PRODUCTIVITY AND UNEMPLOYMENT

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Popular and political discussion of the connection between productivity growth and employment is generally afflicted with deep ambivalence. The fear of widespread technological unemployment seems always to lie just below the surface of thought. And then, whenever unemployment is persistently higher than the perceived norm, the idea emerges that the advance of technology is destroying jobs that can not be replaced because productivity is already too high and rapidly getting higher. That idea is commonplace in Europe right now, and almost equally so in North America where the going rate of unemployment is considerably lower and falling very slowly.

At the same time, most people are vaguely aware that periods of fast productivity growth are often periods of prosperity and high employment. The alarming increase in European unemployment that began in the mid-1970s coincided with a slowing of the productivity trend, not a speeding up. The twenty years before that, when unemployment rates hovered around two percent of the labor force, were years of extraordinarily rapid increase in productivity. A recent OECD
publication (Employment Outlook, 1993) urged that the cure for excessive unemployment includes faster innovation and diffusion of technological change.

The motive for this paper is precisely to bring an empirical perspective to bear on this tacit contradiction.

There is, of course, a perfectly simple relationship between productivity and employment. Since Productivity = Output/Employment, it follows that Employment = Output/Productivity. This identity holds whether the output and employment in question relate to a single department of a single firm or to a whole industry or to a national economy. Even so elementary a remark teaches a useful lesson: when productivity changes, the effect on employment depends on what happens to the level of output.

The easiest case to understand is that of a single firm producing a single commodity. Suppose that an improvement in technology or organization permits the firm to increase its productivity by ten percent without any purchase of new plant or equipment. Will the firm then employ more or fewer workers? Obviously one can not know without some more information. If the firm can take advantage of its lower costs
to reduce its selling price, and if this price reduction allows it to increase its sales by more than ten percent, then clearly the firm will need to increase employment. If, on the other hand, the nature of the market is such that the lower selling price either does not occur or elicits a smaller increase in sales than ten percent, perhaps none at all, then the firm will have to lay off some workers. This almost trivial case illustrates an important conclusion. The effect of changing productivity on employment depends on the characteristics of the demand for the final output.

The analysis of a whole national economy is much less transparent precisely because the determinants of the demand for "output as a whole" are more complicated than the determinants of the demand for one commodity or for a cluster of commodities. Probably that is why the popular view of the relationship between productivity and employment has changed from time to time, sometimes optimistic, sometimes pessimistic. These fluctuations in opinion need not be wholly erratic. They could be related to variations in the way aggregate demand has actually behaved from time to time.
More often than not, and certainly now, the prevailing opinion is that an acceleration of productivity growth will cause employment to fall (and unemployment to rise). This is equivalent to the belief that an acceleration of productivity growth will not usually lead to a parallel acceleration of production itself. Since aggregate demand can be influenced by fiscal and monetary policy, this belief is in turn equivalent to the judgment that policy can not or will not expand aggregate demand enough to maintain employment in the aftermath of an episode of faster productivity growth. But there have been times when experience led to the opposite conclusion, that faster productivity growth is good for employment. In France, for example, productivity increased at an average rate of 4 3/4 percent a year between 1960 and 1974 and the unemployment rate averaged about two percent. Between 1974 and 1990, however, the rate of productivity growth fell to 2 1/2 percent a year and the unemployment rate rose fairly steadily to more than ten percent. Nor was France atypical: other countries experienced the same conjunction of slower productivity growth and higher unemployment during the later period.
Such crude comparisons are never conclusive. The rise in unemployment after 1970 could have come about for reasons having little to do with the behavior of the productivity trend. Theoretical arguments are unlikely to settle the issue, precisely because it turns so decisively on the reaction of aggregate output to a (favorable or unfavorable) productivity shock. The problem is located at the intersection of the demand side and the supply side, the least developed and most controversial area of macroeconomic theory. The goal of this paper is to see if systematic analysis of the data can uncover a persistent pattern of interrelationship between productivity and employment and to do this in a way that does not depend on any elaborate theory of macroeconomic behavior.

