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Measuring Capacity Utilization in OECD Countries: A Cointegration Method

by

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I. INTRODUCTION

Growth and technological change go hand-in-hand, because it is new investment that generally ushers in new technologies. But capital accumulation is inherently turbulent, subject to a variety of intrinsic cycles (van Duijn, 1983, ch 1) as well as conjunctural events such as wars, economic policies, and natural events. Therefore, in order to identify the slower and steadier influence of structural change, one must somehow adjust for the cyclical and conjunctural fluctuations. Since the latter variations are generally expressed as fluctuations in capacity utilization, one way to distinguish between short-run influences and structural ones is to develop measures of capacity utilization and of economic capacity. Such considerations are critical to all long-run analysis.

This paper aims to develop a simple general methodology for measuring capacity. The essential idea is that "capacity" is the aspect of output that co-varies with the capital stock over the long-run. This makes cointegration a natural tool for measuring capacity. The technique used here was previously developed for U.S. data, and proved to provide capacity utilization measures that are remarkably close to completely independent measures based on the rate of utilization of electric motors used to drive capital equipment in manufacturing and on unpublished survey data from the McGraw-Hill (Shaikh 1987, 1992, 1999). In this paper we extend the results to encompass various OECD countries.

It is important at the outset to distinguish between "engineering capacity," which is the maximum sustained production possible over some interval, and "economic capacity," which is the *desired* level of output from given plant and equipment. For instance, it may be physically feasible to operate a plant for 20 hours per day 6 days a week, for a total of 120 hours per week of engineering capacity. But it may turn out that the potentially higher costs of second and third shifts make it most profitable to operate only a single 8-hour shift per day for five days a week, i.e. 40 hours per week. This is what defines economic capacity, the firm's benchmark level of output. Equivalently, economic capacity would be represented by an engineering capacity utilization rate of 33.33 % (40/120). Production persistently below this level would signal the need for a slowdown in planned capacity growth,[1] while that persistently above it would signal the need for accelerated capacity growth (Foss 1963, p. 25; Shapiro 1989, p. 184; Kurz 1986, pp. 37-38, 43-44).

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[1] In a growing system, adjustments take place by changes in relative *growth* rates.

It should also be noted that economic capacity is not the same thing as "full employment output."[2] Since both measures have been labeled "potential output," it is important to distinguish them. Even though the full capacity and full employment are common assumptions of standard economic theory, in actual practice there is no reason to suppose that production at economic capacity would serve to fully employ the existing labor force. Indeed, within classical, Keynesian, and Kaleckian traditions, the two are not synonymous even at the theoretical level (Garegnani, 1979; Shaikh, 1987).

It might be supposed that one could distinguish between actual output and capacity by means of some appropriate filtering technique. Indeed, if all actual fluctuations were roughly symmetric, then this might work. But actual data may not only contain multiple cycles, some as long as 20 years, but also generally exhibits a long-term trend (which itself may or may not be part of some longer "wave"). Most techniques for identifying cycles therefore require that the data first be detrended. One common approach is to define the trend as some *a priori* function of time. But there is little reason to believe that growth trends are independent of actual rates of growth, and there is no real reason to prefer one time function over any other. Another procedure is to smooth the data so as to bring out the trend. But here we face the difficulty of disentangling the unknown trend from a multiplicity of cycles, ranging from 3-5 year inventory cycles to 20 year fixed capital cycles. Taking out the most rapid fluctuations leaves in all the longer ones mixed together with the trend. On the other hand, focusing on a particular longer cycle leaves in all of the shorter ones. Moreover, it is well known that various smoothing methods can give rise to spurious long cycles. Finally, there is the problem that fluctuations brought about by depressions, wars, and various other conjunctural events are not generally symmetric. Smoothing techniques tend to split the data into symmetric "ups and downs," which means they generally misrepresent the actual deviations from the trend. For instance, in the case of the Great Depression with its sharp collapse and protracted trough in output, the distortion would be quite significant. The oil price shocks of the 1970s would present similar difficulties.

