Seminar Paper No. 34

INFLATION IN OPEN ECONOMIES:
SUPPLY-DETERMINED VERSUS
DEMAND-DETERMINED MODELS

by

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INFLATION IN OPEN ECONOMIES: SUPPLY-DETERMINED VERSUS DEMAND-DETERMINED MODELS

I. Introduction

During the last few years there has been a gradual shift from emphasis on aggregate demand policy to emphasis on supply or cost factors as a determinant of the rate of inflation in the Scandinavian countries. This shift seems to have been accelerated by publication by Aukrust [1970, 1972] for Norway and Edgren, Faxén and Odhner [1969] [1970] [1973] of an analysis of inflation, sometimes called the "EFO model" in Sweden, that makes the rate of inflation "structurally determined" from the supply side of the economy. This view is now drawing international attention, as evidenced by the citations noted in section II below.

To date, no empirical test of the EFO model as a predictor of inflation, relative to even the most simple demand-oriented models, has been published. ¹ Edgren, Faxén and Odhner do not even cast their model in a readily testable form. Further, no attempt to integrate the EFO structure with an aggregate demand side has been published. ² The Aukrust and EFO publications assume an "accommodating" aggregate demand, and include no discussion of possible interactions between demand and supply sides in determining the rate of inflation.

Our object here is to present a rudimentary test of the EFO structure against other potential predictors of the rate of inflation, and to reinterpret the role of the EFO structure in a simple model including both demand and supply sides.

¹ One (partial) exception to this statement might be Nordhaus [1972], who included an equation partially based on EFO-type analysis in a survey paper analyzing recent wage increases in several major countries. The contrasts between Nordhaus' study and ours are mentioned in context below.

² Again, one possible exception might be in the wage-price sectors of one or two large-scale econometric models in the United States. But these are typically elaborations of the price-wage mechanisms in an essentially closed economy, and they pay no attention to the kinds of questions we focus on here.
In section II we write down and discuss three simple, partial models explaining the rate of inflation: The Aukrust-EFO equations, the quantity theory, and a naive Phillips curve equation. These we take initially as competitors in explaining the rate of inflation in order to test the Aukrust-EFO equations against some equally simple demand-side equations. Then in section III we present the results of some simple tests of the three models in predicting annual rates of inflation in Sweden and Norway. For Sweden, the ranking is clearly (1) Phillips curve, (2) EFO, (3) Quantity Theory. For Norway the ranking is (1) Aukrust, (2) Quantity Theory, with the Phillips curve collapsing because of the very small deviations of real GNP about its trend value (low variation in unemployment). In the Swedish case there is substantial variance in real GNP about its trend and this does significantly affect the rate of inflation.

II. Three Partial Models of Price Movements

A model predicting price changes solely from the supply side of the economy has been developed by Aukrust [1970] [1972] in Norway and Edgren, Faxén and Odhner (EFO) [1969] [1970] [1973] in Sweden. In both cases, the authors claim that the model provides at least a satisfactory explanation of the rate of inflation. This view seems to be achieving fairly widespread acceptance. In the Swedish context, Lundberg [1972, p. 469] says that, "There is no doubt that the EFO models is a great improvement over the old aggregative type of analysis." Further, "... the EFO model seems to have worked well and fitted 'the facts'..." And, "As the authors of the EFO model express it, it seems that the price level is 'structurally determined'."

Evidence of the spread of this view internationally is provided by recent references in Johnson and Nobay [1971, p. 183] and in the survey article on recent wage increases by Nordhaus [1972, pp. 451-455], who refers to the Aukrust-EFO model as a "Scandinavian model". But explaining the rate of inflation from the supply or cost side alone is equivalent to assuming that it is only the supply blade of the Marshallian supply-and-demand scissors that does the cutting. This is recognized by Aukrust [1970, p. 7], who calls his framework a "pure cost-push" model and assumes accommodating demand adjustment. EFO are not as clear about these assumptions, leaving them mainly implicit.
The Aukrust-EFO Model

The Aukrust and EFO models begin with a division of the economy into two sectors. The competitive C-sector produces commodities that are traded on world markets, and the C-sector is assumed to be a price-taker. The sheltered S-sector produces commodities not traded externally (services and government output, for example), and the S-sector price level is set by the firms in that sector. If we add the assumptions that (a) productivity trends are exogenous, (b) the wage rate is the same in both sectors, and (c) the labor share of output in the S-sector is fixed, i.e. there is a fixed mark-up on unit cost in this sector, then (1) given an exogenous rate of change of wages we can determine the labor (and capital) share in the C-sector and the rate of price increase in the S-sector, or (2) given the labor share in the C-sector we can determine the rate of wage increase and the S-sector rate of price increase. 3)

The model can be laid out in a few simple equations. 4) First, define the labor shares of each sector's output:

\[ \rho_i \equiv \frac{W_i L_i}{P_i Q_i} , \quad i = C, S. \]

Converting this to growth rates, where \( \dot{x} = \frac{dx}{dt} \), we have

\[ \dot{\rho}_i \equiv \dot{W} - \dot{P}_i - \dot{Q}_i, \]

3) The Aukrust and EFO models have the same structure as that developed earlier by Baumol and Bowen [1966] and Baumol [1967]. Their model divided a closed economy into a "progressive" (manufacturing) and "non-progressive" (services) sectors and derived the implications of differential productivity growth for relative costs of the output of the two sectors.

