During the past decade of stagflation, a debate has raged among economists about the real costs in output and employment of using demand restraint to reduce inflation. This paper suggests that the costs of demand restraint may go beyond the short-term cyclical costs captured in most Keynesian models, to include long-term reductions in physical and human capital, and permanent increases in the unemployment rate. A dynamic model is developed which explicitly considers the links among demand, capacity, and unemployment, and demonstrates formally how demand restraint can reduce future capacity and thereby lead to permanently higher unemployment and lower output. There is thus no "natural" rate of unemployment independent of monetary and fiscal policy. The paper concludes that models which ignore long-term capacity effects may seriously underestimate the true costs of demand restraint as an anti-inflationary tool.

TIME AND THE NATURAL RATE OF UNEMPLOYMENT

Consider a model with a unique natural rate of unemployment to which the economy will return in the long run after a change in demand conditions. The policy implications of such a model depend crucially on the time required to reach the new equilibrium or, on how long the "long run" is. At one extreme on this issue are the rational expectations theorists like R. E. Lucas (1972) and T. J. Sargent and N. Wallace (1975), who collapse the long and short runs into periods of almost instantaneous adjustment to changing demand conditions. Variations of unemployment from the natural rate are mainly stochastic, and a "classical dichotomy" between nominal and real variables is established. Whatever their theoretical attractions, such models appear to be poor guides to macroeconomic policy, as F. Modigliani (1977) and J. Tobin (1980a) have argued, because actual adjustments in the aggregate economy require significant amounts of time.

If time matters in models of unemployment and demand, it should be treated explicitly, as it is in simulation models of period analysis. Such models can be used to provide normative guidance on optimal economic policy, as in J.G.W. Cramlich (1979) and F. Modigliani and L. Papademos (1978). For present purposes, we prefer the very simple simulation model of James Tobin (1980a), which consists of four equations:

\[ y = y_n - 295 (0.333 y = 712) \]

\[ p = p_0(1 + \frac{A}{y_n - y}) \]

The first three equations show the percentage change from the previous quarter, expressed as an annual rate, of nominal national income (y), the price index for national income (p), and real income or output (y). We begin in a steady state with \( p = 10 \) percent and \( y = 3 \), which implies from equation (3) that \( y = 13.3 \); unemployment is initially at the natural rate of 6 percent. The natural rate is here synonymous with the non-accelerating inflation rate of unemployment, or NARU in equation (2), the rate of inflation will be constant, accelerate, or decelerate as the rate of unemployment is equal to, below, or above the model of equations (1) to (3), which we will call the NARU model, shows the results of a policy of restrictive aggregate demand which lowers the rate of growth of nominal income by 1.03 percent per year (2.575 percent per quarter) for six years, and then maintains a steady \( y = 7.12 \), which is consistent with \( q = 3 \) and \( p = 4 \), the new trend rate of inflation.

Price changes in the NARU model depend upon the average value of a Phillips curve term which is zero at the natural rate of unemployment, and upon the average rate of inflation over the previous eight quarters (p). This latter term captures the inertia of prices and wages, which has been analyzed in great detail by the late Arthur Okun (1961) and resulting from the institutions characteristic of advanced market economies, including implicit contracts, corner-labour markets, and customer product markets. In Tobin's specification, the inertia lasts two years. By definition, the growth of real output depends upon the difference between the growth of income and prices.

Equation (4) is a rule (or law) of inflation which Tabor prefers to earlier estimates of one-third, including those of Okun (1962) itself.

Panel A of Figure 1 shows the development of unemployment and inflation in the NARU model, beginning at 0 (at time zero) and ending at F (after twenty years). Panel B indicates the long-term equilibrium with \( p = 4 \) and \( y = 6 \). Four other points are indicated: A has maximum unemployment (\( y = 9.90 \)), B, minimum unemployment (\( p = 1.03 \)), C, minimum unemployment (\( u = 4.72 \)), and D, a local maximum for inflation (\( p = 5.63 \)). The number of years required to reach each point is shown below the graph. The diagram shows the spiral produced by inertial prices and the Phillips curve, as the economy heads slowly towards its new equilibrium. The rate of growth of output can be deduced from equation (3); it falls rapidly at first in response to falling nominal demand growth, reaching a minimum of 1.37 percent after 3.25 years, but then as prices are slowed by high unemployment, \( p \) rises, reaching a maximum of 6.07 percent at 3. After six years, with \( y \) fixed at 7.12 percent, output growth is a simple function of inflation: \( q = 7.12 - p(1.03 + dp) \).

