---

3/ R. G. Bodkin, "A Short, Nontechnical Description of CANDIDE Model 1.0", mimeo.

4/ Duesenberry *et al.*, *op. cit.*, p. v.

to make the claim that -- apart from generally uninteresting details -- we have learned anything from these large models about business cycles and policy effects that could not have been learned from more highly aggregative (and thus much smaller) models. If, on the other hand, the purpose of the model is to serve as a tool for policy decisions, then the assessment of the model is to be viewed in a different light. A policy maker (at least in Canada) is presumably interested in a high degree of disaggregated detail, otherwise the budget for the CANDIDE model would hardly have been approved. If the alternative to having the detailed information provided by a large model is to rely on trend fitting, independent guessing and crystal ball prophesy, then the superiority of the model is unquestionable. Whether a large, disaggregated model is necessarily preferable to a smaller, more highly aggregated model supplemented by a set of partial equilibrium models of various markets is perhaps more of an open question since the importance of the feedbacks from, e.g., the individual commodity or factor markets to the system at large is not always clear. However, it is also not clear that the cost of this alternative would be less than that of constructing CANDIDE.

One aspect of the proliferation of large-scale models that has drawn a substantial amount of criticism in the United States[5/] is the extent of differentiation between various models purporting to explain the same economic phenomena. When the

---

[5/] See in particular Brunner, op. cit., pp. 281-283.

differences are due to different degrees of spatial and/or temporal aggregation, a reconciliation may be possible by taking these differences into account. For instance, a forecast of next year's total consumption expenditure based on a medium-term annual model can be compared with the sum of quarterly forecasts of total consumption expenditure based on a short-term quarterly model. If there is a difference, it must be due to different sample and/or prior information used in making the respective forecasts. An obvious conclusion to be drawn is that there is a strong case for trading information and reconciling the existing differences -- or at least making them explicit and providing for statistical tests on the basis of future observations. The large-scale model builders in the United States have done very little in this respect.[6/] The creators of the CANDIDE model are not immune from this criticism either. A reviewer of the CANDIDE model is bound to be struck by the singular lack of references to the specification and results of other existing models of the Canadian economy.[7/] While the CANDIDE model is clearly much more disaggregated than other

---

6/ One of the participants at the conference reported in Brunner, op. cit., not implausibly conjectured that the main reason for building yet another large-scale model of the U.S. economy was that its creator was presumed to be closer to God than his predecessors and that the funding agency would not take the risk of not believing him.

7/ For a convenient summary of these models see H. Tsurumi, "A Survey of Recent Canadian Macro-Econometric Models," Institute for Economic Research Discussion Paper No. 81 (May, 1972), Queens University, Kingston.

models, results for major aggregates are also available or at least derivable. Yet the authors of the CANDIDE model give no indication of any utilization of the results of the other existing models, and no explanation of the differences. For instance, the reported values of the marginal propensity to consume for the CANDIDE model are 0.887 (short run) and 0.920 (long run).[8/] There is no comment at all about the corresponding values obtained from other Canadian models and about the reasons for the difference.

2. SPECIFICATION OF THE CANDIDE MODEL

General Remarks

The correctness of the specification of an econometric model can be tested in the following ways:

(1) By checking for internal consistency and for contradictions with received and tested theory.

(2) By examining the closeness with which the model "tracks" the historical observations that were used in its estimation.

(3) By studying the performance of the model in simulated situations or -- which in principle amounts to the same

---

8/ See M. C. McCracken, "An Overview of CANDIDE Model 1.0", CANDIDE Project Paper No. 1, p. 37. Incidentally, the quoted figures for the MPC appear to be remarkably high. For instance L. R. Klein in his discussion on the construction of an econometric model for India states that 'a plausible value [for the marginal propensity to consume] should be at least 0.85. This is larger than the corresponding parameter value estimated for advanced industrial countries.' (See L. R. Klein, "What Kind of Macroeconometric Model for Developing Economies?". Econometric Annual of the Indian Economic Journal 13 (1965), pp. 317-8.)

thing -- in forecasts for the periods for which actual observations are not yet available.

(4) By comparing new observations outside of the sample with the values predicted by the model, after allowing for discrepancies that are likely to arise to pure chance.