It is not possible to proceed in a complete theoretical vacuum, however. Some sort of minimal model is required. The following example will show why. It is a well-established fact that productivity has a component related to the business cycle: typically productivity rises faster than trend in the upswing of a business cycle, and rises more slowly than trend—or may even fall—in the downswing. There are other nuances but they are not necessary to illustrate the important point. This
is a case in which the causality runs from demand and employment to productivity and not from productivity to employment. If the data show a predominantly positive quarterly association of productivity and employment, it could be a matter of aggregate demand and employment pulling productivity along. It would be wrong to conclude from this observation that an autonomous increase in productivity or acceleration of productivity growth would be followed by higher employment or faster employment growth. The truth of that assertion would depend on a different mechanism that might not be present in the data. Something has to be done to isolate the supply-side productivity shocks. Any method of doing that will involve some theoretical presuppositions. The point is to keep them as few and as simple as possible. The same need to segregate demand shocks from supply shocks has implications for econometric method too.

These considerations about the direction of causality, and the results that we report later on, relate to the business-cycle time scale. Effects occur, as well be seen, from quarter to quarter, and may complete themselves in a year or two. Both the pessimistic and optimistic interpretations of rapid productivity increase can also be played out on a
much longer time scale, however, with the relevant comparisons covering intervals of a decade or more. The basic time series on unemployment and productivity change are not long enough or good enough to allow detailed analysis; if the time-unit is more than a decade, even 50-year time series may contain effectively only three or four "observations."

Nevertheless we begin with an overview of the long-run picture in France and the United States. Even a non-technical visual impression of development over a century provides a useful and perhaps unexpected perspective on the quarter-to-quarter or year-to-year movements that tend to dominate public discussion.

Table A and Figure A exhibit productivity growth rates and unemployment rates for the U.S. averaged over decades and covering the century from 1890. The figures can be read in two ways. The overall association between productivity growth and unemployment is very weak. If one omits the outlying observation for the decade of depression in the 1930s, when unemployment was extraordinarily high and productivity stagnated, there is very little to be seen. Omitting the depression decade makes some sense because the stagnation of productivity may very well have been induced by the Depression itself. Anyway, if the Depression
decade is taken at face value and included, the literal reading would be that the correlation is strongly negative. In fact the rank correlation associated with Table A is -0.73.

On either interpretation, the long-period data for the United States give evidence against the hypothesis that rapid productivity growth is associated with high unemployment. Whatever a detailed analysis of the short-run may show, the result will have to be consistent with the absence of any showing of persistent technological unemployment.

The story for France is shown in Table B and Figure B. The data are not arranged so neatly in decades and the unemployment rates are missing for the two wartime intervals. It is plain, however, that the French history confirms the conclusions drawn for the United States. There appears to be no significant long-run association between productivity growth and unemployment. The slight impression of a downward slope in Figure B comes mainly from the observation for the period 1930-1939, when productivity actually fell. It can hardly be doubted that this was an effect of the Depression and not a cause. The rank correlation associated with Table B is -0.43, but without the Depression observation it would be close to zero.
There is thus no basis in the past for a pessimistic evaluation of the likelihood of persistent technological unemployment. Of course the future need not be like the past; the next surge of fast productivity growth could be associated with high unemployment, technological or otherwise. But that case can not be made as an induction from history. (It goes without saying that the advance of technology can inflict unemployment on some disadvantaged segment of the labor force. But that can happen even if overall productivity growth is slow.)

The preceding discussion shows that even on the time-scale of decades it is not always possible to evade the possibility of causality running from the demand side to productivity growth. That danger becomes a preoccupation when we turn to the analysis of the short-run connection between unemployment and productivity growth.

To proceed, we need to maintain a distinction between quantities determined from the demand side and those determined from the supply side. Let $y$, $e$ and $x$ represent the logarithms of current output, employment and productivity. The suffix "*" will designate the same quantities measured at "potential" or "natural" or "normal" states of the economy, so that $y^*$ is the logarithm of potential output (real GDP). Our
intention is to avoid unnecessary debate about the meaning and significance of these concepts; but the mode of argument will make more sense to someone who is prepared to accept that much of the time the economies we observe are operating at below-potential employment and output.