James Tobin (1980a) has used this simple model to argue that even in an economy with an immoveable natural rate of unemployment to which the actual rate must return "in the long run," anti-inflationary demand restrictions can be a very unattractive
policy. The unemployment rate is above the natural rate of 6 percent for the first ten years of the simulation, and above 8 percent for six of those years. Such results imply large economic costs and might well be disastrous politically for the government carrying out the policy, the "long-run" is simply too long in coming. The costs involved would be reduced if credible government policy statements and the threat of high unemployment led to more rapid wage and price adjustment, as William Feller (1978) and William Paske (1980) have argued, but some inertia would still remain, and there are limits to the credibility of democratic governments facing elections at regular intervals.

There is, moreover, an aspect of the NAIRU model which may tend toward an understatement of the dynamic costs of demand restraint. The model ignores the negative impact of high unemployment on economic capacity, an investment in physical and human capital is reduced. If prices depend on capacity utilization, as distinct from unemployment, demand restraint can raise the natural unemployment rate consistent with stable inflation. To demonstrate this, we must modify the NAIRU model to take explicit account of capacity and capacity utilization.

**ENDOGENOUS CAPACITY AND DEMAND RESTRAINT**

In an economy with a steadily growing labour force, capacity will be a function of past investments in human and physical capital. Such investments are pre-cyclical, in that they increase when general economic activity increases. Recessions depress investor confidence and reduce investment not only in physical capital, but also in human capital, as the unemployed lose the opportunity for on-the-job training and the acquisition of employment skills. Thus, capacity growth is an endogenous function of capacity utilization. We may define $X$ as capacity output and $Q$ as actual output, with growth rates $x$ and $q$, respectively. Let $v = 100Q/X$ be capacity utilization in percentage terms, with normal utilization defined as 100 percent. Then capacity growth may be modelled as follows:

$$x = 3 + 0.5(100v - 100) \tag{6}$$

where $v$ is an eight-quarter moving average of $v$, analogous to $p$ and $pp$ for prices. Capacity growth depends upon past investment (see Davidson, 1978a), and thus upon lagged utilization. When utilization is steady at the normal rate ($v = 100$), capacity grows at three percent per year.

By (6), a sustained one percent reduction in utilization ($dv = -1$) will reduce capacity growth by one-tenth of a percent. The effect of variations in this coefficient will be considered below; the choice of an initial value of one-tenth has been discussed elsewhere (Davidson, 1979a, pp. 30, 11). We begin our simulations below with normal utilization of $v = 100$. Changes in $v$ may be computed as:

$$v = 100 \left(1 + \frac{0.02}{X}ight) \left(1 + \frac{Q}{X}ight) = v \left(1 + \frac{250}{X}ight) \tag{7}$$

The 25 exponent converts the growth rates from an annual to a quarterly basis. Thus, for example, capacity utilization will rise when output grows faster than capacity ($q > 0$).

Our new model assumes that inflation is a function of capacity utilization rather than unemployment, and thus we must modify equation (2) above. The message of that equation is simple: over time prices adjust to conditions on the labor market to produce full employment, or at least a level of unemployment independent of demand policy. The NAIRU may vary with demographic conditions and the level of certain transfer payments (unemployment insurance benefits, for example), but it is assumed to be independent of past movements in aggregate demand. This assumption has been increasingly challenged over the past decade, as the economy seems stuck at rates of unemployment too high to be explained demographically, with surprisingly little impact on inflation. In models like those of Arthur Okun (1981) and James Tobin (1972), the unemployed are generally poor substitutes as employees for those who continue working during a recession, because of firm-specific skills and implicit long-term commitments (Okun’s "invisible handshake"). Thus, high unemployment may have only a small impact on the rate of inflation, and there is no tendency for inflation to adjust so as to drive the economy to an exogenous NAIRU.