The CANDIDE model has been subjected to a more or less thorough test only with respect to historical tracking and seems to have passed this test quite well.[9/] Some partial checks have apparently been made with respect to internal consistency and agreement with standard economic theory, and with respect to simulated results, but not with respect to the forecasting accuracy for the post-1970 years for which observations are now available. The projections to 1980 presented in the Ninth Annual Review of the Economic Council indicate that the CANDIDE model is, indeed, internally consistent, although this consistency is at times achieved by some very rough-and-ready means. As for general agreement with standard economic theory, no blatant violations -- such as a positive response in demand to an increase in price -- are in clear evidence but occasionally some specifications are somewhat dubious. On the whole the model is theoretically "neutral" in spite of the claim of a "neo-Keynesian spirit"[10/] since both fiscal and monetary factors play an important role.

[9/] See Economic Council of Canada, Ninth Annual Review: The Years to 1980, ch. 2, and The Economy to 1980: Staff Papers, ch. 4 and 8.

[10/] See R. G. Bodkin, op. cit., p. 2. While the role of the monetary factors is somewhat underplayed in the first version of the CANDIDE model, this shortcoming is appropriately recognized (see M. C. McCracken, op. cit., p. 109) and will presumably be removed in the next version.

Concerning the performance of the model in simulated situations, the projections to 1980 reveal no startling contradictions of prior expectations, with the significant exception of business investment. What should be done further, though, is to run the model through enough repetitions to assure that the solution is stable and to check that the inherent cyclical movement is in reasonable agreement with historical experience.[11/] Finally, with respect to testing of the outside-of-sample forecasts with actual observations, the matter is apparently complicated by the recent revision of the Canadian national accounts. Since this test -- particularly when applied to projections that feed upon themselves -- is the most stringent test of any model, its execution is highly desirable. Further comments on individual parts of the model are given below.

Savings and Consumption

The approach taken here is to estimate the relationships determining aggregate savings (distinguished by type) and to treat aggregate consumption as a residual by subtracting personal savings from disposable income. This procedure is not implausible but some of the rationalization for it is. Specifically, in rejecting the idea of estimating an aggregate consumption function it is stated that "a regression equation with consumption as the dependent variable and disposable income as

---

11/ See, e.g., I. Adelman and F. L. Adelman, "The Dynamic Properties of the Klein-Goldberger Model," Econometrica 27 (October, 1959), 597-625.

the key explanatory variable is by definition a near identity ... The value of this type of equation to hypothesis testing is questionable..."[12/] Let us examine this contention in the context of the following model:

$$C_t = \alpha + \beta Y_t + u_t \qquad \text{(consumption)}$$

$$S_t = \gamma + \delta Y_t + v_t \qquad \text{(saving)}$$

where C = consumption, S = saving, and Y = disposable income. Applying the least squares estimation method (which is the method used in CANDIDE), we obtain the following estimates of the regression slopes:

$$\hat{\beta} = \Sigma(C_t - \bar{C})(Y_t - \bar{Y})/\Sigma(Y_t - \bar{Y})^2$$

$$\hat{\delta} = \Sigma(S_t - \bar{S})(Y_t - \bar{Y})/\Sigma(Y_t - \bar{Y})^2$$

However, since by definition

$$S_t = Y_t - C_t$$

we get, by substitution,

$$\hat{\delta} = 1 - \Sigma(C_t - \bar{C})(Y_t - \bar{Y})/\Sigma(Y_t - \bar{Y})^2$$

$$= 1 - \hat{\beta}$$

Thus the properties of the two estimators are identical and there is no gain in using one or the other in testing hypotheses about β or δ (= $1-\beta$). Further statement that "an R^2 of .99 in an aggregate consumption function may still yield

[12/] T. T. Schweitzer and T. Siedule, "CANDIDE Model 1.0: Savings and Consumption," CANDIDE Project Paper No. 2, p.1.

a vector of residuals larger than that produced by an alternative method, such as the derivation of total consumption from saving" is equally unjustified. By reference to the above, the residuals obtained directly from the consumption function are

$$\hat{u}_t = (C_t - \bar{C}) - \hat{\beta}(Y_t - \bar{Y})$$

while the consumption residuals obtained from the estimated saving function are

$$\begin{aligned} \hat{u}_t^* &= (C_t - \bar{C}) - [(Y_t - \bar{Y}) - (\hat{S}_t - \bar{S})] \\ &= (C_t - \bar{C}) - [(Y_t - \bar{Y}) - \hat{\delta}(Y_t - \bar{Y})] \\ &= (C_t - \bar{C}) - \hat{\beta}(Y_t - \bar{Y}) \end{aligned}$$

i.e., the two sets of least squares residuals are identical.