4) See Table 1 for definitions of all symbols.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W$</td>
<td>wage rate</td>
</tr>
<tr>
<td>$L$</td>
<td>labor input</td>
</tr>
<tr>
<td>$P$</td>
<td>output price level</td>
</tr>
<tr>
<td>$Q$</td>
<td>output</td>
</tr>
<tr>
<td>$\rho$</td>
<td>labor share of output</td>
</tr>
<tr>
<td>$Y$</td>
<td>nominal GNP</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>GNP at constant prices</td>
</tr>
<tr>
<td>$y^x$</td>
<td>logarithmic trend value of $y$</td>
</tr>
<tr>
<td>$M$</td>
<td>money stock including savings deposits</td>
</tr>
<tr>
<td>$\dot{X}$</td>
<td>percentage rate of change of $X$: $\dot{X} = \frac{dX}{dt}$</td>
</tr>
</tbody>
</table>

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*a) All variables are measured on annual data. Flow variables are annual flows and stocks are average annual values. Rates of change are year over year changes in annual values.*
where labor productivity $q = Q/L$.\(^5\) The wage variable $\dot{w}$ has no subscript in equation (2), reflecting the assumption that the wage rate is the same in both sectors. Also, for given values of $\dot{p}_i$ and $\dot{q}_i$, an increase in $\dot{w}$ above the sum of these gives by identity (2) an equal increase in $\dot{\rho}_i$. This provides a source of offsetting error variation in the empirical application of the Aukrust-EFO model, as we shall see below.

Consider first the C-sector. If, following the original authors, we take $\dot{P}_c$ as exogenously determined by world market prices and fixed exchange rates, $\dot{q}_c$ as an exogenous productivity trend, and $\dot{w}$ as determined by a wage negotiation, we can interpret (2) as determining movements in the labor share $\rho_c$:

$$\dot{\rho}_c = \dot{w} - \dot{P}_c - \dot{q}_c. \tag{3}$$

On the other hand, for analyses of wage policy, both Aukrust and EFO sometimes use (2) to determine the "room" for wage increase $\dot{w}$ that will hold $\dot{\rho}_c = 0$, i.e., constant shares, with exogenous $\dot{P}_c$ and $\dot{q}_c$:

$$\dot{w} = \dot{P}_c + \dot{q}_c. \tag{4}$$

Next consider determination of the rate of inflation in the S-sector. The most general equation for $\dot{P}_s$ in the Aukrust-EFO structure can be obtained as follows. Equations (2) with subscript on the $\dot{W}$ terms, dropping for a moment the assumption that $\dot{W}$ is the same in the two sectors, can be rewritten as

$$\dot{W}_c - \dot{P}_c - \dot{q}_c - \dot{\rho}_c \equiv \dot{W}_s - \dot{P}_s - \dot{q}_s - \dot{\rho}_s \equiv 0.$$

---

5) Note that assuming that productivity trends are exogenously determined is equivalent to assuming fixed proportions, at any one point in time, in production. The value of productivity at any one point in time is then labor-output ratio, and the productivity trend gives the rate of change of the production coefficients through time.
Rearranging this identity with \( \dot{p}_s \) on the left-hand side yields an identity for \( \dot{p}_s \):

\[
\dot{p}_s = \dot{p}_c + (\dot{q}_c - \dot{q}_s) + (\dot{w}_s - \dot{w}_c) - (\dot{\rho}_s - \dot{\rho}_c).
\]

If we now assume that \( \dot{w}_s = \dot{w}_c = \dot{w}, \dot{c} = 0, \) and that \( \dot{\rho}_c \) is determined by (3), that is that \( \dot{\varphi} \) is exogenous, identity (5) becomes

\[
\dot{p}_s = \dot{w} - \dot{q}_s.
\]

On the other hand, if we still assume that \( \dot{w}_s = \dot{w}_c = \dot{w}, \) but that \( \dot{\varphi} \) adjusts to hold the labor share in the C-sector constant, that is that \( \dot{\rho}_c = 0 \) along with \( \dot{\rho}_s \), identity (5) becomes

\[
\dot{p}_s = \dot{p}_c + (\dot{q}_c - \dot{q}_s).
\]

This is the equation that will be used to predict \( \dot{p}_s \) in the tests of the Aukrust-EFO model in section III.

The basic equation (7) in Aukrust and EFO follows from equation (5), which is an identity, under the assumptions of equal wage development in the two sectors and constant labor shares. This is in essence the theory to be tested. Immediately the very important question of whether this is a theory of inflation in the short run or long run arises. The EFO report generally stresses the long-run aspects. This is particularly clear in the case of price developments as the EFO report claims to present a "new" theory for price change. In their view the general price level is not determined by demand factors but by long-run "structural" factors. On the other hand the model is very often used to discuss the room for wage increases or, as Aukrust [1970, p. 16] puts it, to "estimate the consequences to be expected for prices and income distribution of changes in the wage level". Since all wage agreements have been for one, two, or three years this must be called a short-run use of the model.