As a matter of definition, then,

\[ (1) \, x = y - e \]

and, with more significance,

\[ (2) \, x^* = y^* - e^*. \]

The point of (2) is that the supply-side concept of productivity is measured at the potential or normal state of the economy. Much of the time, the economy generates less-than-potential employment and output; at such times measured productivity from (1) will differ systematically from potential productivity as in (2). The question to be explored is this: if there is an exogenous shock to \( x^* \) or to its rate of growth, how does that affect the time path of \( e \)?

We observe directly only the "actual" quantities \( y, e \) and \( x \). The others have to be inferred. The standard way to connect actual and
potential quantities is Okun’s Law which we adopt in slightly generalized form:

\[(3) \ e-e^* = k(y-y^*) + a(e_{-1}-e_{-1}^*).\]

The well-documented fact is that \( k < 1 \). That is: when output falls below potential in recessions, employment falls proportionally less, so that productivity falls below its normal (supply-side-determined) level. The second term on the right-hand side of (3) is just to allow employment to adjust sluggishly to a change in the aggregate demand for output. It could be replaced by any other distributed-lag process. The important thing is that there be some opportunity for adjustment costs to affect the time series responses.

Since all of the quantities being discussed have characteristic trends, it is sometimes more intuitive to talk in terms of rates of growth, especially for productivity. This can be done by defining \( g = x-x_1 \) and \( g^* = x^*-x^*_1 \). Then \( g \) is the observed rate of productivity growth and \( g^* \) is the rate of growth of the underlying supply-side-determined productivity trend. We are interested in the effects on \( e \) of shocks to \( g^* \). We can use (1) and (2) to eliminate \( y \) and \( y^* \) in (3), and then take first differences to convert to rates of growth. The result is
(4) \[ g = m(\Delta e - \Delta e^*) - b(\Delta e_{-1} - \Delta e^*_{-1}) + g^*, \]

or equivalently

(4') \[ g = -m(\Delta u - \Delta u^*) + b(\Delta u_{-1} - \Delta u^*_{-1}) + g^*. \]

Here \( m = (1-k)/k \) and \( b = a/k \). Expressions like \( \Delta e \) and \( \Delta e_{-1} \) represent current and lagged rates of growth. The meaning of (4) is that if we knew the time-path of the "potential" or "normal" or "natural" or "equilibrium" level of employment, we could isolate the supply-determined rate of growth of productivity by estimating (4) and looking at the residuals. But there is no generally acceptable measure of \( e^* \); and, even if there were, the estimation of (4) (with a constant term added to the right-hand side) would not be straightforward. For example, some methods would guarantee that the residuals from (4) would average to zero over the sample period. That would be acceptable if it were safe to assume that the underlying rate of productivity growth is constant. But that may not always be the case.

In a first pass, we can assume that the "equilibrium" rate of unemployment \( u^* \) is approximately constant in the sample period, or else that it follows a random walk with no drift. That may not be far from
the truth for the U.S. and perhaps Japan. For the major European economies, constancy (or stationarity) of $u^*$ is a much more dubious proposition. Observed unemployment rates have been much higher in the late 1970s and 1980s than before. One widely believed story is that this reflects a higher equilibrium unemployment rate which may, in turn, reflect the increasing rigidity of labor markets. Even if there is only a little truth in this account, that may be enough to make the assumption of a stationary $u^*$ unattractive for Europe. One possibility is to detrend the unemployment rate; but doing so may just eliminate the very characteristic we aim to understand.

If we assume $u^*$ to follow a random walk in the U.S. then the terms in $\Delta u^*$ in $(4')$ reduce to white noise. (If instead $u^*$ is a constant plus white noise, then $\Delta u^*$ becomes a first-order moving average.) If $(4')$ can be reasonably estimated, the residual from the regression will be a fair approximation to $g^*$, the supply-side component of the quarterly growth rate of productivity. So a two-stage procedure suggests itself. In the first stage we try to obtain a reasonable estimate of $(4')$ and thus a time series representing $g^*$. In the second stage the object is to explore
the relation between observed unemployment and the calculated "autonomous" shocks to productivity growth. (4')