With respect to the specification of the aggregate savings functions, the estimated equations seem to fit the observations quite well, but there is clearly some room for improvement. In particular, one might expect at least on theoretical grounds that a savings function would include an interest rate variable among its explanatory factors. The authors do not mention whether any consideration has been given to this. Further, the dummy variable for "the year 1960" in the discretionary saving equation is artificial and represents an unsatisfactory way of dealing with an "outlier" problem. This variable is characterized only by reference to a specific point in time and thus is meaningless as an explanatory factor. Either there is a systematic cause that accounts for the "abnormally low" discretionary savings in

1960, in which case it should be identified, or the phenomenon should be attributed to the regression disturbance.

As for the disaggregated consumption equations, the Houthakker-Taylor specification is, in general, acceptable and seems to produce reasonably good fit.13/ What is more questionable is the use of adjustment equations designed to make sure that the sum total of the forecasts for individual consumption items will always be equal to total consumption. A clearer and preferable way of dealing with this problem would be by imposing the appropriate restrictions during the process of estimation.14/

13/ The derivation presented in Schweitzer and Siedule, op. cit., pp. 13-16, appears to be unnecessarily complicated. Given the basic equation

$$(1)\quad q_t = \alpha + \beta s_t + \gamma x_t + \eta p_t + u_t$$

and the definition of the stock variable

$$(4)\quad \Delta s_t = q_t - \delta s_t$$

or

$$(4')\quad (1 + \delta)s_t - s_{t-1} = q_t$$

we can proceed by multiplying (1) by $(1 + \delta)$:

$$(1 + \delta)q_t = \alpha(1 + \delta) + \beta(1 + \delta)s_t + \gamma(1 + \delta)x_t + \eta(1 + \delta)p_t + (1 + \delta)u_t$$

and by deducting (1) lagged by one period from the preceding equation we get

$$q_t = b_0 + b_1 q_{t-1} + b_2 x_t + b_3 x_{t-1} + b_4 p_t + b_5 p_{t-1} + u_t^*$$

which is identical with equation (15) of the text.

14/ See R. G. Bodkin, "Additively Consistent Relationships for Personal Savings and the Categories of Consumption Expenditures, 1949-1963", (May, 1972), mimeo, and the references cited therein.

Residential Construction and Business Investment

The specification of the equations determining residential construction appears to be reasonable and to yield quite a good fit considering the volatile nature of this variable. In the case of business investment, however, the adjustment of the regression constants in the projections to 1980 clearly indicates incorrect specification of the private fixed investment equations. The hopefully not too prevalent practice of adjusting the regression constant any time the forecaster does not happen to like the value projected by his model is a very poor one. Indeed, the whole idea of constructing a model is to create an instrument that will provide the same response to a given stimulus regardless of who pulls the handle. By adjusting the flow of endogenous variables as it comes out to suit one's liking is clearly unscientific. This is not to say that the model builder should not use all of the available prior information, judgements, beliefs (and even prejudices), but these must all be integrated into the model and not be saved for future messing with projections. If business investment is expected to be enhanced by "incentive programs" then incentive programs -- properly defined -- should be included as explanatory factors in the estimated equations. (Note, though, that the use of dummy variables for "investment boom" in the 1950's is appropriate only if the values of the dummy variables can be tied to some <u>observable</u> characteristic of each year.) If no "incentive programs" have been experienced in the past and thus their effects cannot be estimated, that is just where the matter has to stand, unless one wishes to revert back to crystal ball gazing.[15/]

Government Sector

The endogenous treatment of government expenditure on goods and services in the CANDIDE model is an excellent idea for which the authors of the model deserve high marks. The estimated equations seem to give quite a good fit. The success of these equations, however, is marred by the apparent need to make "exogenous additions" to the projected governmental fixed capital formation. This, as emphasized above, is a very poor way of dealing with the problem of getting forecasts that are considered to be too low (or too high). What is needed is a proper re-specification of the relevant equations. If, as claimed, the reason for the adjustment is the expected increase in private investment for resource development (which would lead to public investment in roads and other construction),[16/] then private investment should be included as an explanatory variable in the equations for government investment.