6) Comparisons of equations (5) and (7) shows that for given values of the right-hand variables in (7), random variations in \( \dot{w}_c \) will be offset by variations in \( \dot{\rho}_c \) (through the definition of \( \dot{\rho}_c \) in (2)) in predicting \( \dot{p}_s \). Thus in section III we will see that a high standard deviation of \( \dot{\rho}_c \) (\( \dot{\rho}_c \neq 0 \) in general) does not lead to poor predictions of \( \dot{p}_s \), because it is offsetting variations in \( \dot{w}_c \) in the error term implicit in (7), that is \( (\dot{w}_s - \dot{w}_c) - (\dot{\rho}_s - \dot{\rho}_c) \).
We will study both the long-run and the short-run interpretation. Let us start with the long run. By long run we mean a period long enough that cyclical fluctuations even out and the trend behavior is the dominant feature of the model. In the long run economic theory would predict equal wage developments in both sectors. But the hypothesis of constant labor shares is more difficult to derive for a supply-side model of this type. It is well known that in a two-sector model the demand side has to be brought in to determine income shares. EFO has a discussion about the determination of income shares, but we have not been able to understand it. [EFO 1969, p. 150].

Accepting these assumptions for the moment let us move $\dot{P}_c$ to the left-hand side of equation (7). The model then says that the rate of change in the relative price between the two goods will be the same as the difference between their rates of change in productivity. This is a neoclassical result about relative prices, but the Aukrust-EFO models go one step further. By taking the rate of inflation in the competitive sector as given from abroad with productivity trends also exogenous, the rate of inflation in the sheltered sector is determined, with cause and effect going from foreign absolute prices to internal absolute prices.

The idea of world market prices and home prices being determined together is not a new one. David Hume [1752] explained how price developments in different countries were evened out; however, he did not explain it from the supply side, but from the demand side. An excess supply of money in one country would under fixed exchange rates flow out through the balance of payments and even out among other countries giving rise to a small uniform price increase, just as an excess supply of money in a closed economy would spread over its different regions. Now, in the Aukrust-EFO model there is no money or any other demand element. We therefore have two simple long-run theories of the determination of inflation to be tested.

Moving to the short-run interpretation of the model we may start by observing that income shares are not constant from year to year. The question then becomes whether it is a good approximation to assume them to be constant, and in particular if it is a good approximation relative to other explanations. To answer these questions a comparison will be made with two other models.
An equation predicting a weighted-average rate of inflation can be obtained by weighting $\hat{P}_c$ and $\hat{P}_s$ from equation (7) by the shares of the C- and S-sectors in total output. Let output $Q = Q_c + Q_s$. Then the rate of inflation as measured on the implicit deflator for output $Q$ is

\begin{equation}
\hat{P} = \frac{Q_s}{Q} \cdot \hat{P}_s + (1 - \frac{Q_s}{Q}) \cdot \hat{P}_c = \hat{P}_c + \frac{Q_s}{Q} (\hat{P}_s - \hat{P}_c).
\end{equation}

If $\hat{W}$ is taken as exogenous, substitution from (6) yields

\begin{equation}
\hat{P} = \frac{Q_s}{Q} (\hat{W} - \hat{P}_s) - \hat{P}_c.
\end{equation}

as the expression for $P$. If, on the other hand, we endogenize $\hat{W}$ and hold shares constant in the C-sector, we can use (4) to eliminate $\hat{W}$ from (9) to obtain

\begin{equation}
\hat{P} = \frac{Q_s}{Q} (\hat{Q}_c - \hat{Q}_s).
\end{equation}

In either case, the Aukrust-EFO model requires some information on the shares of the two sectors in total output to determine the overall rate of inflation. EFO are not explicit on this point, while Aukrust [1970, p. 433] assumes that these, too, are exogenously determined.

A Quantity Theory Model

The first demand-side model we will study is the familiar quantity-theory model in which changes in the money supply drive changes in the price level with velocity and real output given exogenously.\(^7\) We use this model as an alternative to Aukrust-EFO not because we particularly believe it to be correct, but rather because it is simple and well-known, and can be used in a way completely analogous to the Aukrust-EFO model.

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\(^7\) See Fisher and Sheppard [1972, ch. 4] for discussion of this model, which they call the "strong" monetarist position. This is also the model of Friedman's monetary theory of nominal income [1971] with real output determined by the Walraskan equations of the real side of the economy. See also Nordhaus [1972, pp. 436-41].
The equation of exchange can be formulated as

\[(11) \quad M \cdot V \equiv P \cdot y\]

where \(M\) is the stock of money, \(V\) is the income velocity of money, \(y\) is real output and \(P\) is its price index. Again, taking growth rates we have

\[(12) \quad \dot{M} + \dot{V} \equiv \dot{P} + \dot{y}\]

This identity is then converted into a theory, the quantity theory, by assuming velocity to be constant (\(\dot{V} = 0\)). The equation can then be written

\[(13) \quad \dot{P} = \dot{M} - \dot{y}\]

It is worth pointing out the resemblance between equations (7) and (13) in basic structure. Both have an endogenous rate of inflation on the left-hand side. On the right-hand side both have an exogenous variable, \(\dot{P}_c\) and \(\dot{M}\) respectively. Then the Aukrust-EFO model (7) treats the difference in productivity increase as exogenously given. The corresponding term in equation (13) is the rate of change of real output which analogously is treated as exogenously determined. Many economists have come to regard the simple quantity theory as something much too oversimplified. That might be so, but in that case the same is true of the Aukrust-EFO model, which has the same basic structure.

