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ABSTRACT

This paper tests New Classical and Keynesian explanations of output determination within an encompassing "factor utilization" model wherein the output decision by producers is modelled as the choice of a utilization rate for employed factors. In this encompassing model, the ratio of actual to normal output (with the latter defined by a nested CES vintage production function with capital, energy and employment as factor inputs) is explained by unexpected sales (a Keynesian element), abnormal profitability (one component of which is the Lucas "price surprise" effect), and abnormal inventories.

Results using Canadian data show that the Keynesian and New Classical elements contribute explanatory power, as does the production-function-based measure of normal output, while each of these partial models is strongly rejected in favour of the encompassing model. The highly structured factor utilization model is also seen to fit better than an unstructured VAR model.

U.S. data confirm the results, and show that there are significant effects from abnormal demand, profitability and inventory levels even if the labour and capital components of normal output are defined using hours and utilized capital rather than employment and the capital stock. The results are also confirmed using alternative output (and hence input) concepts, using a translog function instead of a CES function to define normal output, and using data for several other major industrial countries.

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Supply-Side Macroeconomics

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The macroeconomics of the supply side, after years of neglect, has passed from obscurity to fame without very much by way of econometric comparison of alternative models. Thus the time seems ripe for an empirical stocktaking based on a comparison of some of the various models that have been used to explain cyclical and longer-term changes in aggregate output.

To make this ambitious task more manageable, I shall limit my consideration to theories and models that have been used to determine directly the level or changes in real aggregate output, thus bypassing many legitimate supply-side issues -- for instance those dealing with factor supply and the determinants of unemployment and inflation. My excuse for this is the hope that I shall thereby be able to assess and compare some diverse approaches that are seldom discussed together, let alone comparably tested with the same body of data.

Setting the Stage

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* Presidential address, annual meeting of the Canadian Economics Association/ l'Association canadienne d'Economique, Winnipeg, May 30, 1986. I am grateful for the valuable and extensive research collaboration of Alan Chung, Tim Fisher, Shelley Phipps, Perry Sadorsky, Peter Thurlow, and especially Robert York. In preparing and revising the address, I have had helpful suggestions from them, and from Pierre Fortin, Marc Gaudry, Andre Plourde, Doug Purvis, Jean Waelbroeck, Tom Wilson, and especially Michael Parkin. In the development of the factor utilization model, much has been due to the continuing research collaboration of Mary MacGregor, Robert McRae, and Andre Plourde. This research has been made possible by many years of financial support from the Social Sciences and Humanities Research Council of Canada.

The three classes of supply models I shall consider, and attempt to generalize, include:

1. New Classical models. Two sorts will be considered. Results are first presented for the Lucas (1973) supply function that has become an important part of many papers and models in the New Classical stream. This equation, in its structural form, explains non-trend changes in output in terms of deviations in the price level from its expected value. Then I shall consider other New Classical models that subsume the Lucas supply function in reduced-form equations that explain departures of output from its trend in terms of unanticipated changes in monetary and other policies (e.g., Barro 1978, Darby et al. 1983);
2. Demand-driven Keynesian models of output determination. In these models, output is determined primarily by changes in final demand, taking account of inventory accumulation and changing imports, but with no direct effect from factor supplies or profitability; and
3. Unstructured Vector Autoregressive (VAR) equation systems. In recent years, there has been criticism of all structural models, especially by Sims (1980,1982), on the grounds that their imposed restrictions are inconsistent with the data. This has led Sims and others to develop alternative equation systems that involve flexible lag structures, no exclusion restrictions, and no imposed functional form beyond the assumption of log-linear relationships among the jointly dependent variables. These models provide a useful benchmark

against which to test more structured models. In choosing variables to be included in the VAR model, we have closely followed Doan, Litterman and Sims (1984).

The main empirical assessments will make use of annual data for Canada covering the period 1954-1982, although some reference will also be made to results from similar tests based on data from the United States and other large OECD economies.

Before proceeding to a separate discussion of each of the model types, I shall present a more general supply model, which I shall describe as the 'factor utilization model'. Within this more general model, the Keynesian and New Classical models can be seen as nested special cases, each emphasizing different, and potentially important, aspects of the more general model that encompasses them. There will follow one section devoted to each model type, a section of econometric tests of the specification and stability of the alternative models, and a short concluding section.

The Factor Utilization Model

The rationale for the factor utilization model lies in a two-stage optimizing procedure by firms. The first stage models the forward-looking process whereby firms make sets of interrelated plans for the levels and prices of output, and the levels of factor inputs, to maximize the present value, in risk-adjusted terms, of future quasi-rents. In doing this, they are assumed to face a less than perfectly elastic demand for output, to form expectations about the relative costs of factor inputs, and to choose factor input combinations to minimize the costs of producing the desired levels of output at normal intensities of factor use. An explicit production function is used to relate planned output to factor inputs. In such a context, the long-run production function can best be thought of as determining a synthetic measure of output: normal output, or the amount that would be produced if all employed factors were used at normal or average rates. Normal output (QSV) is determined by:

$$QSV = [\mu(\Pi NNE)^{(\tau-1)/\tau} + \nu KEV^{(\tau-1)/\tau}]^{\tau/(\tau-1)} \qquad (1)$$

where μ and ν are scale/distribution parameters, τ is the elasticity of substitution between the two composite inputs, which are efficiency units of labour (ΠNNE) and a vintage bundle of capital and energy (KEV).[1]

In the second stage of the optimizing process, firms choose their preferred short-term combinations of utilization rates, inventory changes, and prices to respond to final demand conditions, cost conditions, and inventory levels that differ from those anticipated at the time the commitments were made to build or hire the currently employed stocks of capital (with their associated energy use) and labour. In reality, of course,

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[1] The nature and estimation of the two-level CES production structure described in more detail in Helliwell and Chung (1987). In a later section of the paper, results will be presented based on alternative functional forms, alternative measures of output, and using data from different countries, to test the extent to which the results are likely to be sensitive to the special assumptions being used in the earlier sections. The results are found to be robust to changes in the choice of functional form, output concept, and factor inputs used in the definition of normal output.

the two stages of the optimization process are interdependent, as capital, energy, and employment are all quasi-fixed rather than truly fixed factors, so that any unexpected or temporary changes in demand or cost conditions will lead to changes in the measured factor inputs as well as in their rates of utilization.

Thus the measure of normal output, which is a production-function-based combination of the measured factor inputs, must be treated as endogenous rather than predetermined in the estimation process. Indeed, there are many who would argue that the production function using measured factor inputs should, if it is appropriately specified, capture all of the systematic variation of output[2], with all remaining variance of output being due to errors of measurement, functional form or aggregation, or to random disturbances of production. The factor utilization model provides a straightforward test of this hypothesis, since if the hypothesis is true the unexpected demand, profitability and inventory variables will have no power to explain the differences between actual and normal output.[3]

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[2] For example, both Keynes and many of the New Classical critics of Keynesian models have assumed that an aggregate production function exists and determines the actual level of output produced. In Keynes' own work, labour was treated as a variable factor of production. New Classical models either make this same assumption, or suppose some costs of adjustment for labour and other factor inputs, but in either case restrain output to that determined by an implicit underlying production function. The role of production functions in models of aggregate output is treated in more detail in the supporting paper.

[3] Tests to be reported later in this paper show that all three of these variables have systematic effects on output beyond those captured by the production function based on measured factor inputs at normal rates of utilization. This is true even if the labour input is measured in hours worked rather than employment, and if some similar adjustment is made to attempt to capture variations in the rate of use of the capital stock.