15/ The explanation for the "exogenous additions to investment in projection period" in The Economy to 1980: Staff Papers, p. 169, is unconvincing. For instance, if the profit maximization model is inappropriate for the transportation industry, then it should not have been used in the first place. Similarly, if price expectations are changing, there must be a reason and the model builder should have ferretted it out.

16/ See The Economy to 1980: Staff Papers, p. 53.

Exports, Imports, and the Balance of Payments

The specification of export equations for endogenously determined exports seems to be successful in tracking the past and, apparently, in producing sensible forecasts. Some categories of exports are said to be difficult to model and, therefore, are treated exogenously. This is probably less satisfactory than providing for an endogenous determination even if the equations should contain a fair amount of 'white noise'. The authors claim that "in many cases knowledge of future contracts and anticipated structural changes result in a much better estimate than an equation estimated from past relationships."[17/] It is difficult to see how the authors know this since future exports have not yet been observed and thus there is no way of making a comparison. But even if the claim were true, it is likely to apply only in the short run and not in the "medium" run of 6-8 years envisaged by the creators of CANDIDE.

The import equations appear to be sensible and track well. One criticism can be raised against the equation for "imports of other highly manufactured goods."[18/] This equation contains an "aircraft import dummy variable" which is given the value of +1 in 1961, the value of -1 in 1964, and is equal to zero in all other years. Unless the originators of this equation have at their disposal extraordinarily specific

---

17/ Overview, p. 53.

18/ Overview, pp. 54-55.

information about the characteristics of aircraft imports, such a specification is inappropriate. Proper specification would involve two dummy variables, one assuming the value of +1 in 1961 and zero in other years, and the other assuming the value of +1 (or -1) in 1964 and zero in other years.

The specification of the balance-of-payments submodel is incomplete since the linkages with the rest of the model are only one-directional. Also, allowance for a flexible exchange rate and its determination would seem in order. All this is acknowledged in the Overview and requires no further comment.

Industry Outputs Sector

The incorporation of an input-output table within the model is ingenious and technically well done. The main difficulty -- as also noted in the Overview -- is the necessarily static nature of the input-output table which does not reflect any changes in relative prices and in technology. The experience elsewhere indicates that the input-output coefficients have to be re-estimated at least every three years to be of any use for policy decisions.[19/] The autoregressive adjustment equations employed to reconcile the discrepancy between the actual real domestic product of an industry and its input-output estimate is clearly a makeshift arrangement which should be regarded as

---

19/ See K. A. Fox and E. Thorbecke, "Specification of Structures and Data Requirements in Policy Models," in Bert Hickman (ed.), Quantitative Planning of Economic Policy (Washington, D.C.: The Brookings Institution, 1965).

strictly temporary. The assumption that value added is a fixed proportion of the gross output for each industry should be checked against actual observations.

Other Sectors

As noted in the Overview, additional work is needed to improve the wage-price mechanism and to develop stronger links between the monetary and the real sectors of the model. With respect to the latter, inspiration could be gained from the RDX2 Model of the Bank of Canada or from the FRB-MIT model of the United States economy.

As the final thought one might consider a possible refinement of the labor requirements equations. According to the CANDIDE 1.0 specification, the desired level of labor input is derived from a Cobb-Douglas function (Overview, p. 67). Since this specification restricts the substitution between labor and capital to a unitary elasticity, a more general formulation may be preferable, especially since the Cobb-Douglas form gives a poor fit. The production surface may alternatively be represented by a CES function, i.e.,

$$Y = ae^{\delta t}[\gamma K^{-\rho} + (1 - \gamma)L^{-\rho}]^{-\nu/\rho}$$

where $\gamma = \beta/(\alpha + \beta)$ and $\nu = \alpha + \beta$

in the notation of the Overview. The parameter ρ determines the degree of substitutability between K and L (for $\rho \to 0$ the function reduces to the Cobb-Douglas form). From this we obtain

$$\log L^* = \frac{1}{\rho}\log(1 - \gamma) - \frac{1}{\rho}\log[a^{\rho/\nu}\ e^{\delta\rho t/\nu}\ Y^{-\rho/\nu} - \gamma K^{-\rho}]$$