A promising substitute for unemployment in our price equation is capacity utilization. Although firms may indeed ignore unemployed workers in their pricing decisions, they can not ignore unemployed plant and equipment, whose fixed costs represent a drain on profits. Thus while the unemployed may be seen as an externality with respect to the behavior of firms and employed workers, the costs of unused plant are internal to the firm, and will exert downward pressure on the rate of inflation. Correspondingly, when utilization is high, firms will feel more confident about raising prices, either by increasing mark-ups, or by passing on wage increases in product prices. Thus, wage and price increases will be a function of plant utilization rates and not of unemployment rates per se. Variations in the rate of inflation should drive the economy over time toward normal rates of capacity utilization, but this may be quite consistent with rising rates of involuntary unemployment.

We thus wish to change equation (2) to make inflation a function of utilization rather than unemployment. Suppose that at the start of the simulation, utilization is at the normal level with $v = 100$, and that $x = 3$ and $u = 6$. Then the Okun's law coefficient of $3$ from equation (4) implies the following initial short-run relation between $u$ and $v$:

$$u = 6 + 3(100 - v) \tag{7}$$

Thus a two percent change in utilization leads to a one percent change in unemployment. Using this relation we may substitute for $v_{1}$ in (10) to obtain:

$$p = pp_{1} + 4 \left(1 - \frac{2}{100 - v_{1}}\right) \tag{8}$$

At normal utilization ($v = 100$), inflation is steady ($p = pp_{1}$). Inflation will accelerate or decelerate as utilization is above or below normal, in a manner which is initially consistent with equation (5). It is important to realize that equation (7) holds only at the start of the simulation. As time passes, the relation between $u$ and $v$ will change. The general short-run relation can be written as:

$$u = u' + 3(100 - v) \tag{9}$$

where $u'$ is the normal capacity unemployment rate, defined as the rate consistent with normal capacity utilization ($v = 100$). Unlike the fixed NAIRU of equation (2), the normal capacity unemployment rate is a function of demand constraints, for example, will reduce investment and capacity growth, and raise $u'$. 
In the capacity model, the spiral arrow is to the right, and the economy never returns to the initial unemployment rate of six percent. The new normal capacity unemployment rate in long-term equilibrium at point E is $u^* = 7.68%$. Demand restraint lowers the rate of capacity growth, which in turn reduces the rate of growth of output relative to that in the NAIRO model, and produces a higher rate of unemployment at A in the capacity model. But disinflation now depends on capacity utilization rather than unemployment, with the result that the rate of inflation at B is higher in the capacity model. This produces a lower rate of growth of output at B ($g = 5.37$, as opposed to 6.07 in the Tobin model), which in turn means the reduction in unemployment after B is much less in the capacity model.

Figure 1 shows the behaviour of five key variables during the twenty years of the simulation indicated on the horizontal axis at the bottom. Solid lines plot values from the capacity model, and dotted lines are from the Tobin model; the horizontal dotted lines are the original equilibrium values, except in the case of $u^*$, where the asymptotic value of $u^* = 7.68$ is indicated. The top graph shows how the slowdown in capacity growth pushes the unemployment rate in the capacity model up above that in the Tobin model. The second graph plots the ratio $Q/Q_0$, where $Q$ is the level of output at a steady growth rate of 5 percent, i.e., the level of output in the absence of demand restraint. The long-term value of $Q/Q_0$ is unity in the Tobin model, and .968 in the capacity model. In the capacity model, a higher permanent unemployment rate means a permanently lower level of output. Since $Q$ grows at a steady 3 percent, $Q/Q_0$ will rise or fall as $g$ is greater or less than 3 percent, but by equation (4) these are also the conditions for reductions or increases in the unemployment rate. Thus for each model, the turning points in the graphs for $u$ and $Q$ occur in the same years.

The bottom three graphs of Figure 2 show the pattern of $u^*$, $x$, and $v$ in the capacity model. Utilization is below normal ($v < 100$) for the first eleven years, but then inflation adjustments move the economy toward $v = 100$. The growth rate of capacity follows $v$, but with a lag, because of the vv term in equation (5). The normal rate of unemployment, $u^*$ from equation (9), rises when $x$ is below 35; $u^*$ reaches its long-term value of 7.68 percent after nine years, and then fluctuates about that value.