The lack of independent measures of factor-specific utilization rates, especially for capital, is a primary reason for according separate treatment to utilization as a determinant of production. A related issue is the lack of any explicit measures of the costs of abnormal utilization rates. Thus it is impossible to treat general factor utilization as a factor of production on all fours with the extensive factors of production (labour, capital, and energy). By definition, total costs of production are unchanged with changes in the utilization rate as defined in this paper, so that per-unit *measured* costs of production must fall as the utilization rate rises. In the real world, of course, abnormally high utilization rates sustained for an extended period of time would lead to fatigue, equipment breakdown due to inadequate maintenance and repair, and higher wages due to the implicit redefinition of labour contracts. In a more subtle way, abnormally high utilization rates bleed away resources from the training, planning and innovation activities of firms, and hence hold back the overall rate of reduction in average costs. Lower utilization rates impose the familiar costs of idle capacity, although the preceding discussion is intended to show that much of what appears to be idle capacity facilitates many types of time-shiftable maintenance, repair, and investment activity.[4]

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[4] There is reason to suspect that abormally high and abnormally low utilization rates may not have symmetric effects on the present value of total costs, especially if they are large or long-sustained. The symmetric functional form adopted for the utilization rate decision may therefore be in error. Tests for non-normality of errors are reported in Helliwell and Chung (1987); they show some, but not a significant amount, of the negative skewness that might be expected.

Since neither the rate nor the costs of abnormal factor utilization are subject to direct measurement, a feasible modelling strategy is to measure the rate of utilization indirectly, as the ratio of actual output to normal output, where the latter is what would be forthcoming from the production function at normal utilization rates. This implicitly splits the production decision into two components: a forward-looking decision process to jointly choose the planned level of output and the associated levels of factor inputs, and the short-term decision about the optimal intensity of factor use. One advantage of this treatment is that all of the dynamic complexities of the forward-looking part of the optimization process can be subsumed in the measures of normal output, thus increasing the simplicity and precision of the modelling of the short-term output decision. By the same token, of course, the resulting equation for output is not sufficient to answer all of the empirical and policy questions that are commonly thought of as supply-side issues. I shall return to this matter in the concluding section.

What are the appropriate determinants of the short-term utilization decision? First, it is necessary to assume something about the form of the implicit costs that must be borne if factor utilization differs from its normal values. The factor utilization model, as specified in this paper, is based on the assumption that average costs are minimized at average historical utilization rates, and that there are symmetric increases in the present value of costs when utilization rates are either above or below their normal values. Why then do firms ever choose to adopt utilization rates different from their normal values? The answer is that actual cost or demand conditions frequently differ from those that were anticipated when the factor combinations were assembled. The alternative ways of dealing with unanticipated changes in cost or demand conditions include changes in production, changes in inventories (or order backlogs), changes in imports, and changes in prices.

Changes in production can be achieved through changes in either the quantities or the rates of utilization of employed factors. Typically it is costly, in terms of the present value of profits, to concentrate adjustment entirely in any one of the alternative forms. For given imports and final sales, the production decision and the inventory decision are in effect the same decision, as any additional output is added to inventories. If there is an increase in final sales, it will in general lead to an increase in the utilization rate and a reduction in inventories. Abnormally low profitability, as represented by high average costs relative to output price, can be taken as a proxy for the marginal profitability of current production for future sale. Finally, the difference between actual and target inventory stocks, which provides a cumulative measure of the extent to which buffering movements of inventories have been used to meet past changes in final sales, also affects the utilization decision, under the conventional assumption that average unit costs rise with inventory shortfalls or excesses. Thus, under the most usual assumptions about the costs of abnormal utilization rates and abnormal inventories, the derived model of optimum factor utilization will depend on final sales, profitability, and inventories. Each variable is measured relative to its normal or target value, with the utilization rate constrained to take its own normal value when sales, profitability and inventory stocks are all at their normal values. Normal output is scaled so that the normal value of the utilization rate is 1.0 by construction. The form for estimation is therefore:

$$Q/QSV = SS^{\beta_1} KGP^{\beta_2} CQ^{\beta_3} v \qquad (2)$$

where SS is the ratio of actual to normal final sales, with both terms expressed as proportions of normal output:

$$SS = (SALES/QSV)/<SALES/QSV>$$ [5]

and KGP is the ratio of desired to lagged actual inventory stocks, with desired stocks expressed as a constant proportion of normal output[6]:

$$KGP = QSV(<KINV(t-1)/QSV>)/KINV(t-1)$$

and CQ, an inverse measure of profitability, is defined as

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[5] <x> denotes the sample average of x.

[6] Thus QSV appears in the denominator of the dependent variable and two of the independent variables. Can this give rise to an upward bias in the estimates of β_1 or β_2? Equation (2) is estimated with lnQ as the dependent variable, and the net coefficient on ln(QSV) constrained to be $1.0-\beta_1-\beta_2$. Unless this constraint is binding, the appearance of QSV in the denominators of the sales and inventory terms cannot be influencing the values taken by β_1 and β_2. F statistics reported in the tables show that constraining the directly estimated coefficient on lnQSV to be 1.0, and therefore the net coefficient to be $1.0-\beta_1-\beta_2$, is easily accepted by the data, so that there is no risk of bias in the estimates of β_1 and β_2.

current unit costs relative to the output price. The theoretically expected values of the parameters are therefore: $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 < 0$. The error term, v, is assumed to be log-normally and independently identically distributed.

Although this is a highly constrained model of production, with only three coefficients subject to unrestricted estimation, it will next be shown that it needs only slight generalization to include Keynesian demand-driven models (which emphasize the roles of final sales and inventory disequilibrium) and Lucas supply functions (based on one component of the profitability variable) as special cases.

There is an econometric complication posed by the fact that although the New Classical and Keynesian models can be treated as special cases of factor utilization models, the version of the factor utilization model normally estimated imposes some restrictions that are not imposed in the Keynesian and New Classical models. To deal with this, we shall develop encompassing[7] models in each section that contain all of the models assessed in that section as special cases. F statistics can then be used to provide approximate tests of the plausibility of each model's restrictions. In a later section of the paper, all of the models tested in earlier sections, including the most highly restricted form of the factor utilization model, will be tested against a general encompassing model that includes each section's encompassing model, and hence each of the structural

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[7] For more on the use of encompassing models as means of comparing otherwise non-nested hypotheses, see Hendry and Richard (1982), Mizon (1984), and Mizon and Richard (1986).

models, as special cases.

Generalizing New Classical Supply Functions

Many of the most influential recent papers in macroeconomics embody the hypotheses of rational expectations and market-clearing equilibrium, and the implication that "... private agents' mistakes in forming expectations are the *sole* mechanism through which variations in aggregate demand provide impulses for the business cycle" (Lucas and Sargent 1981, p. xxv, emphasis in original).

The supply function proposed by Robert Lucas (1973) has played a key role in the subsequent development of theoretical and applied macroeconomics. This section considers direct estimates of the Lucas supply function and then the parallel applications by Barro (1978) and Darby et al. (1983) of reduced-form output equations which test the effects of anticipated and unanticipated changes in monetary policy.

The Lucas supply function, like much other work in the rational expectations tradition following Muth (1961), explains deviations of output from its normal value in terms of unanticipated differences between actual and expected prices. Although only relative prices and not absolute price changes should influence real variables in New Classical models, Lucas argues that producers have difficulty in distinguishing absolute and relative price changes. In these circumstances it is rational for them to treat changes in the absolute price level as containing some element of relative price increase. Thus when prices rise relative to prior expectations, producers temporarily raise their output, with the effect subsequently diminishing as the gap between actual and expected prices disappears. In applying the model, we have followed the U.S. applications by Mishkin (1982a;1982b) and the Canadian application by Darrat (1985) in defining the expected price level as the predicted value from a multivariate regression on previous values of a number of key macroeconomic variables.[8] Since the current price level is an endogenous variable, especially so in the context of a flexible-price equilibrium model of the sort hypothesized by Lucas and Friedman, we estimate the supply equation (shown as model 1.1 in Table 1) by means of Instrumental Variables[9] with the list of instruments for the price level including all of the variables used in the regression for the expected price plus the current values of the exogenous variables (which are mostly foreign variables, as shown in the Glossary) of the macroeconomic system in which the supply model is imbedded.