By using Taylor series formula the expression on the right-hand side of the above equation can be expanded around $\rho = 0$ and the terms involving powers of ρ higher than two dropped. This gives

$$\log L^* = \frac{1}{\alpha}[-\log a - \delta t + \log Y - \beta \log K]$$
$$+ \frac{\rho}{2}\frac{\beta}{\alpha}\left(\frac{1}{\alpha + \beta}\right)^2 [-\log a - \delta t + \log Y - \beta \log K]^2$$

The first term on the right-hand side corresponds to the Cobb-Douglas formula while the second term constitutes a "correction" due to the departure of ρ from zero. On the assumption that

$$L_t/L_{t-1} = (L_t^*/L_{t-1})^{\lambda}$$

and by the introduction of simplifying notation we get

$$\log L_t - \log L_{t-1} = b_0 + b_1(\log Y_t - \beta \log K_t + \delta t)$$
$$+ b_2(\log Y_t - \beta \log K_t + \delta t)^2$$
$$+ b_3 L_{t-1} + u_t$$

If the appropriate formulation is of the Cobb-Douglas type, the estimated value of b_2 should not be significantly different from zero.

3. ECONOMETRIC PROBLEMS

Simultaneous Equation Estimation

Most of the equations of the CANDIDE model have been estimated by ordinary least squares (and the remaining ones by three-pass least squares). No simultaneous equation estimation methods have been employed in any part of the model. Initial employment of ordinary least squares is probably the most efficient way of getting an impressionistic picture of the agreement of the model with historical observations. However, it is well known that in a general interdependent system of equations ordinary least squares estimates are inconsistent and the application of conventional tests of significance invalid. Therefore it is strongly recommended that those equations which involve current endogenous variables (or lagged endogenous variables and autocorrelated disturbances) on the right-hand side of the equation be re-estimated using a consistent estimation technique. The question is which of the several methods designed for simultaneous equation systems should be used. Since the model involves several hundred predetermined variables, it is impossible to estimate the reduced form equations and this makes two-stage least squares infeasible. The size of the model also precludes the use of system methods of estimation such as full information maximum likelihood or three-stage least squares. Probably the most practicable and easiest to use would be the structurally ordered instrumental variables method proposed by F. M. Fisher.[20/] This method involves a judicious choice of instrumental variables on the basis of the closeness of causal relation of each predetermined variable to a given endogenous variable in the equation to be estimated. The SOIV method has been proposed for estimation of the SSRC-Brookings model and has been successfully applied in the Michigan Quarterly Econometric Model of the United States.

20/ See F. M. Fisher, "The Choice of Instrumental Variables in the Estimation of Economy-Wide Econometric Models," International Economic Review 6 (September, 1965), pp. 245-274; and, by the same author, "Dynamic Structure and Estimation in Economy-Wide Econometric Models," in J. S. Duesenberry, op. cit., ch. 15.

Distributed Lags

The specification of the CANDIDE model involves in many cases the use of polynomial distributed lag. The use of distributed lag formulation in the context of a large econometric model is relatively new and adds a nice touch of sophistication to the CANDIDE model. Whether polynomial lag is the best way of representing delayed reactions of the dependent variables is perhaps debatable but the point is certainly of a low order of importance at present. More relevant is the problem of estimation of distributed lags in simultaneous equation models to which we now turn.