An alternate approach is to focus on a measure of capacity, because we know that cycles, as well as conjunctural events such as policy changes, depressions and wars, will be reflected in

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[2] Short-run fluctuations in employment are likely to be correlated with short-run fluctuations in output. Thus short-run fluctuations in the employment rate (employment over labor supply) are likely to be correlated with short-run fluctuation in the capacity utilization rate (output over capacity). But unless the ratio of capacity to labor supply, which is a kind of potential productivity of labor, happened to be always constant over time, we can be sure that the capacity utilization rate would deviate from the employment rate over the medium and long-runs.

capacity utilization.[3] The problem of estimating economic capacity would be relatively simple if one could accept the widely held (neoclassical) assumption that, except for downturns associated with the short (3-5 yr.) cycle, capitalist economies generally operate at normal capacity. Indeed, this is the premise of the well-known Wharton method, which defines capacity as the peak output achieved in each business cycle or conjunctural fluctuation. The implicit assumption is that all short-run peaks in output represent the same level (100%) of capacity utilization (Hertzberg, et al, 1974; Schnader, 1984), which automatically excludes the possibility of medium and long term variations in capacity utilization.

A second group of measures tries to get around this problem by relying on economic surveys of operating rates, as in those by the Bureau of Economic Analysis (BEA) and the Bureau of the Census. Here, firms are typically asked to indicate their current operating rate, i.e. their current rate of utilization of capacity. The difficulty with such surveys is that they do not specify any explicit definition of what is meant by capacity. Thus the respondents are free to choose between various measures of capacity, and the analysts who use this data are free to interpret them in manners consistent with their own theoretical premises. A typical case in point is the widely used Federal Reserve Board (FRB) measure of capacity utilization in manufacturing. It begins with a preliminary estimate of capacity by using two different surveys, one by McGraw-Hill (recently discontinued), and one by the Bureau of the Census. The Federal Reserve first combines them in some manner whose details it does not make public. It frequently finds that the resulting estimates of capacity utilization are not plausible from its point of view, so it further operates on the combined capacity measures to smooth them out, using regressions on the capital stock and on time (Shapiro 1989, pp. 185-188). Various other adjustments are also made so as to "move the capacity estimate from a peak engineering concept toward an economic concept" consistent with its underlying theory. It is one of the stated goals of these adjustments that the resulting measure of capacity utilization rate is not "chronically below 'normal' capacity utilization" (Shapiro 1989, pp.187-188). In other words, just as in the case of the Wharton method, the operative premise here is that the economic system generally operates at, or near, full capacity.

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[3] The fast process will produce fast fluctuations in output, and since capacity is relatively slowly changing in the short-run, it will also produce corresponding fast fluctuations in capacity utilization. On the other hand, over the medium process both the average output and average capacity levels generated in the fast process will themselves fluctuate around each other. Hence, here we will get a corresponding medium cycle in capacity utilization.

A third procedure, such as that employed by the IMF, estimates potential output by means of fitted production functions. As has been often pointed out, a production function represents the *optimal* output which can be produced by given *fully utilized* capital and labor inputs (Fisher 1969). Since actual capital and labor cannot be assumed to be fully utilized at any moment (this being the problem under investigation), this method requires some adjustment of the inputs. Thus potential output is estimated using a labor input defined by the natural rate of unemployment and a capital input defined by the trend level of total factor productivity for that particular labor input (De Masi, 1997). Needless to say, this requires theoretical faith not only in the much criticized notion of an aggregate production function (McCombie 2000-2001; Felipe and Fisher 2003; Shaikh 2004) but also in the existence of a natural rate of unemployment. We will return to this issue in the next section when we compare our own measures of capacity utilization to those of the IMF.