Our results are more like those of Mishkin (1982b) than those of Darrat (1985), since we show no significant output effect from unanticipated inflation. Since our price variable is the expected price divided by the actual price, it should, and

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[8] The exact list of variables is shown in the Glossary. Following a suggestion by Michael Parkin, the results reported in Table 1 are based on an expected price equation whose information set includes all past endogenous variables plus predicted values (based on univariate time-series models) of current exogenous variables. Alternative specifications reported in the companion paper show that the results are similar if the information set is reduced to include only lagged endogenous variables, or based on a univariate time-series model for the price level itself.

[9] Mishkin and Darrat both use ordinary least squares rather than simultaneous estimation. This is more defensible in their case than in ours, as they use quarterly rather than annual data, and use so many periods of lagged data that the role of current prices is correspondingly much reduced.

does, take a negative sign in the Lucas supply equation[10].

Our equation 1.1, like that of Lucas (1973), uses a time trend and lagged output to capture the joint effects of normal output and persistent cyclical influences:

$$Q = A_0 e^{a_0 QT} Q_{-1}^{a_1} (Pe/P)^{a_2} \epsilon_1 \qquad (3)$$

where QT is a linear time trend and A_0 is a constant. Since the time trend and lagged output represent simplifications rather than desired features of the Lucas supply function, the natural first step in generalizing the model is to substitute a production-function-based level of normal output for the time trend and the lagged level of output[11]:

$$Q/QSV = A_0 (Pe/P)^{a_2} \epsilon_2 \qquad (4)$$

As shown in equation 1.2, this substantially improves the fit of the model, but does not have much effect on the role of unanticipated inflation. Mishkin (1982b, p. 797) suggests that the poor performance of the Lucas supply equation in his tests may be due to the inclusion of data from the stagflationary

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[10] To help explain the apparent discrepancy between our results and those of Darrat, there is a table in the supporting paper showing a series of regressions altering one by one the differences in sample period, data definition, degree of time aggregation, and estimation method that distinguish our study from his.

[11] Those who treat the production function as a continuously binding structural relation would consider the step more natural if QSV were defined to include normal or potential employment rather than actual employment. Using a version of QSV smoothed in such a manner does not alter the role of the expected price variable, although it does increase somewhat the impact of the subsequent inclusion of the demand and profitability variables.

episodes of the 1970s, during which producers were confronted with unexpectedly high prices and unexpectedly low demand.

The model can be generalized in two ways to help remedy the inability of the unexpected price variable to capture the combined effects of unanticipated higher prices, higher costs and lower demand in the 1970s. The first addition is a variable (lnSS) representing abnormal sales, where SS is the level of final sales divided by normal output (QSV), adjusted so that the ratio of sales to scaled normal output equals 1.0 on average over the 29-year sample period. Normal output, when scaled to take account of the average size of imports and inventory investment, is taken to be a good measure of normal anticipated sales, since the past factor demand decisions (which are embodied in current employment and capital stock, and hence in normal output) were presumably based on the then prevalent expectations for sales levels now. When actual and normal sales are equal, the log of their ratio equals zero, and the term drops out of the equation, leaving output equal to normal output unless actual price differs from expected price:

$$Q/QSV = A_0(Pe/P)^{\alpha_2} SS^{\beta_1} \epsilon_3 \qquad (5)$$

As shown in equation 1.3, adding the unexpected sales variable substantially improves the fit of the model, although the coefficient on the expected price variable remains insignificant.

The next adjustment recognizes that there can be unexpected changes in costs as well as in prices:

$$Q/QSV = A_0(Pe/P)^{a_2}(C/Ce)^{a_3}SS^{\beta_1}\epsilon_4 \qquad (6)$$

Adding the log of the ratio of current to expected unit costs[12], further improves the fit of the equation, and raises also the effect of the price variable, as shown in equation 1.4.

Since it may take a long time to bring the stocks of capital and labour into line with the desired level and structure of production, there is also reason to expect that abnormally low profitability (as measured by the ratio of normal costs to expected price) may have a continuing effect on output (relative to normal) as long as it differs from its normal value of 1.0:

$$Q/QSV = A_0(Pe/P)^{a_2}(C/Ce)^{a_3}(Ce/Pe)^{a_4}SS^{\beta_1}\epsilon_5 \qquad (7)$$

This further generalization of the Lucas supply model, still in the general spirit of the model (since output will be at its normal value when profitability is normal), is shown in equation 1.5 to add materially to the explanatory power of the model, and to increase the coefficient on the expected price variable.

A final generalization of the model is to add the log of the ratio of the desired to the target level of inventories, KGP, as defined below equation (2). This addition improves the logic of the short-term production decision, by acknowledging limits to

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[12] The definition of expected costs makes use of the structure of the production model rather than a regression. Expected or normal costs are defined by the cost function dual to the nested three-factor CES production function used to define normal output. It represents what unit costs will be, given current relative prices for capital, energy, efficiency units of labour, after factor proportions have been adjusted so as to minimize costs.

the use of inventories as buffer stocks. Some buffering role for inventories is implied by the fact that production does not rise commensurately with abnormal sales. The inventory term also is in the spirit of the Lucas equilibrium model in that production equals normal output when inventories are at their target values (as long as profitability and sales are also at their normal values). The form of the equation is therefore:

$$Q/QSV = A_0(Pe/P)^{\alpha_2}(C/Ce)^{\alpha_3}(Ce/Pe)^{\alpha_4}SS^{\beta_1}KGP^{\beta_2}\epsilon_6 \qquad (8)$$

Adding the inventory variable, as shown in equation 1.6, also improves the performance of the unanticipated price variable, so that it now passes conventional tests of statistical significance.

Equation 1.6 is the most general specification tested in Table 1. The final equation of this series tests whether the three relative price and cost variables can be combined to form a single variable:

$$Q/QSV = SS^{\beta_1}KGP^{\beta_2}CQ^{\beta_3}\epsilon_7 \qquad (9)$$

where CQ = (Pe/P)(C/Ce)(Ce/Pe) = C/P, or current unit costs relative to the output price. In addition, the constant term A in equation (8) is constrained to be equal to 1.0 in equation (9), to ensure that factor utilization equals 1.0 when sales, inventories and profitability are at their normal values. These constraints are accepted easily, as shown by the F statistic below equation 1.7.[13] By contrast, if we look back at the F statistics on the constraints imposed in equations 1.1 through 1.5, and especially in equations 1.1 through 1.3, it is apparent that the generalizations are virtually demanded by the data. In addition, as we have seen, they increase the weight of evidence in favour of the Lucas hypothesis that unexpected increases in prices lead to temporary increases in output. As we shall see later, however, this does not imply anything about the likely effectiveness or ineffectiveness of policy, since that will depend in the longer term on the extent to which the policies influence the desired future level of output, and hence factor demands and the normal level of output. Additional econometric tests of the equations reported in Table 1 are shown in Table 5. They will be discussed later, when comparisons are made with the other models to be reported in Tables 2 through 4.

Barro's papers (1977;1978) provide an alternative test of New Classical assumptions by means of reduced-form equations that explain real cyclical variables in terms only of unanticipated changes in the money supply. To make this operational, it is also

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[13] The constraints do, however, lower the DW statistic to the point where positive autocorrelation of residuals is revealed. Given the likelihood that the errors of aggregation and the other approximations involved in the aggregate production function are themselves autocorrelated, this result is not surprising. It is necessary to ensure, however, that the autocorrelation is not evidence of deeper problems of specification. The broadest assurance against this risk is provided by the differencing test results reported in the specification tests section of the paper. Note also that the equation shows no need for the lagged dependent variable, since the lagged dependent variable is one of the variables whose exclusion is tested by the F statistic below equation 1.7. Tests reported in the companion paper also show that the parameter estimates are not affected by estimation in first difference form, and the same is true if Cochrane-Orcutt transformations are used.

necessary to have a model for the formation of expectations about the level of the money supply. This is the same issue that arises for the direct estimation of the Lucas supply function, and is usually handled in the same way -by an equation that explains the expectation for the current period in terms set of relevant information variables known in the previous period. In equation 2.1, we have attempted to replicate as closely as possible the methods used by Barro (1978) in his study of the effects of unanticipated money on the level of output in the United States. Equation 2.1 contains a time trend and the previous year's values of the difference between actual and anticipated money growth, and of anticipated money growth. Unanticipated money growth, both current and lagged, has significant positive effects on real output. There is also a significant positive effect from lagged anticipated money growth, although under New Classical assumptions only unanticipated money growth is supposed to influence real income. Adding the previous year's value of transitory income, as suggested by Darby et al (1983) and shown in equation 2.2, increases the explanatory power of the equation and reduces the effect of anticipated money growth.