Consider an equation which is a part of a simultaneous equation system and which is of the form

$$y_t = \sum_{i=1}^{g} \gamma_i Y_{i,t} + \sum_{i=1}^{k} \delta_i X_{i,t} + \sum_{i=0}^{m} w_i Z_{t-1} + \varepsilon_t$$

Here y_t is the dependent variable, $Y_{1,t} \dots Y_{g,t}$ are the included endogenous variables, $X_{1,t} \dots X_{k,t}$ are the included predetermined variables, Z_t is the variable (either endogenous or exogenous) to which the polynomial lag is applied, and ε_t is the disturbance. The polynomial lag specification is that the (m+1) lag weights $w_0, \dots, w_m$ lie on a polynomial of order p; that is,

$$w_i = \lambda_0 + \lambda_1 i + \lambda_2 i^2 + \dots + \lambda_p i^p \quad , \; i = 1,2,\dots,m \; .$$

Usually p is considerably less than m, so that there is a reduction in the number of parameters from the (m+1) w's to the (p+1) λ's. Correspondingly, we can reduce the number of explanatory variables by defining the new variables

$$A_{0,t} = Z_t + Z_{t-1} + \ldots + Z_{t-m}$$

$$A_{1,t} = Z_{t-1} + 2Z_{t-2} + \ldots + mZ_{t-m}$$

$$\vdots$$

$$A_{p,t} = Z_{t-1} + 2^p Z_{t-2} + \ldots + m^p Z_{t-m} \quad ,$$

and noting that

$$\sum_{i=0}^{m} w_i Z_{t-i} = \sum_{i=0}^{p} \lambda_i A_{i,t} \quad .$$

Hence the equation to be estimated is just

$$y_t = \sum_{i=1}^{g} \gamma_i Y_{i,t} + \sum_{i=1}^{k} \delta_i X_{i,t} + \sum_{i=0}^{p} \lambda_i A_{i,t} + \varepsilon_t \quad .$$

Given that the above equation is part of a simultaneous equation model, ordinary least squares estimates are inconsistent and hence inappropriate. However, the equation can be estimated by the usual simultaneous equation techniques such as the structurally ordered instrumental variables method mentioned above. If Z_t is exogenous then the $A_{i,t}$ are also exogenous and can be treated as such. If, on the other hand, Z_t is endogenous, then $A_{0,t}$ is endogenous while $A_{1,t}$, $A_{2,t}$, ..., $A_{p,t}$ are predetermined. In this case as instrument for $A_{0,t}$ must be found.

Three-pass Least Squares

The method of three-pass least squares yields, in general, inconsistent estimates and is thus inappropriate. This is generally known in the profession and the method is politely ignored in the textbooks.[21/] When it is mentioned, it is with disapproval. Dhrymes, for instance, writes:[22/]

> absence of auto-(and cross auto-) correlation is both a necessary and a sufficient condition on the exogenous variables -- the x_i -- in order for the consistency... to be valid. [1]Since most economic data exhibit substantial autocorrelation, <u>we conclude that this procedure (3PLS) is not very useful in estimating the parameters of the model...</u>

Consistent estimates of the parameters of the Houthakker-Taylor type of demand equations (as formulated in footnote 13 above):

$$q_t = b_0 + b_1 q_{t-1} + b_2 x_t + b_3 x_{t-1} + b_4 p_t + b_5 p_{t-1} + u_t^*$$

can be obtained as follows. First, it is assumed that the disturbance u_t^* follows a first-order autoregressive scheme, i.e., that

$$u_t^* = \rho u_{t-1}^* + v_t \qquad (0 \leq \rho < 1)$$

where v_t is normally distributed with zero mean and a constant variance, and is nonautoregressive and independent of u_{t-1}^*. Then consistent estimates of the demand coefficients are obtained by minimizing

$$S = \sum_t [(q_t - \rho q_{t-1}) - b_0(1-\rho) - b_1(q_{t-1} - \rho q_{t-2}) - \ldots - b_5(p_{t-1} - \rho p_{t-2})]^2$$

21/ There is no mentioning of the method of all in the most recent advanced econometrics texts. See H. Theil, <u>Principles of Econometrics</u> (New York: Wiley, 1971) or P. J. Dhrymes, <u>Econometrics</u> (New York: Harper and Row, 1970).

22/ P. J. Dhrymes, <u>Distributed Lags</u> (San Francisco: Holden Day, 1971). A similar statement can also be found in J. Johnston, <u>Econometric Methods</u>, Second Edition (New York: McGraw-Hill, 1972), p. 320.

with respect to b_0, b_1, ... , b_5. The minimization can be carried out quite conveniently by "searching" over different values of ρ from -1 to +1. If x_t and p_t are endogenous, they have to be replaced by their fitted (partial) reduced form values $\hat{x}_t$ and $\hat{p}_t$ before carrying out the minimization process.