A Phillips Curve Model

The reasoning behind the wage-Phillips curve can be carried over to price determination from the demand side fairly easily. We assume that aggregate supply of output can be represented by the trend value of real GNP, \(y^*\). Then we assume that given \(y^*\), the actual value of real output \(y\) is determined by demand conditions. Next we take \((y - y^*)/y^*\) as a measure of output - market tightness, or excess demand, and assume that the rate of inflation \(\dot{P}\) is positively related to it:

\[(14) \quad \dot{P} = f \left(\frac{y - y^*}{y^*}\right), \quad f' > 0.\]
For concreteness, and to have an actual predicting equation to test against the Aukrust-EFO and monetarist models, we assume a linear form for (14):

\[ \dot{P} = \alpha_0 + \alpha_1 \left( \frac{y^* - \bar{y}^*}{y^*} \right), \]

with \( \alpha_0 \) and \( \alpha_1 \) to be estimated by ordinary least squares (OLS) on annual data since we have no a priori theory concerning their values aside from \( \alpha_1 > 0 \), in contrast with the Aukrust-EFO and monetarist models. The \( y^* \) series is the logarithmic trend value of \( y \).

Compared with the Aukrust-EFO and monetarist models, the parameters \( \alpha_0 \) and \( \alpha_1 \) are estimated by OLS at their "average" values over the period in question. \( \dot{P} \) is then predicted using actual values of \( y \) and the trend values \( y^* \).

This concludes our discussion of the three partial models to be compared in section III. The Aukrust-EFO model predicts \( \dot{P}_s \) using supply-side factors only. The quantity-theory and Phillips models predict overall \( \dot{P} \) using demand-side factors only; the Phillips model uses a fairly direct measure of excess demand while the quantity-theory model relies on variation in the money stock. If the Aukrust-EFO model deserves the praise cited at the beginning of this section, it should be able to explain variations in \( \dot{P}_s \) at least as well as the simple demand-side models explain variations in \( \dot{P} \).

III. A Simple Test of the Explanatory Power of the Models

Some models for the determination of price changes have been presented in section II. In this section we will test their predictive performance on Swedish and Norwegian data.

Let us first consider the long-run interpretation of the Aukrust-EFO and quantity-theory models. The EFO report claims that prices are determined by long-run "structural" factors and not by demand factors such as the money supply. Now, if we take equation (7) and insert average values for price development in the competitive sector and for productivity change in both sectors we get a forecast or prediction of the average rate of price increase in the sheltered sector.
Using the Swedish data described in the Appendix, we get the actual rates of inflation and the EFO predictions shown in Table 2.

Table 2: Prediction of Average Rates of Inflation in Sweden

<table>
<thead>
<tr>
<th>Period</th>
<th>Actual</th>
<th>Predicted</th>
<th>Difference</th>
<th>Actual</th>
<th>Predicted</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954-68</td>
<td>4.6</td>
<td>4.8</td>
<td>-0.2</td>
<td>3.9</td>
<td>4.0</td>
<td>-0.1</td>
</tr>
<tr>
<td>1964-70</td>
<td>5.7</td>
<td>6.4</td>
<td>-0.7</td>
<td>4.9</td>
<td>4.4</td>
<td>+0.5</td>
</tr>
</tbody>
</table>

These predictions are considered to show "good agreement" between the model and the facts according to EFO [1969, p. 150, 1970, p. 235] and Lundberg [1972, p. 469]. Is this true? The last column in Table 2 gives the quantity-theory predictions for the same periods. Evidently good old quantity theory does just as well in predicting average price changes over long periods.

We now turn to a way of testing the explanatory power of the models in the short run. In this case the assumptions of constant profit shares in the Aukrust-EFO model and of constant velocity in the monetary model are retained but here the models' explanatory power is tested by looking at the deviations between actual and predicted values from year to year, as suggested by Aukrust [1970, p. 29].

The Swedish Data

Let us start with the Aukrust-EFO model. As discussed in section II, the equation to be tested is (7) explaining $\dot{p}_s$:

\[ (7) \quad \dot{p}_s = \dot{p}_c + \dot{q}_c - \dot{q}_s. \]
This says that the rate of change of prices in the sheltered sector can be explained by the actual values of the rate of change of prices in the competitive sector and the difference between the rates of change of productivity in the two sectors. 8)

For the period 1954-68, using the data given by EFO [1970], the root mean square error of prediction of $\dot{P}_s$ from (7) is:

$$\text{RMSE} = 2.1\% \text{ per year}.9)$$

However, all the data from EFO [1970] have been revised and re-calculated by the Swedish Confederation of Trade Unions from 1964, and 1969 and 1970 have been added. For this period we have a RMSE in predicting $\dot{P}_s$ from equation (7) of:

$$\text{RMSE} = 2.6\%$$

(For the overlapping period 1964-68 the original data give RMSE = 2.7 and the revised data give RMSE = 3.0. This is difficult to understand since better data should give better results.)