Even if we are willing to proceed tentatively with such a simplifying assumption for \( u^* \), there are still problems with (4'). In particular there is every reason to suspect that \( \Delta e \) or \( \Delta u \) will be correlated with \( g^* \); supply-side shocks to productivity growth will affect current employment and unemployment. One sensible way to proceed is by the use of instrumental variables, using as instruments demand-side variables that can safely be taken as uncorrelated with the pure supply-side component of productivity. In effect one first regresses \( \Delta u \) on demand-side instruments and then uses the fitted values from that regression in estimating (4'). Those fitted values, unlike the observed \( \Delta u \), are constructed to be demand-side variables and thus uncorrelated with \( g^* \). The standard requirement on the instruments is that they be correlated with \( \Delta u \) but not with \( g^* \). For example, in one experiment we use as instruments nine lagged changes in the federal funds rate, four lagged changes in \( M_2 \), and current and five lagged changes in real spending by state and local governments.
To summarize: the procedure has three steps. First, regress $\Delta u$ on demand-side variables. The calculated values from this regression can stand for $\Delta u$ purified of supply-side influences. Second, regress $g$ on these calculated values of $\Delta u$, perhaps also with lags. The residuals from this regression according to (4') can stand for $g^*$. Third, regress the observed $\Delta u$ on itself lagged, on the estimated $g^*$ and lags, and perhaps on some other variables intended to capture idiosyncratic supply shocks. This regression provides the sought-for empirical relation between autonomous supply shocks and observed unemployment.

For the first step in this program we did quite a lot of experimentation with different sets of instruments. Obviously it matters which set is used, but not drastically. The choice whose consequences we are reporting is not extraordinary. It includes some monetary and some fiscal variables.

The calculated $g^*$ from the second step is used in a regression that has $\Delta u$ on the left-hand side, lagged values of $\Delta u$, current and lagged values of $g^*$, and some further supply-side variables on the right-hand side. The additional variables are intended to capture supply disturbances that might be affecting unemployment quite independently of productivity
shocks. Examples are changes in population that might affect the labor
force and changes in the price of oil. In both cases some lag structure is
allowed.

The final step produces a characteristic conclusion. When the last
regression is performed using observed changes in productivity the
immediate effect of a rise in productivity growth is a reduction in
unemployment: the message is that a burst of productivity growth causes
the unemployment rate to diminish initially. This is followed by short-
run dynamic effects but, in general, the fall in unemployment continues
for a while. When the calculated series for $g^*$ is used instead, the
apparent contemporaneous effect of a rise in productivity growth is an
increase in unemployment, but this is reduced in the next few quarters.

Here we exhibit some sample results from the final stage. These
are "impulse response functions" calculated from the third-step regression
described above. The first, in Figure C, is for the U.S. and the second,
Figure D, for Germany. In each case the graph shows the cumulative
change in the unemployment rate following a one-standard-deviation
shock to productivity growth. It should be kept in mind that this is a
large shock. In the U.S. data, for example, the mean value of $g$ is 0.4
percent quarterly, or a bit over 1½ percent per year. The quarterly
standard deviation is 0.8 percent, so a one-standard-deviation jolt to
productivity change for a quarter would cumulate to 3.2 percent if
prolonged through a year. (We actually cut it off after a single quarter.)

In both countries the immediate response to a positive shock to the
growth rate of underlying productivity ($g^*$) is a small increase in the
unemployment rate. By the third quarter after the shock, the
unemployment rate starts to fall. By the fourth quarter, unemployment is
back to where it was before the productivity shock. Thereafter the
unemployment rate falls slightly below its initial value and stays there.
In view of the large size of the productivity shock, however, it would be
more accurate to say that the permanent response of unemployment is
essentially negligible.

It is interesting to observe, in both countries, that the same
operation gives a different result if it is performed with observed
productivity growth ($g$) and not with the underlying productivity growth
($g^*$). In that case the immediate response to a one-standard-deviation
shock is a small reduction in the unemployment rate. This initial
reduction cumulates and then stabilizes at about 0.3 percentage points.
Even this is small compared to the size of the shock. The reason for the larger response is that the regression mistakenly credits the productivity shock with the demand-side reaction that makes productivity rise when unemployment falls in the upswing of the business cycle.