4. SIZE OF THE MODEL

The advantages and disadvantages of large-scale vs. small and highly aggregative models have been debated at length in the economic literature and at various conferences.[23] Briefly, the large models are claimed to be more realistic by paying attention to specific detail, and to allow "conditional simulations on fine-grained policy choices and structural changes".[24] On the other hand, the critics of large-scale models point out that these models are very complex and typically messy, that they are considerably more sensitive to misspecification than more aggregative models, and that they are poorer predictors of broad aggregates.[25] Recent economic events, however, have tended to boost the reputation of more

---

23/ For a convenient summary of the debate and an in-depth examination of the question see G. Fromm and G. R. Schink, "Aggregation and Econometric Models," International Economic Review 14 (February, 1973), pp. 1-32.

24/ Ibid., p. 2.

25/ See Y. Grunfeld and Z. Griliches, "Is Aggregation Necessarily Bad?" Review of Economics and Statistics 42 (February, 1960), pp. 1-13.

detailed models since the highly aggregative model were not equipped to deal with such micro-distortions as the movement in the price of fuel or of meat. One possible reconciliation of the dilemma is to supplement a large-scale model by a companion "summary" model of a much smaller size but one which would be fully consistent with the large model and would capture its main characteristics. This is what some researchers at the Federal Reserve Board in Washington are now trying to provide for the big FRB-MIT model. Having a "summary" model on hand would eliminate the problem of complexity and difficulty of understanding, and possibly of aggregate prediction. Such a model could also be used for all policy simulations and predictions that do not require a great deal of detail, for examination of the dynamic properties of the model, for testing for structural change, etc. For a model as large as CANDIDE a simplification of this sort would undoubtedly be especially useful.[26/]

5. OTHER COMMENTS

Re-estimation of the Model

It is clear that the equations of the CANDIDE model have to be re-estimated, if for no other reason because of the recent revision of the Canadian national income data. Therefore,

---

26/ If a "summary" model is not to be constructed, a thought should be given to the possibility of "tearing" CANDIDE apart by breaking its weak linkages. See D. V. Steward, "On An Approach to Techniques for the Analysis of the Structure of Large Systems of Equations," Society for Industrial and Applied Mathematics Review 4 (October, 1962), pp. 321-342.

it is appropriate to emphasize that in estimating each relationship one should make use of all the relevant information that is available. This applies not only to prior, theoretical information but also to observational evidence. Specifically, since long (or medium) run consists of a series of short runs, observations of short run behavior contain information about the long run behavior. This implies that, when estimating an annual relationship, one should not ignore the observations on smaller parts of the year when they are available. Quarterly or monthly observations should be utilized wherever possible, even if it means that various equations of the model may be estimated from a different number of sample observations. Similarly, if information about some (or all) of the coefficients of a relationship is available from sample surveys, it should be used together with the time-series observations that provide the basis for estimation.

Validation of the Model

Validation of a model means checking its performance against theoretical expectations and against statistical observations. With respect to the former, the CANDIDE model (or its abbreviated version) should be checked for internal stability. Since the Canadian economy is clearly not internally explosive, it would be disturbing to find otherwise.[27/]

27/ It is interesting to note that the Klein-Goldberger model of the U.S. economy was preceded by a considerably more elegant and theoretically sophisticated model of about equal size, Klein Model III (L. R. Klein, Economic Fluctuations in the United States, 1921-1941, Wiley, 1950). I was puzzled by the fact that this model was replaced by the much more 'ad hoc' K-G model until I found out that Klein Model III is internally explosive.

The check can be carried out by letting the model run through many repetitions with the exogenous variables being held constant. As for statistical observations, it is strongly recommended that the forecasts of the model (with correct values of the exogenous variables) be checked against actual observations as they become available. Ideally, one would like to have "tolerance limits" calculated for each predicted endogenous variable, very much the same as the quality control bands that are used to test the performance of machines. Continuous exposure of the model to reality is the only way of detecting its fundamental weaknesses, if they exist.