In the remaining columns of Table 2, we show the effects of sequentially adding the normal output, abnormal sales, abnormal profitability, and abnormal inventory variables of the factor utilization model of supply. Using normal output instead of a time trend, and adding the variables for abnormal sales, profits, and inventories lowers the size of the coefficients on the money variables, so that in equation 2.6 they are small and insignificant. Thus equation 2.7, which is equation 2.6 restricted to exclude the Barro and Darby variables, fits the data as well as equation 2.6.

Our results do not imply that monetary policy, whether anticipated or not, has no effect on aggregate output. The results do suggest, however, that the output effects of monetary policy are best represented indirectly: in the longer term through changes in factor demands and hence through changes in the normal level of output, and in the shorter term by changes in abnormal sales, profitability, and inventories.

Adding Supply Effects to a Demand-Driven Keynesian System

In this section, we start with a demand-side explanation of output, and then gradually introduce key elements of supply-side modelling until we reach the same factor utilization model in which the Lucas supply function was nested.

It is not immediately clear how to set up a Keynesian equation for the determination of the level of aggregate output. In most Keynesian models, real GNP is the sum of separately determined equations for consumption, fixed investment, export, and inventory investment, minus imports:

$$GNP = C + I + G + IINV + X - M \tag{10}$$

To obtain a stochastic form for such a model, it is necessary to substitute into the GNP identity one or more of the key behavioural equations. To preserve the demand-oriented spirit, we have chosen to treat real final sales (SALES = C+I+G+X) as determined elsewhere in the system[14] and to obtain the output equation by substituting the inventory investment and import equations into the GNP identity. The logic of this is that inventory changes, output changes, and changes in imports represent the three alternative ways (apart from price changes) to accommodate changes in final demand conditions. The combination of the inventory and import equations thus implicitly incorporates the Keynesian model of the producers' output decision. The usual inventory demand equation in a Keynesian macro model relates the change in inventories to sales, expected sales, and the gap between actual and target inventories. This usually involves sales, the change in sales,[15] and the lagged inventory stock in the estimation equation:

$$IINV = f(\overset{+}{SALES}, \overset{-}{KINV}(t-1)) \qquad (11)$$

Real imports depend, in the main, on final sales and the relative prices of imports and domestic output:

$$M = g(\overset{-}{RELP}, \overset{+}{SALES}) \qquad (12)$$

where RELP is the ratio of the import to output price index. Using a log-linear form, which can only be an approximation when log-linear behavioural equations are combined with the linear identity for real GNP,[16] we derive the equation for real output

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[14] In estimation, final sales therefore has the status of an endogenous variable in the instrumental variables regression.
[15] The change in sales, reflecting the generally offsetting effects of sales expectations and inventory buffering, proved insignificant and is excluded from our reported equations.
[16]In our application, there is the additional approximation posed

as a function of real final sales, the lagged stock of inventories, and the price of imports relative to domestic output:

$$Q = A_0 SALES^{\gamma_1} KINV(t-1)^{\gamma_2} RELP^{\gamma_3} u \qquad (13)$$

where u is a log-normally distributed error term, and where the theoretically expected values of the parameters are: $\gamma_1 > 0$, $\gamma_2 < 0$, $\gamma_3 > 0$. Equation 3.1, the fitted form of (13), has significant coefficients with the expected signs. The results show that production rises slightly more than proportionately with final sales, much in keeping with the demand-oriented models on which the equation is based. By combining inventory and import responses, the equation does not permit separate identification of the buffer role for inventories. If imports also rose proportionately with unexpected sales (other evidence suggests that they rise less than proportionately), then the 1.07 coefficient on the final sales variable would imply no buffering role for inventories.

Before jumping to any such conclusion, consider the effect of adding some supply structure to the system. As a first step, equation 3.2 adds the relative profitability variable lnCQ, with little effect. But when output is linked more closely to the supply side, as in equation 3.3, the situation changes substantially. To move from equation 3.2 to 3.3, the normal

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[16](cont'd) by the fact that the output concept is based on real domestic product at factor cost, while final sales are at market prices. The results reported in Table 7, based on GDP at market prices, show that this approximation does not influence the results reported in Table 3.

supply variable lnQSV is added, with coefficient constrained to unity, and the final sales and inventory variables both are redefined to make them consistent with the factor utilization model, with normal sales and the inventory target both being made proportional to normal output. The net effect of these changes is simply to add one more variable and one more constraint to the demand-driven equation 3.2. This introduction of the supply structure increases the goodness of fit of the model, cuts the sales coefficient in half, and establishes an important role for the profitability variable. This suggests that the very high coefficient on sales in the demand-driven equation 3.1 is due to the exclusion of the supply-oriented measure of normal output, thus putting an upward bias on the sales coefficient, since the sales and normal output variables are positively correlated.

It can be seen that equation 3.3 encompasses the Keynesian demand-driven model (since equation 3.1 is equal to 3.3 with the coefficients on the normal output and profitability variables constrained to equal zero) and the factor utilization model, since equation 3.3 is equation 1.7 with the addition of the relative price variable. The F value of 18.2 under equation 3.1 shows that the Keynesian model can be rejected relative to the encompassing model, while equation 3.4, which restricts the import price variable out of the encompassing model, and thus reproduces equation 1.7, shows that the factor utilization model has all of the explanatory power of the encompassing model.

It is tempting to consider the demand-driven Keynesian model of equation 3.1 and the Lucas supply function of equation 1.1 as competitors, and then to make statistical comparisons between them in terms of non-nested hypothesis tests. However, the advantage of the tests that we have constructed to test each of the models separately against the factor utilization model of short-term supply is that we can now see that both of the simple models are heavily rejected by the more general models that were constructed to encompass them separately with the factor utilization model.

In a subsequent section I shall report the results of the tests of all of the structural models assessed in the context of a single equation encompassing them all. In the meantime, the current results show some of the likely ways in which the Lucas supply function and the Keynesian demand-driven models of output can be seen to represent different aspects of a more general model of aggregate supply. Attempts to fit the partial models were seen to produce misleading and imprecise estimates of the partial effects, as well as to give less accurate and robust explanations of the level of aggregate output.

Of course, it is still possible that there is a yet more general model to be found that would lead to the rejection of the factor utilization model tested in the preceding sections.

Testing Structural Models against Theory-Free Alternatives

One convenient way of assessing the likelihood of more plausible models is to test the credibility of the restrictions imposed by the structural models relative to some unrestricted reduced form.

What if a structural model's restrictions are heavily rejected by the sample data? We can then conclude either that there must be another structural model with more appropriate, or fewer, restrictions, or that economic reality is too complex and varying to be usefully depicted by structural models of the sort used in macroeconomics. Comparative tests of the factor utilization model and the structure-free VAR model proposed by Sims are shown in Table 4. The VAR is shown as equation 4.1, and the factor utilization model as equation 4.3, with equation 4.2 being the synthetic equation that encompasses them both. The VAR allows for second-order autoregressive errors and uses instrumental variables estimation to permit current values of right-hand-side endogenous variables to be included in the equation. The F statistics and the standard errors both indicate that the structural model is to be preferred to the VAR, while the F statistics also suggest that the structural model and the unrestricted reduced form each contain some information that is lacking in the other. How can a structural model with so many theoretical restrictions, all of which involve errors of aggregation and approximation, possibly fit better than a reduced form without restrictions? The reason is that the VAR itself imposes restrictions, on the functional form and the number and nature of included variables, that introduce error. In addition, the lack of parsimony of the VAR means that the additional variables, while always adding to the uncorrected coefficient of determination, may well reduce the explanatory power of the equation after correction is made for the loss of degrees of freedom. This explains why the restrictions of the structural model are more easily accepted than those of the VAR, and why the standard error of estimate is lower for the structural model.