The equation to predict movements in the GNP deflator from the quantity-theory model is

$$(13) \quad \dot{P} = \dot{M} - \dot{y},$$

where $\dot{P}$ is the percentage rate of change in the GNP deflator, $\dot{M}$ is the rate of increase in the money stock, defined to include savings deposits, and $\dot{y}$ is the rate of increase in constant-price GNP.

8) Nordhaus [1972] goes one step further in assuming a constant rate of change of productivity in each sector, which is actually more in the spirit of the EFO model. However, this amounts to introducing another source of error into the model and therefore our test should give better results than his.

9) The RMSE is calculated as

$$\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i} (y_i - \hat{y}_i)^2}$$

where $\hat{y}_i$ is the predicted value of the variable, $y_i$ is the actual value and $N$ is the number of observations.
The predictive performance here is described by

\[ \text{RMSE} = 3.6\% \]

for the period 1954-68, and for the period 1964-70 we have

\[ \text{RMSE} = 4.2\%. \]

Evidently the predictions from the quantity theory are not as good as the predictions from the EFO model.10)

The third model to be tested is the naive Phillips curve explanation of \( \dot{P} \). Instead of regressing wage changes on unemployment as in Jacobsson and Lindbeck [1971], we have taken the deviation of real income from its trend value as the independent variable that predicts the rate of change in the GNP deflator. The equation is

\[ (15) \quad \dot{p}_{t+1} = \alpha_0 + \alpha_1 \left( \frac{y_t^* - y^*}{y^*} \right), \]

where \( y_t^* \) is the trend value of GNP in constant prices, \( y_t \) is actual real GNP, and \( \dot{p}_{t+1} \) is the percentage price change as measured on the implicit GNP deflator from year \( t \) to year \( t+1 \).

A scatter diagram of the data for equation (15) is shown in Figure 1. Ordinary least squares estimation of equation (15) through the data covering the period 1954-68 yields a standard error of estimate (SEE), to be compared with RMSE from the earlier equations, of 0.96%. When the regression is estimated on data for 1964-70, the SEE falls

10) In the beginning of our investigation the quantity-theory model seemed to give better results. This impression came from a comparison of the stability of velocity compared to the profit shares in the two sectors. Measuring stability as standard deviation divided by the mean value of the variable, velocity was more stable. However, testing the EFO-equation implies assuming profit shares to be constant and wage developments to be the same in both sectors. Furthermore, the two profit shares are positively correlated. The conclusion is that positive correlation between the two shares and a slight difference in wage developments tend to offset the errors coming from the variability in each profit share. That is, two different errors tend to even out in a systematic way.
to 0.15%.\textsuperscript{11)} This performance is much better than either the Aukrust-EPO model or the quantity-theory model, at least as far as predicting the rate of inflation goes.

The results of these tests using the Swedish data are summarized in Table 3. Evidently in predicting price inflation the naive Phillips-curve model is best, even when the dependent variable for the Aukrust-EPO model is only the S-sector rate of inflation.

<table>
<thead>
<tr>
<th>Model</th>
<th>Measure of Prediction Error</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1954-68</td>
<td>1964-70</td>
<td></td>
</tr>
<tr>
<td>Aukrust-EPO</td>
<td>RMSE 2.1</td>
<td>SEE 2.6</td>
<td></td>
</tr>
<tr>
<td>Quantity Theory</td>
<td>RMSE 3.6</td>
<td>SEE 4.2</td>
<td></td>
</tr>
<tr>
<td>Naive Phillips Curve</td>
<td>RMSE 1.0</td>
<td>SEE 0.5</td>
<td></td>
</tr>
</tbody>
</table>

This result may appear to be in disagreement with the findings of Nordhaus [1972, pp. 456-59] that in predicting the overall rate of wage increase the models ranked (1) EPO, (2) Naive Phillips curve, (3) Quantity Theory. However, the explanation may be that commodity prices respond more rapidly and with more regularity to excess demand for goods and services than wage rates do to excess demand for labor. In that case a price-Phillips curve would behave better than a wage-Phillips curve. But this is simply speculation; solution to this puzzle will have to await development of a carefully specified set of wage and price equations for Sweden. What we can say here, though, is that a demand-oriented naive Phillips curve predicts movements of the GNP deflator substantially better than the EPO structure predicts movements of the S-sector price level, and both outperform the quantity-theory model on Swedish data for the 1950s and 1960s.