The costs of demand restraint are far greater in the capacity model than in the NAIRO models. Restraint now produces a permanent increase in the unemployment rate. Thus in a surprisingly simple model, we are able to capture a phenomenon of concern to a growing number of economists--the possibility that because of lagging capacity, some of the policy-induced unemployment of the past decade may be permanent in nature. If people are to live comfortably, it is a significant problem. If the central bank's inflation rate is a major recession, they too will be impaired. When the central bank tries to stop inflation, the economy may be able to sustain a short-term increase in unemployment. If demand is held too low below capacity output, capacity itself may shrink (at least to avoid the potential labour force) with disastrous consequences for the economy.
Figure 2

UNEMPLOYMENT, RELATIVE OUTPUT, AND CAPACITY

James Tobin (1980a, p. 59) makes a similar point in discussing the upward drift of the natural rate of unemployment during the 1970s:

Normal rates of operation of capital capacity are now reached at higher rates of unemployment of labor than in the 1960s. In other words the ratio of capacity to labour force has declined; peak values encountered bottlenecking earlier labor productivity falls and markups rise when unemployment is still high. The stagnation of the 1970s discouraged capital formation, and businesses positioned themselves to survive cycles of higher involuntary unemployment.

Our capacity model brings out precisely the links among demand restraint, capacity utilization, capacity growth, inflation, and unemployment with which Lipsey and Tobin are concerned. These links are absent in standard models of inflation and unemployment which are based on a NAIRU independent of demand, and which either ignore capacity, or confine the growth rate to an exogenously given value.

OUTPUT LOSS AND THE SACRIFICE RATIO

During the latter half of the 1970s, the late Arthur Okun repeatedly stressed the high costs of anti-inflation demand restraint, often by computing rough estimates of the loss of output necessary to reduce inflation by one percent. In a review of six estimates of the short-run Phillips curve, Okun (1978) found the cost of a one percent reduction in inflation to vary from 6 to 18 percent of a year's GNP, with a mean of about 10 percent. The ratio of output loss as a percentage of GNP to inflation reduction has been dubbed the "sacrifice ratio" by Gordon and King (1982), who prefer a ratio of 5.6 for the U.S. economy among several which they compute.

The sacrifice ratio and other summary data from the simulations of the NAIRU and capacity models are indicated in lines 1 to 3 of Table 1. The five columns of the table show the average values of p and u over twenty years; the values of the normal capacity unemployment rate (u*) toward which the economy is tending asymptotically; the output loss over twenty years, as compared to steady growth at q = 3, with losses discounted at 3 percent, and the total loss expressed as a percentage of the initial level of output and the sacrifice ratio, the ratio of the output loss to the reduction in inflation below the original value of p = 10. Line 1 shows the results of allowing the economy to grow in its initial steady state for 20 years; p = 10 and u = 6 are constant, and there is no output loss. The remaining lines in the table show the result of demand restraint which reduces the rate of growth of national income from y = 13.3 to y = 7.12, the latter being consistent with long-term inflation of four percent.

The second line of the table shows the result of simulating the NAIRU model over twenty years. Average p is reduced by 5.01 percent (from 10 to 4.99) at the cost of a discounted output loss of 40.6 percent of initial output, with a sacrifice ratio of 5.1 = 0.5.6 (7.1). The economy spirals toward a value of u* = 6, with an average value of u = 7.02 over twenty years. Line 4 of the table shows the simulations of the capacity models: inflation is marginally higher than in the NAIRU model, but unemployment, the output loss, and the sacrifice ratio are all substantially higher. Note that Okun's law produces a rough relation between output loss and unemployment. Relative to the no restraint scenario, the NAIRU model increases average unemployment by about 1 percent with an output loss of about 40 percent; roughly speaking, the capacity model raises the average unemployment rate by an additional 1 percent, and the output loss by an extra 40
percent. Thus each additional point of unemployment raises the output loss by about 40 percent of initial output. This relation derives from the Okun’s law equation common to both models, in which an extra point of unemployment is associated with an annual reduction in output of two percent, which becomes 50 percent when the higher unemployment is maintained (on average) over twenty years.