Specification Tests of Alternative Models

In the preceding sections, each of the separate model types (Lucas, Barro, Keynesian, VAR) has been tested against an encompassing model that includes itself and the factor utilization model as special cases. In each instance, except for the VAR, the factor utilization model involved only minor restrictions on the encompassing model, and these restrictions were easily accepted. In this section we draw together the basic equations for each of the model types, test them against a more comprehensive model that encompasses all of the structural models as special cases, and subject them to further stability and specification tests.

These results are shown in Table 5. The first column shows the standard errors, which are the same as those reported in the earlier tables in which each equation was first presented. The second column shows the Chow tests for stability, with the sample split after 1967 (results shown in the first row) and after 1972 (shown in the second row). The third column shows the results for the differencing test, using the form proposed by Davidson, Godfrey and MacKinnon.[17] In the fourth column, we show the F test on the restrictions required to restrict each of the structural models against the model that encompasses them all. These

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[17] As shown in Davidson, Godfrey and MacKinnon (1985), this is computed as a test for omitted variables with close parallels, also noted by Nakamura and Nakamura (1981), to the Durbin, Hausman (1978), and Wu specification tests. We use IV estimation, since many of the right-hand-side variables, as well as their differences, are endogenous variables.

F-statistics are all smaller than in the preceding tables, since the jointly encompassing model is less parsimonious than the earlier ones, and the degrees of freedom are correspondingly reduced. However, the Lucas, Barro and Darby equations are all still rejected at the 99% level, and the Keynesian model at the 95% level, while the factor utilization model passes easily.

The results of the tests against the encompassing model are mirrored by those of the Chow and differencing tests, which the factor utilization model passes easily. The Barro equation also passes these tests, but remains heavily rejected by the F test against the encompassing model, and is much inferior in terms of standard error.

Since all of the above evidence appears very strong in terms of its support for the factor utilization model relative to both New Classical and Keynesian models of output determination, further testing seems to be indicated. If a model is to be of general importance, and not just applicable to a particular functional form relating to a certain period of one country's history, it should be robust to changes in functional form, sample period, and country. The Chow tests in Table 5 show that the choice of data period does not seem important, and especially that there appears to be no break in structure before and after 1973. The evidence in Tables 6, 7 and 8, and the more extensive tests reported in the supporting paper, address the questions of functional form, of alternative output concepts, and also report the results of applying the same models to data from the United States. In each table, each of the basic structural models is fitted, and the results tested against the jointly encompassing model, and also against the more restricted model encompassing each structural model separately with the factor utilization model.

Table 6 shows the effects of using a translog production function, instead of the nested CES vintage production function, to define normal output. These results, which strongly support those of the earlier tables, are very important, because they provide the necessary evidence that the significant explanatory power of the factor utilization model is not simply due to the use of an insufficiently flexible functional form for the underlying production function. The results from the translog and other flexible functional forms[18] all show that there is systematic variation in output beyond that explained by the production function based on measured factor inputs[19], and that the factor utilization model dominates the New Classical and Keynesian models in explaining that variation.

All of the analysis so far has made use of a three-factor production function, and a matching concept of the output of the energy-using sector, equal to GDP plus net energy imports. Since

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[18] As developed by Tim Fisher and Alan Chung. The translog production function fits better than the other flexible functional forms, whether the comparison is made with or without the inclusion of the abnormal sales, profitability and inventory variables.

[19] This is easy to test, since the hypothesis that the economy is always on its aggregate production function is nested within the factor utilization model. The test is done by restricting the coefficients on the factor utilization variables to be equal to zero. The F value for these restrictions is 78.2 for the translog, compared to 87.7 for the nested CES function. In both cases this implies strong rejection of the production function against the more general model.

most other aggregate work has made use of GDP, and hence of a two-factor production function explaining value-added, Table 7 repeats all of the model tests and comparisons using real GDP as the output variable and total employment and capital as the factors of production.[20] Once again, the ranking of the models is the same as before, although now there is some evidence that the data reject the imposed restrictions of the two-factor model for normal output. This offers further evidence in favour of the three-factor model of production analyzed previously.

Finally, Table 8 tests all of the same models using United States data. These tests are of special importance, because the alternative structural models have been developed in the United States, and were designed to explain macroeconomic events there. Since the Lucas, Barro and Darby equations were designed to explain United States experience, while the factor utilization model was developed and tested in Canada, it would not be surprising if some of the rankings in earlier section were reversed. However, Table 8 shows that the rankings remain as they were previously, and that the United States data are even stronger in their rejection of the New Classical and Keynesian restrictions on the encompassing model, while the restrictions of the factor utilization model are easily accepted.

Another important feature of the United States data is that they provide a chance to obtain and apply independent measures of the rates of utilization of labour and capital, and hence to see whether the apparent success of the factor utilization model is

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[20] The GDP version of the model is based on research by Peter Thurlow.

really as a backdoor way of explaining hours worked for employees and equipment. We have fitted[21] the model to United States annual data in two ways, once by using employees and capital as the inputs on labour and capital (which is what was done with the Canadian data) and again by using total hours worked (employees times average hours) as the labour input, and utilized capital (capital stock times an index of actual relative to average hours worked by capital) as the capital input. The results from the two sets of tests are identical in their rankings of the alternative models. The results using total hours worked and utilized capital are reported in Table 8, while the supporting paper gives both sets for comparison. Since the results are so similar, and do not depend on whether employment and capital are separately adjusted[22] for changes in their rates of utilization, they provide support for continuing to apply the model using employment and the capital stock as the measured inputs of labour and capital.

The factor utilization model has also been applied on a comparable basis to all seven of the major OECD countries, as reported in Helliwell, Sturm, Jarrett, and Salou (1986). For three of the European countries, and for Japan, the ranking of the alternative models is different from the Canadian and U.S.

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[21] These results are part of joint research with Shelley Phipps, with the objective of testing alternative models for jointly explaining short-term output changes and longer-term productivity changes in the United States context. The capital utilization data are from Shapiro(1985).

[22] The F value on the restrictions required to determine output solely from the production function is 217.1 if employees and capital are used, and 123.0 if total hours and utilized capital are used instead.

rankings reported here, as the Keynesian model is sometimes preferred to the factor utilization model, with both models strongly preferred to the Lucas, Barro, and Darby equations.[23]

Conclusion

The main conclusion from the tests reported in this paper is that it is possible to develop structural models for output determination that include New Classical and Keynesian models as special cases, and which easily dominate them on statistical grounds. Perhaps more important, the results show that such a model can be based on an explicit production function, and hence provide a consistent supply-based explanation of the evolution of aggregate output over the longer run. Consistent linkage of short-run and longer-run explanations of aggregate supply was shown to involve both Keynesian and neoclassical elements in the short run, and to support the use of an aggregate production function for the determination of normal output.