\textsuperscript{11)} The Durbin-Watson statistic is 1.91 for the first regression and 1.97 for the second, showing no evidence of serial correlation in the residual terms.
Figure 1: Scatter Diagram of Equation (14) using Swedish Data
The Norwegian Data

As we noted earlier, Aukrust [1970], in contrast to EFO, presented actual and predicted rates of change in the overall consumer price index from his model of Norway for the period 1961-68. \(^{12}\) We have calculated the RMSE of prediction of $\dot{\hat{p}}$ from his Table 3, p. 29 to be

$$\text{RMSE} = 0.92\% \text{ per year.}$$

Next, using money supply data from Teigen, Schilbred, and Thore [1971] and published data for the implicit GNP deflator and GNP at constant prices for Norway for 1961-68, we have calculated the RMSE of prediction from the quantity-theory equation

$$\dot{\hat{p}} = \ddot{M} - \ddot{y}.$$  

Again we define money stock to include savings deposits, the sum of the last two columns in Teigen et. al [1971, Table 1, p. III 6]. For Norway, over the period 1961-68, this equation predicts $\dot{\hat{p}}$ with

$$\text{RMSE} = 1.98\%$$

As in the Swedish data, the quantity-theory model has a much higher RMSE in predicting annual inflation rates than does the Aukrust-EFO model.

Finally, the naive Phillips curve data for Norway, 1961-68, are shown in Figure 2. Obviously this explanation of inflation in Norway is no good at all. During the sample period 1961-68 there was hardly any deviation of real GNP from its trend path. While in Sweden real GNP gaps ranged from -2.5% to +2.5% during 1954-69, in Norway the gap was held to a range of -0.2 to +0.5% in 1961-68. Thus output growth was so stable in Norway that the naive Phillips curve collapses to a vertical line, and this explanation of $\hat{p}$ is a complete failure.

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\(^{12}\) Calculations for Norway are limited to the period 1961-68, since that is the only data presented by Aukrust [1970].
Figure 2: Scatter Diagram of Equation (14) using Norwegian Data
Tentative Conclusions from the Empirical Evidence

It appears that in Norway the Aukrust model does provide a good explanation of the year-to-year rate of inflation, while in Sweden the EFO model, identical in structure to Aukrust's, is distinctly inferior to the naive Phillips curve approach. Also, it seems that the quantity-theory approach is inferior to the Aukrust-EFO model in both cases.

While explanations of these results that are not simply ad hoc must await much more careful analysis, we can offer two speculative observations. The first is that aggregate demand policy in Norway has been much more accommodating than in Sweden, at least during the period under observation. This is consistent with Aukrust's assumption of accommodating demand policy and also with the difference between the scatter diagrams in Figures 1 and 2.

The second observation is that the Aukrust model may not travel well, at least to Sweden. EFO [1970] try to carry over Aukrust's assumption about accommodating demand policy, but it just does not hold in Sweden. And it seems that a demand policy that has been sufficiently non-accommodating to generate a 5% range in variations of real GNP around its trend value in Sweden has had a quite significant effect on the rate of inflation, contrary to the assertions of EFO [1969, p. 157].

IV. Demand Elasticities in the Aukrust-EFO Model

Before we go on in section V to discuss ways to merge the supply-side and demand-side models, it is useful to pause to discuss assumptions about demand elasticities that seem to be implicit in the Aukrust-EFO model. It will turn out that these assumptions seem plausible, and they play an important role in the equilibration mechanism in the merged model.

Both the Aukrust and EFO models are silent on demand conditions. Output in the two sectors is taken as exogenously determined, and demand is assumed to be accommodating, in that these outputs are sold at the cost-push-determined prices fixed by the model. But
in the Aukrust-EFO model, the price level in the S-sector rises continuously relative to that in the C-sector; from equation (7) above we see that

$$\dot{p}_s - \dot{p}_c = \dot{q}_c - \dot{q}_s$$

in the model. Normally, we would expect that if $p_s$ rises relative to $p_c$ through time, this would tend to reduce the quantity of S-output demanded relative to that of C-output. This is the problem analyzed by Baumol [1967]. In order for this not to happen, the income-elasticity of demand for S-output must be large relative to the income-elasticity of demand for C-output. The exact relationships between price- and income-elasticities of demand in the two sectors that maintain balanced growth in the economy, i.e. $\dot{q}_c = \dot{q}_s$ can be developed as follows.

The demand function for the output of the S-sector, $Q_s$, can be written as

$$Q_s = f^s \left( \frac{p_s}{p_c}, Y \right),$$

where $f^s_1 < 0$, $f^s_2 > 0$, and $Y$ is domestic nominal income. The demand function should be homogenous to degree zero in all prices and nominal income. The growth rate of demand for $Q_s$ is then given by

$$\dot{Q}_s = s_y Y + s_p (\dot{p}_s - \dot{p}_c),$$

where $s_y > 0$ and $s_p < 0$ are the elasticities of demand for S-sector output with respect to changes in relative price $p_s/p_c$ and income respectively.\(^{13}\)

\(^{13}\) To go from (16) to (17), begin by taking the derivative with respect to time:

$$\frac{dQ_s}{dt} = \frac{\delta f^s}{\delta (p_s/p_c)} \cdot \frac{d(p_s/p_c)}{dt} + \frac{\delta f^s}{\delta Y} \frac{dY}{dt}$$

Dividing through by $Q$ and (a) multiplying the first term on the RHS by $(\frac{p_s}{p_c})$ and (b) multiplying the second term by $Y/Y$ then yields

$$\dot{Q}_s = s_p (p_s/p_c) + s_y Y,$$

which can be rewritten as (17).
The demand function for $Q_c$ can be written in the same form as that for $Q_s$, but with foreign demand, $F$, added:

$$Q_c = f^C \left( \frac{P}{P_c}, Y, F \right).$$

(18)

The growth rate of demand for $Q_c$ is then given by

$$\dot{Q}_c = c_y \dot{Y} + c_p \left( \dot{P}_s - \dot{P}_c \right) + c_f \dot{F},$$

(19)

where $c_y$, $c_p$, and $c_f$ are the positive income- and price-elasticities of demand for C-sector output. Note that $c_p > 0$ since the relative price term is stated as $P_s/P_c$.