If this result holds for other countries and after we have made what explicit adjustment we can for changes in $e^*$, our conclusion would have to be that changes in the underlying growth of productivity have only trivial implications for unemployment. Recent data tell us that there is no fundamental reason why aggregate demand can not expand to absorb the extra capacity generated by faster productivity growth. (This says nothing about temporary obstacles to adaptive policy or to other sources of expanded demand.)

The conclusions that emerge from this exercise are simple and straightforward. They can not be stated with confidence because extension of the analysis to other countries could lead to qualitatively different answers. Out tentative answers, however, have the merit of consistency across examples and as between short run and long run.

In the short run, it appears, an increment to productivity growth is likely to be accompanied by a small increase in unemployment. This
Immediate effect is not only small, it is temporary. After about a year the unemployment effect disappears. A literal reading of the statistical results says that, from then on, unemployment is if anything slightly lower than it would have been without the productivity shock. But the "permanent" effect seems to be trivially small.

This fits with the conclusion that emerges from crude inspection of decade averages extending over a century. On that time scale there is essentially no relation between the pace of productivity growth and the rate of unemployment. Only the Great Depression left a noticeable trace, and then the natural interpretation is that the Depression itself was such a disruption of normal production that productivity growth disappeared. The key to high employment does not lie in the rate of productivity growth but in a demand for aggregate output that fully uses normal productive capacity.
<table>
<thead>
<tr>
<th>Period</th>
<th>Productivity</th>
<th>Unemployment Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>(annual growth rate)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1870-1880</td>
<td>2.28</td>
<td>-</td>
</tr>
<tr>
<td>1880-1890</td>
<td>1.86</td>
<td>-</td>
</tr>
<tr>
<td>1890-1900</td>
<td>1.96</td>
<td>10.4</td>
</tr>
<tr>
<td>1900-1913</td>
<td>1.98</td>
<td>4.7</td>
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<tr>
<td>1913-1929</td>
<td>2.39</td>
<td>4.8</td>
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<tr>
<td>1929-1938</td>
<td>0.74</td>
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<tr>
<td>1938-1950</td>
<td>4.03</td>
<td>5.7</td>
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<tr>
<td>1950-1960</td>
<td>2.41</td>
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<tr>
<td>1960-1970</td>
<td>2.51</td>
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<tr>
<td>1970-1979</td>
<td>1.92</td>
<td>5.9</td>
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<tr>
<td>1979-1990</td>
<td>0.80</td>
<td>7.1</td>
</tr>
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</table>

Source: A. Maddison: *Phases of Capitalist Development*. 
TABLE B: FRANCE (all productive sectors)

<table>
<thead>
<tr>
<th>Period</th>
<th>Productivity (annual growth rate)</th>
<th>Unemployment Rate</th>
</tr>
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<tbody>
<tr>
<td>1896-1900</td>
<td>2.0</td>
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<td>1900-1906</td>
<td>0.1</td>
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<td>1906-1913</td>
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<td>1913-1919</td>
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<td>-</td>
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<tr>
<td>1919-1930</td>
<td>5.5</td>
<td>2.58</td>
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<td>1930-1939</td>
<td>-0.4</td>
<td>6.72</td>
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<tr>
<td>1939-1946</td>
<td>-2.5</td>
<td>-</td>
</tr>
<tr>
<td>1946-1958</td>
<td>5.9</td>
<td>2.00</td>
</tr>
<tr>
<td>1958-1968</td>
<td>3.9</td>
<td>2.17</td>
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<tr>
<td>1968-1974</td>
<td>6.2</td>
<td>3.39</td>
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<td>1974-1985</td>
<td>3.1</td>
<td>8.35</td>
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<td>1985-1993</td>
<td></td>
<td>13.02</td>
</tr>
</tbody>
</table>

Source: Carré, Dubois, Malinvaud: *French Economic Growth*. 
Response of Unemployment Rate, US
1 Std Err Shk to Prod, regn inc sup & dmd

Cumulative Change in Unemployment Rate

Period since shock

UNDERLYING PROD

OBSERVED PROD
Response of Unemployment Rate, GM
1 Std Err Shk to Prod, regn inc sup&dmd