How do the models and results relate to what is popularly known as 'supply-side' economics? Feldstein (1986) has recently made a distinction between the 'old' supply-side economics, in which the evolution of output depends on the accumulation of labour, capital, and know-how, and the 'new' supply-side

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[23] These preliminary results, by Perry Sadorsky, are reported in the supporting paper. The results for France support those in North America, while the model of normal output based on a nested CES function fits slightly less well than the Keynesian model for Germany, Japan and Italy, and significantly less well for the United Kingdom. Using a translog function to define normal output for the European countries (the data sample for Japan is not sufficiently long to permit this) gives a factor utilization model that fits better than the Keynesian model for Germany and the United Kingdom, leaving only Italy with a slight preference for the Keynesian framework.

economics in which lowering of tax rates is argued to increase incentives and output by enough to raise output and tax revenues. Using that classification, the factor utilization model is clearly 'old' supply-side economics, but with added features, as it shows that there are important short-term variables, arising from both the supply and demand sides of the economy, that make output differ in the short run from the level dictated by the evolution of the quantities and quality of employed factors of production.

What are the implications of our results for economic policy? Some have suggested that the important role for the unexpected sales variable in the factor utilization model, and the corresponding lack of evidence for a long-term break in productivity growth, argue for expansionary demand management in the Canadian context. However, the main structure of the model shows that over the longer term the evolution of output depends solely on the supplies of factors, which in turn depend on the expected level of profitable output and on the relative costs of capital, labour and energy. The fact that current demand levels are below what they were thought likely to be when today's plants were assembled does not suggest that expansionary fiscal policy would speed the progress to a new and more fully employed equilibrium. Such a result is not ruled out by the factor utilization model, but certainly is not implied by it. Similarly, the fact that the Barro model is heavily rejected in relation to the factor utilization model does not mean that monetary policy has no substantial effect on the level of output; only that the effects of monetary policy are better represented indirectly, via changes in the level of normal output and in the determinants of factor utilization, than by simple attempts to explain output by unexpected or expected changes in the money supply. Nor does the strong empirical support for the 'old' supply-side economics mean that the incentive effects emphasized in the 'new' supply-side economics are without content. Rather, as emphasized by Feldtein, their relative importance can only be assessed properly when they are integrated into a complete macroeconomic framework that permits factor supplies and and output to be determined in a mutually consistent manner.[24]

Thus this paper provides nothing dramatic by way of policy advice, except to the extent that its strong evidence against some popular simplified models will reduce the temptation for their policy implications to be taken seriously. The main implications of this paper are more for the way in which macroeconometric research ought to be carried out, with more attempt to develop and test alternative explanations in ways that permit them to be compared directly to one another and to more general models that encompass them. The factor utilization model provided a useful device to bring together New Classical and Keynesian models of output determination in a comparable form, and in so doing was seen to have greater claims to data coherence than any of the alternative equations tested. If that should help

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[24] A chapter in Canto, Joines and Laffer (1983) uses estimates of marginal tax rates on labour and capital to explain U.S. real GNP. Comparing these results to those in Table 8 suggests that the factor utilization model is preferable, but attempts are being made to develop data for more precise tests.

to increase the long-run supply of two-handed economists, so much the better. In the meantime, there is lots to do in the continuing search for even better models.[25]

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[25] Our own continuing efforts include testing the factor utilization model against a wider range of alternatives, including some (e.g., those by Bruno and Sachs (1985) and Laidler and Bentley (1983)) that attempt to combine some supply-side and demand-side influences in the determination of aggregate output.

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Supply-Side Macroeconomics - List of Variables

Variable[1]	Description
lnQ	Gross output (at factor cost) of the non-energy sector, billion 1971 \$. (Equals real GDP plus net energy imports minus non-energy indirect taxes)
QT	Time trend
lnQSV	Normal output based on a three factor CES production function, billion 1971 \$
ln(Pe/P)[2]	Ratio of the expected to actual price of gross output of the non-energy sector
ln(c/Ce)	Ratio of actual to expectd costs, which are the cost dual to the nested three-factor CES production function used to define normal output
ln(Ce/Pe)	Ratio of expected costs to expected price
lnDMA(t-i)[3]	Anticipated growth of the high powered money supply, billion \$
lnDMU(t-i)	Unanticipated growth of the high powered money supply, billion \$
lnYT(t-1)	Transitory income (GNP), billion \$
lnSALES	Final sales, billion \$
lnKINV(t-1)	Stock of inventories, billion \$
lnRELP	Weighted average of the current and lagged values (t-1 and t-2)of the ratio of the import to output price, 1971=1.0
lnSS	Ratio of actual to normal sales, normalized by normal output (QSV)
lnCQ	Average unit cost relative to output price for producing gross output of the non-energy sector
lnKGP	Ratio of the desired to the target level of business inventories, billion \$
lnPQ	Implicit price for gross domestic output, 1971=1.0
RS	Average yield on Government of Canada bonds, 1-3 years, percent
lnRNU	Unemployment rate, percent
lnWNE	Wage rate in the non-energy sector, thousands of dollars per year per employed person
lnHPM	High powered money, billion \$
lnLB	Net stock of government non-monetary liabilities, billion \$
lnMNE	Imports of goods and services (excluding energy, interest and dividends), billion 1971 \$
lnXNE	Exports of goods and services (excluding energy), billion 1971 \$
lnPXM	Ratio of the export to import price of goods and services in the non-energy sector, 1971=.0
B	Current account of the balance of payments, billion \$
lnYW	Real output in the major OECD economies, billion US \$
lnPW	OECD real output deflator, 1971=1.0
RUS	Average yield on U.S. government bonds, 5 years

List of Instrumental Variables

Exogenous Variables

lnG	Real government current and capital expenditures on goods and services, billion 1971 $
lnPW	O.E.C.D real output deflator, 1971=1.0
RMUS	Average yield on U.S. government bonds, 5 years, percent
lnYW	Real output in the major O.E.C.D. economies, billion 1972 U.S. $
lnABUS	Real U.S. absorption, billion 1972 $
lnPAUS	Implicit price of U.S. absorption, 1972=1.0

Lagged Endogenous Variables

lnNNE	Total employed in the non-energy sector (excluding armed forces), millions of persons
lnEKSTAR	Optimal energy to capital stock ratio
lnINEW	Re-investment with energy use malleable in the current year, billion 1971 $
lnPE	Price of energy to final users, 1971=1.0
lnWNE	Wage rate in the non-energy sector, thousands of dollars per year per employed person
lnABS	Real absorption, billion $
lnPQ	Implicit price for gross domestic output, including imported energy, 1971=1.0
lnPKE	Price of the capital-energy bundle
lnXNE	Exports of goods and services (excluding energy), billion 1971 $
lnK	Business fixed capital stock (excluding energy), billion 1971 $
lnKINV	Stock of inventories, billion 1971 $
QT	Time trend
ELEFFCES	Labour productivity index for Harod-neutral technical progress

[1] ln denotes the natural logarithm.

[2] The expected price is the predicted value from a linear regression of lnPQ on an information set comprising the lagged endogenous variables; lnNNE, lnEKSTAR, lnINEW, lnPE, lnWNE, lnABS, lnPQ, lnPKE, lnXNE, lnK, lnKINV, QT, ELEFFCES and lnHPM, and predicted values of the exogenous variables G, PW, RMUS, YW, ABUS, and PAUS generated from equations of the form: $G_t=\beta_0+\beta_1 G_{t-1}+\beta_2 G_{t-2}+\epsilon_t$ where $\epsilon_t=\rho\epsilon_{t-1}+\upsilon_t$

[3] The anticipated growth of the high powered money supply is the predicted value from a linear regression on the growth rates of the lagged endogenous variables used to define Pe. The unanticipated growth is the difference between the actual and predicted growth.