For balanced output growth in the Aukrust-EFO model we set $\dot{Q}_c = \dot{Q}_s$ to obtain

$$c_f \dot{F} + c_y \dot{Y} + c_p \left( \dot{P}_s - \dot{P}_c \right) = s_y \dot{Y} + s_p \left( \dot{P}_s - \dot{P}_c \right).$$

Rearranging, this gives us a condition for balanced growth:

$$s_y - c_y = \left( s_p - c_p \right) \frac{\dot{P}_s - \dot{P}_c}{\dot{Y}} + c_f \frac{\dot{F}}{\dot{Y}}.$$

(20)

Here we assume that $\dot{P}_s - \dot{P}_c$, $\dot{Y}$, and $\dot{F}$ are all given and positive. Since $c_f$ and $c_p > 0$ and $s_p < 0$, a necessary condition for balanced output growth that $s_y > c_y$, that is that the income elasticity of demand for S-sector output exceeds that for C-sector output.

In equation (20) we see that (a) the larger are the price-elasticities of demand, or (b) the faster the growth rate of relative prices (the productivity growth differential) relative to the growth rate of income or (c) the faster is the growth rate of foreign demand for C-sector output relative to domestic income, the bigger is the gap between $s_y$ and $c_y$ needed to maintain balanced growth.

It seems intuitively reasonable to assume $s_y > c_y$, if we (more or less) identify the S-sector as producing services and government output and the C-sector as producing goods. Thus the implicit assumptions about elasticities in the Aukrust-EFO model seem to
be reasonable ones. And an income elasticity of demand for S-sector output that is substantially greater than that for C-sector output provides us with an interesting adjustment mechanism in the merged EFO-demand model.

V. A Merged EFO-Demand Model

In section III we saw that the naive Phillips curve model predicts the rate of inflation in Sweden from the demand side at least as well as the Aukrust-EFO model predicts it from the supply side. The monetarist model is inferior to both, perhaps because of lags and slippage between monetary policy as reflected in \( \dot{M} \) and real output \( \dot{y} \) which actually exerts pressure on the price level. In this section we assume that the Aukrust-EFO equations and the naive Phillips equation are consistent; they are the supply and demand blades of the scissors determining the price level. On this assumption, we try to write down a kind of minimum model – much too simple, of course – that is self-contained and includes both elements.

On the supply side, we saw in section II that the Aukrust-EFO model can be reduced to one equation in \( \dot{P} \) and \( Q_s/Q \):

\[
(21) \quad \dot{P} = \dot{P}_c + \frac{Q_s}{Q} (\dot{q}_c - \dot{q}_s).
\]

This is the same as equation (10) in section II. On the demand side we have the equation linking \( \dot{P} \) to deviations of real output from its trend value,

\[
(22) \quad \dot{P} = \alpha_0 + \alpha_1 \frac{(Y - Y^*)}{Y^*}.
\]

One possible interpretation of the Aukrust-EFO models is that equation (21) determines \( \dot{P} \) from the supply side, taking \( Q_s/Q \) as exogenously determined. The equation (22) could be used to determine the level of aggregate demand needed to accommodate that rate of inflation. This would be the accommodating demand management policy implicit in both Aukrust and EFO.

This interpretation seems unsatisfactory for two reasons. First, the assumption of a passive accommodating aggregate demand management policy seems unrealistic. Surely the monetary and fiscal
authorities have a mind of their own, and think they can influence the rate of inflation by using the instruments that they control. Thus at least part of \( y \) must be determined exogenously, or at least outside the 2-equation system shown here. Second, in the Aukrust-EFO interpretation we have no way to determine \( q_s/Q \), the \( S \)-sector's share of total output.

An alternative interpretation would assume that \( y \) is exogenous, determined by the demand management authorities. Then the Phillips equation (22) would determine \( \hat{P} \). The Aukrust-EFO equation (21) could then be used to solve for \( q_s/Q \). On this interpretation, the overall rate of inflation is determined by demand factors. Then, given the rates of inflation in the two sectors from the Aukrust-EFO equations, the share of the sectors in total output adjusts to give the overall rate of inflation determined by demand conditions. Here the Aukrust-EFO equations determine the shares of the sectors in total output, rather than the aggregate rate of inflation.