Simulations like that of our capacity model in line 3 raise the following kind of questions: to what degree would the results vary if a particular parameter value were changed? We consider this question with regard to five key parameters contained in the behavioural equations of the capacity model:

\[ y = y_0 - a_1 \cdot (13.3 \cdot y - 7.2) \]  \hspace{1cm} (\text{1})

\[ p = p(p(s_1) + a_1 \cdot \frac{12}{12 + v}) \]  \hspace{1cm} (\text{2})

\[ u = u_0 + a_2 \cdot (3 - q) \]  \hspace{1cm} (\text{3})

\[ x = 2 + a_4 \cdot v_0 \cdot 100 \]  \hspace{1cm} (\text{4})

\[ s = \frac{3}{a_6} \]  \hspace{1cm} (\text{5})

The parameters are \( a_1 \), the rate at which aggregate demand is reduced; \( a_2 \), the number of quarters in the inertial price term \( s_1 \), which indicates the responsiveness of inflation to variations in utilization; \( a_3 \), the Okun coefficient; and \( a_4 \), which shows the responsiveness of capacity growth to variations in utilization. In the simulation of the model reported in line 3 of the table, these parameters have the following values: \( a_1 = 2.575 \), \( a_2 = 8 \) quarters, \( a_3 = 1, a_4 = 1.25 \), and \( a_6 = 1 \). Lines 4 to 13 of the table are based on simulations when an alternative value is used for one of the parameters. Two alternatives are shown for each parameter; in each case, the one with the lower sacrifice ratio is shown first. In all cases but one, the new parameters are \( .5 \) and \( 1.5 \) times the original values just cited; the exception is \( a_1 \), for which the new values are \( .3 \) and \( 3 \) times the original.

In the original simulation of line 3, demand restraint reduces the growth of national income from 13.3 to 7.12 percent over six years. Line 4 shows the effect of a more gradual reduction of the same total amount over ten years (implying a reduction of \( a_1 = .545 \) percent per quarter), and line 5 shows a cold turkey policy which achieves the full reduction in just two years. The cold turkey policy greatly increases unemployment and the output loss, because of the nonlinearity of the right hand term in equation (2): as utilization drops below \( v = 100 \), each additional percentage point fall in \( v \) has a smaller incremental effect in reducing inflation.

With regard to the inflation equation (3), lines 6 and 7 show the effect of an inertial term based on the average inflation in the four previous quarters, and one based on twelve quarters. The simulation results are clearly quite sensitive to the inertial specifications: optimists will take heart at the lower unemployment rates and output loss with weak inertia, while pessimists will be appalled at the impact of demand restraint with strong inertia. Lines 8 and 9 indicate the significant impact of variations in the coefficient relating inflation to utilization rates; these two lines generate the lowest and highest output losses among all eleven simulations of the capacity model.

Changes in the coefficient of Okun’s law are considered in lines 10 and 11. Since unemployment does not enter into the pricing equation in the capacity model, inflation and the output loss are unaffected. With a low coefficient (.95625), variations in output are largely absorbed by variations in productivity, and unemployment is relatively low; a high coefficient means that output reductions require layoffs and unemployment is higher. Finally, lines 12 and 13 show the results of sluggish capacity growth which is little affected by variations in utilization, and capacity growth which is quite responsive to such variations. This is clearly a key variable: the greater the reduction in capacity growth during a recession, the greater the costs of demand restraint.

CONCLUSION

Table 1 indicates the importance of endogenous capacity in the estimation of the costs of demand restraint. In the NAIRU model of line 2, the sacrifice ratio is 8.1, about midway between the preferred value of 5.8 in Guppy and King (1982) and the mean of 10.0 in the articles reviewed by Okun (1978).11 With pricing based on endogenous capacity, the model of line 3 has a sacrifice ratio nearly double that of the NAIRU model. The difference arises because in the NAIRU model the long run classical dichotomy holds: higher unemployment and the output loss are only temporary, although remarkably persistent, as Tobin (1980a) showed. In the capacity model the classical dichotomy is false, not only in the short run, but also in the long run: higher unemployment and an annual output loss are permanent. The extent of the loss is clearly a function of the exact size of the parameters, which of course is an empirical rather than a theoretical issue. Harry restraint is a particularly unattractive policy: comparing gradual with cold turkey restraint in lines 4 and 5, the cold turkey policy achieves an extra 1.14 percent reduction in inflation with an extra output loss of 65.2, for an unappealing sacrifice ratio of 39.6.