Table 1
From the Lucas Supply Equation to Factor Utilization Models of Aggregate Supply
(Dependent Variable is lnQ)†

Equation	1.1 Lucas	1.2	1.3	1.4	1.5	1.6	1.7 Factor Utilization
CONSTANT	.1149 (.55)	.0010 (.20)	-.0011 (.38)	-.0010 (.61)	-.0002 (.15)	-.0006 (.45)	
QT	.0001 (.00)						
lnQ(t-1)	.9823 (5.20)						
lnQSV		1.0	1.0	1.0	1.0	1.0	1.0
ln(Pe/P)	-.3452 (.16)	-.5116 (.26)	-.2244 (.19)	-.7530 (1.19)	-.7667 (1.30)	-.9050 (1.78)	-.2604 (12.06)
ln(c/Ce)				-.2419 (8.45)	-.2212 (7.80)	-.2759 (9.24)	-.2604 (12.06)
ln(Ce/Pe)					-.2280 (2.13)	-.1932 (2.09)	-.2604 (12.06)
lnSS			.4792 (6.60)	.4510 (11.84)	.5446 (9.66)	.5358 (11.02)	.5647 (19.96)
lnKGP						.1135 (3.18)	.1037 (3.38)
$\bar{R}2$	.9947	.9958	.9984	.9996	.9996	.9997	.9998
s.e.e.	.02843	.02537	.01553	.00811	.00754	.00650	.00579
D-W	1.544	.540	.655	1.798	1.750	1.769	1.171
F-test	73.139	45.465	18.017	2.833	2.246	.147	.485

Equation	Constraints
1.1	lnQSV=ln(c/Ce)=ln(Ce/Pe)=lnSS=lnKGP=0.0
1.2	lnQSV=1.0 and QT=lnQ(t-1)=ln(c/Ce)=ln(Ce/Pe)= lnSS=lnKGP=0.0
1.3	lnQSV=1.0 and QT=lnQ(t-1)=ln(c/CE)=ln(Ce/Pe)=lnKGP=0.0
1.4	lnQSV=1.0 and QT=lnQ(t-1)=ln(Ce/Pe)=lnKGP=0.0
1.5	lnQSV=1.0 and QT=lnQ(t-1)=lnKGP=0.0
1.6	lnQSV=1.0 and QT=lnQ(t-1)=0.0
1.7	lnQSV=1.0, QT=lnQ(t-1)=0.0 and ln(Pe/P)= ln(c/Ce)=ln(Ce/Pe)

† Estimation technique is Instrumental Variables. Sample 1954-1982.

Table 2
From the Barro Equation to Factor Utilization
Models of Aggregate Supply
(Dependent Variable is lnQ)†

Equation	2.1 Barro	2.2 Darby	2.3	2.4	2.5	2.6	2.7 Factor Utilization
CONSTANT	1.3326	1.2267	-.0120	.0030	-.0053	.0032	
	(28.73)	(24.86)	(1.61)	(.33)	(1.28)	(.58)	
lnQSV			1.0	1.0	1.0	1.0	1.0
QT	.0422	.0436					
	(52.84)	(46.14)					
lnDMA(t)	.1208	-.0064	-.0187	.0300	.0194	.0048	
	(.39)	(.02)	(.09)	(.16)	(.23)	(.05)	
lnDMA(t-1)	.9138	.5707	.1302	-.1208	.0846	-.0635	
	(2.82)	(1.73)	(.68)	(.61)	(.92)	(.64)	
lnDMU(t)	.5949	.4469	.3523	.1422	-.0343	-.0376	
	(3.21)	(2.47)	(2.84)	(1.01)	(.52)	(.58)	
lnDMU(t-1)	.5625	.4710	.2480	.1389	.0406	.0208	
	(3.31)	(2.94)	(2.13)	(1.23)	(.79)	(.33)	
lnYT(t-1)		.4770	.3608	.2293	-.2480	-.2014	
		(2.32)	(3.09)	(1.96)	(3.38)	(1.82)	
lnSS				.3485	.6313	.6367	.5647
				(2.44)	(8.93)	(8.96)	(19.96)
lnCQ					-.2953	-.2945	-.2604
					(9.25)	(9.26)	(12.06)
lnKGP						.0339	.1037
						(.56)	(3.38)
$\bar{R}2$	.9965	.9971	.9984	.9987	.9997	.9998	.9998
s.e.e.	.02319	.02115	.01561	.01391	.00620	.00617	.00579
D-W	1.237	1.847	1.943	1.566	1.336	1.254	1.171
F-test	54.143	52.735	22.888	20.756	.525	.640	.435

Equation	Constraints
2.1	lnQSV=lnYT(t-1)=lnSS=lnCQ=lnKGP=0.0
2.2	lnQSV=lnSS=lnCQ=lnKGP=0.0
2.3	lnQSV=1.0 and QT=lnSS=lnCQ=lnKGP=0.0
2.4	lnQSV=1.0 and QT=lnCQ=lnKGP=0.0
2.5	lnQSV=1.0 and QT=lnKGP=0.0
2.6	lnQSV=1.0 and QT=0.0
2.7	lnQSV=1.0, QT=lnYT(t-1)=lnDMA(t-i)=lnDMU(t-i)=0.0, i=0,1

† Estimation technique is Instrumental Variables.Sample 1954-192.

Table 3
From Keynesian to Factor Utilization
Models of Aggregate Supply
(Dependent Variable is lnQ)†

Equation	3.1 Keynesian	3.2	3.3	3.4 Factor Utilization
Constant	-.3118 (3.87)	-.3181 (3.80)	-.0013 (.47)	
lnQSV			1.0	1.0
lnSALES	1.0777 (20.98)	1.0744 (20.25)		
lnKINV(t-1)	-.1238 (2.20)	-.1163 (1.91)		
lnRELP	.2490 (4.80)	.2578 (4.43)	.0200 (.38)	
lnSS			.5854 (9.54)	.5647 (19.96)
lnCQ		-.0218 (.36)	-.2561 (10.37)	-.2604 (12.06)
lnKGP			.1034 (3.26)	.1037 (3.38)
$\bar{R}^2$	.9994	.9994	.9998	.9998
s.e.e.	.00958	.00975	.00599	.00579
D-W	.637	.632	1.163	1.171
F-test	18.176	36.030	.097	.108

Equation	Constraints
3.1	lnQSV=lnCQ=0.0
3.2	lnQSV=0.0
3.3	lnQSV=1.0
3.4	lnQSV=1.0 and lnRELP=0.0

† Estimation technique is Instrumental Variables. Sample 1954-1982.

Table 4
Comparison of the Unstructured VAR Equation With the Factor Utilization Supply Model
(Dependent Variable is lnQ)┼

Equation	4.1† VAR		4.2		4.3 Factor Utilization	
CONSTANT	.0403	(.03)	-1.8001	(1.19)		
lnQ(t-1)	.1129	(.75)	-.1957	(1.00)		
lnPQ	-1.1730	(2.19)	.2040	(.44)		
RS	.0123	(2.44)	.0057	(1.06)		
lnRNU	-.0384	(1.03)	.0033	(1.40)		
lnWNE	.4775	(1.10)	.1164	(.35)		
lnHPM	.9410	(3.84)	-.1073	(.73)		
lnLB	.0701	(1.51)	-.0272	(.84)		
lnMNE	-.0804	(.50)	.0750	(1.08)		
lnXNE	-.0659	(.74)	-.1735	(1.30)		
lnPXM	.4200	(2.36)	-.2093	(1.62)		
B	-.0012	(.58)	-.0001	(.01)		
lnYW	.1819	(.59)	.4692	(1.25)		
lnPW	-.4184	(2.68)	-.0781	(.84)		
RUS	.0161	(1.75)	-.0008	(.07)		
lnQSV			.8594	(2.90)	1.0	
lnSS			.4228	(.91)	.5647	(19.96)
lnCQ			-.8434	(2.97)	-.2604	(17.06)
lnKGP			-.1571	(1.38)	.1037	(3.38)
$\bar{R}^2$	.9992		.9999		.9998	
s.e.e.	.01076		.00439		.00579	
D-W	2.463		2.896		1.171	
F-test	32.040				20.570	

Equation	Constraints
4.1	lnQSV=lnSS=lnCQ=lnKGP=0.0
4.2	Unconstrained
4.3	lnQSV=1.0 and lnQ1=lnPQ=RS=lnRNU=lnWNE=lnHPM=lnLB=lnMNE=lnXNE=lnPXM=B=lnYW=lnPW=RUS=0.0

┼ Sample 1954-1982.