It should be clear that this latter interpretation is not dependent on our particular illustrative use of the naive Phillips curve to represent demand-side factors. All the statements in the preceding paragraph would hold for any reformulation of (22) that included only demand factors on the right-hand side:

\[
\hat{P} = f \text{ (demand relative to potential output)}
\]

For example, the statements would hold if we used the quantity-theory equation to predict \( \hat{P} \). The point is that once demand factors are introduced, the Aukrust-EFO equations are thrown into a new light, with a much different interpretation than usual.

This interpretation of the Aukrust-EFO equations can be arrived at in a fairly simple intuitive way. The equations determine the price level of the two sectors at any point in time. In the ordinary supply-and-demand diagrams of Figure 3 this means horizontal supply curves at those prices. But then if the demand curves for the two sectors are fixed, these prices determine outputs in the two sectors, along the demand curves.

14) This implicitly assumes sterilization of the potential effects of the balance of payments on the money stock.
The adjustment mechanism that moves $Q_s/Q$ to align $\dot{P}$ from (21) with the demand-side $\dot{P}$ from (22) is the demand elasticity conditions.

Figure 3: Demand effects on composition of output

implicit in the Aukrust-EFO model. As we saw in section IV, the income-elasticity of demand for the S-sector output must be greater than that for the C-sector output. Starting from an initial equilibrium pair $\hat{p}_o$, $(Q_s/Q)_o$, assume an expansionary monetary-fiscal policy, raising the level of real income relative to its trend and, from equation (21), the equilibrium rate of inflation. With price growth in each sector given, the increase in income increases the demand for S-sector output more than that for C-sector output since $s_y > c_y$ from section IV. This raises the S-sector share of output, $Q_s/Q$, increasing the rate of inflation indicated by the supply-side equation (21) until it equals the equilibrium rate from (22). This process is illustrated in Figure 3. There we show price in the two sectors (momentarily) fixed by the Aukrust-EFO equations. The initial demand curves $D_o$ are identical, for simplicity. The increase in income shifts the S-sector demand curve out more than the C-sector demand curve, increases the S-sector share of total $Q$, and increases $\dot{P}$ in equation (21).
Thus embedded in the implicit demand assumptions in the Aukrust-EFO model is an adjustment mechanism that makes that model consistent with a demand-oriented theory of the rate of inflation. This requires only a re-interpretation of the EFO-equations as determining output shares.

The same mechanism could explain the changing composition of employment between the two sectors in Sweden since the Korean War. In 1954 the profit share in the C-sector was 33.8%. Since then it has shown a fairly steady decline to 25.6% in 1968. This continuing profit squeeze can be taken as evidence of wage increases in excess of productivity growth, as was shown in equation (2) in section II. As a result of the squeeze, we would expect employment in the C-sector to fall, or to rise less rapidly than in the economy as a whole; with the profit share falling on average in the C-sector, firms doing better than average would not be expanding rapidly enough to employ all the workers laid off by firms at the low end of the sector's profits distribution.

Let us assume the monetary and fiscal authorities react to this potential rise in unemployment by expanding aggregate demand. Then, given the implicit Aukrust-EFO assumptions about income elasticities of demand, we would expect a continuing shift in the mix of output and employment toward the S-sector. In fact, from 1954-68 employment in the C-sector fell by nearly 2%, while employment in the S-sector rose by nearly 4%, consistent with this revised interpretation of the EFO mechanism.

Of course, other adjustment mechanisms also lie below the surface in the Aukrust-EFO model. Despite their view that \( \dot{W} \) is exogenous, EFO themselves [1969, p. 146] note that the rate of wage increase depends on "labor market conditions". Thus one additional adjustment mechanism would be movements in relative wages as labor demand changes between sectors. This would tie \( Q_s/Q \) to relative wages. Another obvious mechanism is government employment, which is part of \( Q_s \). As labor demand varies in the C-sector, government employment in the S-sector will show at least partially offsetting employment variations, as the government attempts to stabilize total employment.

15) These data and the employment data mentioned below come from EFO [1970].
VI. Conclusions

The Aukrust-EFO model is an attempt to take account of the international dependence of a small open economy. This dependence comes from an exogenously given development of foreign prices and is transmitted through the supply side to the internal price level. The authors of the EFO-report claim that they have a new theory for price determination and that all traditional demand side explanations are inferior. Many of these theories also recognize the international dependence although the transmission of foreign impulses is through the balance of payments and the money supply rather than directly through the price level. The EFO-report does not mention this mechanism or what happens to the money supply. (Further, it is very unclear if the model is a short-run or a long-run model.)

In this paper we have presented the analytical content of the Aukrust-EFO model and we have then performed some simple tests of its predictive performance. It turns out that for the long-run comparison the simple quantity theory works just as well as a price predictor. For the short run it is the naive Phillips curve model that gives the best result for Sweden, while in Norway the Aukrust-EFO model is the best price predictor.

Our interpretation of these findings is the following: In the long run, and even more so in the short run, the demand side is important in determining price changes unless the demand side is made passive through an accommodating economic policy, as seems to be the case in Norway. The claim in the EFO report about the inferiority of the demand side models is therefore simply not justified. This point becomes more important when we consider that we only tested the crudest type of demand models. The way to a more satisfactory explanation of price developments in the future is through a model that combines demand and supply factors, not through more single-factor models.
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