The capacity model thus supports the view of Keynes (1936) that nominal magnitudes, including the money supply and aggregate demand, do matter for the behaviour of the real economy. The classical dichotomy is then poor theory and an inaccurate guide to policy: demand managers must continue to act in a Keynesian world, in which nominal demand restraint will have real costs, and gains in reducing inflation must be balanced against resulting losses in employment and output. Thus the Keynesian context can not be dismissed, contrary to the suggestions of Lucas and Sargent (1976). Rather, the warnings of Tobin (1980a) and Lipsey (1981) that restraint-induced unemployment may be permanent, require far more attention than they have yet received.
Table 1

<table>
<thead>
<tr>
<th>Specification</th>
<th>Average Value</th>
<th>Output</th>
<th>L old</th>
<th>Sacrifice</th>
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<tr>
<td></td>
<td>p (1)</td>
<td>u (2)</td>
<td>(3)</td>
<td>Ratio (5)</td>
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<td>1. No Restriction</td>
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<td>6.00</td>
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<td>2. NAIRU Model</td>
<td>4.99</td>
<td>7.02</td>
<td>6.06</td>
<td>40.6</td>
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<td>7.60</td>
<td>77.3</td>
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<td>7.49</td>
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<td>(a1 = .5545)</td>
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<td>8.62</td>
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<td>102.6</td>
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<td>(a1 = .7725)</td>
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<td>6. Weak Inertia</td>
<td>6.94</td>
<td>6.97</td>
<td>6.77</td>
<td>38.1</td>
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<td>(a2 = .4)</td>
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<td>7. Strong Inertia</td>
<td>5.16</td>
<td>8.94</td>
<td>8.51</td>
<td>112.1</td>
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<td>(a2 = .12)</td>
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<td>8. Flexible Prices</td>
<td>6.95</td>
<td>7.16</td>
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<td>(a3 = .6)</td>
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<td>9. Stagflation</td>
<td>5.23</td>
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<td>10. Low Okun</td>
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<td>11. High Okun</td>
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<td>12. Sluggish Capacity</td>
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<td>13. Responsive Capacity</td>
<td>5.14</td>
<td>8.44</td>
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<td>(a5 = .15)</td>
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Notes
1. Tobin (1980a, p. 68) describes the model but does not write out the equations. I have made two minor changes to the parameters of Tobin's simulation. The annual steady growth rate of output has been changed from 2 to 3 percent, which seems more in line with most projections for the U.S. in the 1980s (cf. Saunders, 1981). In addition, nominal demand reductions lower the steady inflation rate from 10 to 4 percent, rather than to 0, as in Tobin's models: this avoids long periods of falling prices, and involves a change in demand policy which is rather less drastic than the one Tobin considers. Note that subscriptions refer to time measured in quarters; thus $u_{t+1}$ is the unemployment rate during the previous quarter.

2. Equation (5) results from solving the identity, $1 + .52y = (1 + .33p)(1 + .51q)$.

3. Tobin (1980a, p. 28) suggests that the Okun coefficient may have risen from one-third to one-half in the United States during the 1970s. Davenport (1982) finds no such change in Canada: the coefficient is about one-third throughout the period 1955 to 1981.

4. Tobin (1980a, p. 61) refers explicitly to these effects of recession, but does not incorporate them in his formal model. Modigliani and Papademos (1978, p. 746) refer in particular to the impact of youth unemployment on the formation of human capital, but again do not formally model the effect. (Clark in 1979, p. 149) is perhaps fairly typical in simply assuming that high employment output grows at an exogenously given trend rate.

5. Note that the .01 coefficients in equations (3) and (6) are used to convert percentages to decimals in the calculation of growth rates.

6. R.J. Gordon (1981, p. 298) refers to the graph of equation (7) as an "Okun's law line."

7. The asymptotic behavior of the model, with regard to $u^*$ and the ratio G/Q described in the next paragraph, is obtained by taking a six-year average beginning in year 41 of the simulation, at which time the cycles are quite small.

8. Barry E. Brown (1977, p. 11) provides a pithy statement of the capacity issue: "In the 1960s we grew accustomed to looking at the problem of recession and boom in terms of the supply and demand for labor. We ran out of workers. Well, today that's not the problem. We're a very wealthy country, but in fact we're running out of capital. We don't have enough capacity to employ everybody."

9. The sacrifice ratios in Gordon and King (1982), Okun (1978), and the present article involve differences in discounting and in the lengths of the periods considered, so that the ratios are not strictly comparable. Nevertheless, the numbers in the text give a good indication of the relative costs of demand restraint in the various models.

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Source: Simulations described in the text.
BIBLIOGRAPHY