† Estimation technique is Instrumental Variables with equation 4.1 having a second order autoregressive error term.

Table 5
Stability and Specification Tests of the Supply Models

Equation	S.E.E.	CHOW†	DIFFERENCE‡	ENCOMPASSING┼
Lucas	.02843	2.100 4.360*	7.572**	21.445**
Barro	.02319	.218 .750	.584	16.107**
Darby	.02115	.894 1.575	6.272**	16.262**
Keynesian	.00958	4.288* 7.841**	2.139	2.078
Factor Utilization	.00579	2.034 2.345	1.274	.520
VAR	.01076	3.572[1] .158[2]	23.280**	

† The Chow test is done using OLS. The first Chow F-statistic for each model is for the sample split 1954-67/68-82, the second split is 1954-72/73-82.

‡ The reported statistic for the differencing test is the F-statistic for all included test variables. Estimation method is 2SLS.

┼ The reported statistic is the joint F-statistic of restricting the encompassing model to each special case.

[1] Dummy variables were used for testing the VAR model for structural stability. The variables were split into three groups for testing (group 1 lnQ(t-1), lnPQ, RS, lnRNU, and lnWNE, group 2 lnHPM, lnLB, lnMNE, lnXNE, and lnPXM, and group 3 B, lnYW, lnPW and RUS). The F-values for group 1 are reported above, for group 2 and 3 they are 5.187* and 2.251 respectively for the sample split 1954-67/68-82, and 1.503, and .245 for the sample split 1954-72/73-82.

[2] The differencing test was done on the same variable grouping as the stability test. The F-statistic for group 1 is given above, for group 2 and 3 they are 23.278** and 32.345** respectively.

* = significant at the 95% level.
** = significant at the 99% level.
*'s indicate rejection of the null hypothesis of stability and/or difference specification.

Table 6
Comparing Structural Supply Models Using a Translog Production Function to Define Normal Output
(Dependent Variable is lnQ)†

Model	Lucas	Barro	Darby	Keynesian	Factor Utilization
CONSTANT	.1013	1.3400	1.2688	-.3115	
	(.48)	(28.27)	(24.04)	(3.75)	
QT	-.0006	.0421	.0436		
	(.06)	(51.51)	(44.47)		
lnQ(t-1)	.9951				
	(5.16)				
lnQSTL					1.0
ln(Pe/P)	-1.0507				
	(.69)				
lnDMA(t)		.0680	(-.0598)		
		(.21)	(.17)		
lnDMA(t-1)		.9970	.6144		
		(2.94)	(1.76)		
lnDMU(t)		.5123	.3454		
		(2.64)	(1.81)		
lnDMU(t-1)		.5767	.4912		
		(3.29)	(2.98)		
lnYT(t-1)			.5038		
			(2.39)		
lnSALES				1.0777	
				(20.38)	
lnKINV(t-1)				-.1239	
				(2.14)	
lnRELP				.2485	
				(4.73)	
lnSS					.5258
					(15.65)
lnCQ					-.2866
					(11.39)
lnKGP					.0702
					(2.10)
$\bar{R}^2$	.9945	.9964	.9970	.9994	.9997
s.e.e.	.02900	.02343	.02151	.00958	.00643
D-W	1.664	1.232	1.871	.636	1.054
F-test[1]	70.012	44.165	36.116	15.805	.876
F-test[2]	11.012	8.334	6.905	1.425	.614

[1]F-tests of Specific Models vs. Factor Utilization:

Lucas	lnQSTL=lnSS=lnCQ=lnKGP=0.0
Barro	lnQSTL=lnSS=lnCQ=lnKGP=0.0
Darby	lnQSTL=lnSS=lnCQ=lnKGP=0.0
Keynesian	lnQSTL=lnCQ=0.0
Factor Utilization	lnQSTL=1.0 and QT=lnQ(t-1)=0.0

[2] Encompassing Constraints (ie. All variables were included, with variables inappropriate to the particular model constrained to zero.)

† Estimation technique is Instrumental Variables. Sample 1954-82.

Table 7
Tests of the Structural Supply Models With GDP as the Dependent Variable†

Model	Lucas	Barro	Darby	Keynesian	Factor Utilization
CONSTANT	.0811 (.42)	1.2909 (24.93)	1.2146 (24.10)	-.3261 (4.09)	
GT	-.0017 (.20)	.0427 (48.55)	.0443 (49.26)		
lnGDP(t-1)	1.0180 (5.53)				
lnGDPS					1.0
ln(Pe/P)	.8951 (.46)				
lnDMA(t)		.5756 (1.20)	.6739 (1.65)		
lnDMA(t-1)		.5710 (1.16)	-.0599 (.13)		
lnDMU(t)		.4319 (2.64)	.3056 (2.11)		
lnDMU(t-1)		.6038 (3.50)	.3869 (2.38)		
lnYT(t-1)[1]			.6460 (3.08)		
lnSALES				1.0832 (20.64)	
lnKINV(t-1)				-.1318 (2.26)	
lnRELP				.2300 (4.84)	
lnSS					.6522 (22.84)
lnCQ					-.2911 (11.55)
lnKGP					.0958 (2.89)
$\bar{R}^2$	.9948	.9966	.9975	.9994	.9997
s.e.e.	.02862	.02313	.01961	.00994	.00655
D-W	1.525	1.153	1.905	.571	.894
F-test[2]	68.830	80.365	58.141	14.600	1.974
F-test[3]	13.456	10.179	7.743	.922	1.546

[1] GDP is used as the income measure.

[2] F-tests of Specific Models vs. Factor Utilization:

Lucas	lnGDPS=lnSS=lnCQ=lnKGP=0.0
Barro	lnGDPS=lnSS=lnCQ=lnKGP=0.0
Darby	lnGDPS=lnSS=lnCQ=lnKGP=0.0
Keynesian	lnQGDPS=lnCQ=0.0
Factor Utilization	lnGDPS=1.0 and GT=lnGDP(t-1)=0.0

[3] Encompassing Constraints (see footnote 2 Table 6).

† Estimation technique is Instrumental Variables. Sample 1954-82.

Table 8
Structural Supply Models for the United States
Constant Growth - Effective Factors†

Model	Lucas	Barro	Darby	Keynesian	Factor Utilization
CONSTANT	1.3880 (1.60)	4.9716 (60.11)	4.9318 (80.50)	.2013 (1.81)	
QT	.0065 (1.02)	.0273 (19.19)	.0285 (26.05)		
lnQ(t-1)	.7403 (3.95)				
lnQSV					1.0
ln(Pe/P)	1.9157 (.97)				
lnDMA(t)		2.2167 (4.09)	1.4186 (3.11)		
lnDMU		.9148 (1.30)	1.0308 (2.01)		
lnYT(t-1)			.5721 (3.48)		
lnSALES				1.0376 (20.85)	
lnKINV(t-1)				-.0929 (2.03)	
lnRELP				.0095 (.49)	
lnSS					.8593 (18.15)
lnCQ					-.1659 (16.14)
lnKGP					.0570 (2.61)
$\bar{R}^2$	.9845	.9834	.9912	.9991	.9998
s.e.e.	.02484	.02573	.01872	.00604	.00287
D-W	1.768	1.416	1.525	.748	1.975
F-test[1]	235.395	323.836	160.327	26.696	1.259
F-test[2]	97.278	86.837	47.115	5.671	.771

[1] Tests of Specific Models vs. Factor Utilization:

Lucas	lnQSV=lnSS=lnCQ=lnKGP=0.0
Barro	lnQSV=lnSS=lnCQ=lnKGP=0.0
Darby	lnQSV=lnSS=lnCQ=lnKGP=0.0
Keynesian	lnQSV=lnCQ=0.0
Factor Utilization	lnQSV=1.0 and QT=lnQ(t-1)=0.0

[2] Encompassing Constraints (see footnote Table 6).

† Estimation technique is Instrumental Variables. Sample 1960-82.