A fourth type measure sidesteps the difficulties inherent in the first two by attempting to directly measure the rate of capacity utilization. In a now classic study, Foss (1963) showed that it is possible to estimate capacity utilization by measuring the utilization rate of the electric motors which are used to drive capital equipment. Foss's initial estimates for selected years were subsequently developed into an annual series by Jorgenson and Grilliches (1967) and then improved and extended by Christensen and Jorgenson (1969) to cover the period from 1929-1967, and by Shaikh (1992) to cover the period from 1909-1928. But there exists a major obstacle to the forward extension of this series: namely, that the data on the installed capacity of electric motors, which is crucial to the construction of the series, was dropped after the 1963 Census. Shaikh showed that direct survey data available from McGraw-Hill yielded a measure of capacity utilization that was very similar to that derived from data on electric motor use, in their periods of overlap. This allowed him to splice the two series together to create a complete capacity utilization series from 1947-1985 which differed significantly from the standard Federal Reserve Board (FRB) measure (Shaikh 1987), particularly in terms of longer run patterns such as the Vietnam War buildup during the 1960s, and post-Reagan profit boom from 1982 onward. Unlike the FRB measure, Shaikh's measure is neither symmetric nor stationary over the long-run, and it exhibits much greater fluctuations. Conversely, the capacity-output ratio it yields has a much smoother trend than that derived from the FRB measure. Further detail is provided in Shaikh (1987, 1992, 1999) and in section III of this paper, and additional

discussion can be found in Winston (1974), Gabisch and Lorenz (1987, pp. 26-40), and Tsaliki and Tsoulfidis (1999).

II. THE THEORETICAL FRAMEWORK

Our framework consists of an identity and two behavioral equations. The identity can be stated as $Y(t) = (Y/Y^*) \cdot (Y^*/K) \cdot K$, where Y = output, Y^* = economic capacity, K = capital stock. If we now define v = capital-capacity ratio = (Y^*/K), and u = capacity utilization rate = (Y/Y^*), then

1) $\log Y(t) = \log K(t) - \log v(t) + \log u(t)$

Since output (Y) and capital stock (K) are observed variables, to make the preceding identity into a model we need to specify capacity utilization (u) and the capital-capacity ratio (v). On the side of the former, we assume that output fluctuates around capacity over the long-run, so that the actual rate of capacity utilization (u_t) fluctuates around some desired or normal rate of capacity utilization ($u^* = 1$).[4] This says that firms are able to maintain some correspondence between economic capacity and actual output over the long-run, which is consistent with classical, Marxian, Harrodian and neoclassical theory. Nothing in particular is implied about the corresponding utilization of labor supply (Winston, 1974; Kurz, 1986). In log terms, with $e_u(t)$ representing a random error term, this implies

2) $\log u(t) = e_u(t)$

Our second behavioral assumption consists of a general specification of technical change in which the capital-capacity ratio changes over time, partly in response to autonomous technical change (coefficient b_1) and partly in response to embodied technical change which itself depends on the rate of capital accumulation (coefficient b_2). Letting g_v = growth rate of the capital-capacity ratio and g_K = growth rate of the capital stock, we have $g_v = b_1 + b_2 \cdot g_K$. In log terms, with an added random error term $e_v(t)$, this yields equation 3 below.

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[4] Although we do not attempt it here, it would be possible to allow for a changing normal rate of capacity utilization in the light of changing real wages and relative material prices. This is because the point at which a plant is most profitably utilized can vary with changes in input prices (Kurz 1986).

3) $\log v(t) = b_0 + b_1 \cdot t + b_2 \cdot \log K(t) + e_v(t)$

Equations 1-3 form a general model of the relation of output to the capital stock in the face of technical change and fluctuating capacity utilization. Combining these three equations then yields

4) $\log Y(t) = a_0 + a_1 \cdot t + a_2 \cdot \log K(t) + e(t)$

where $a_0 = -b_0$, $a_1 = -b_1$, $a_2 = 1 - b_2$, and the error term $e(t) = e_u(t) - e_v(t)$.

Equation 4 implies that log Y and log K are cointegrated, up to a possibly linear deterministic trend in the actual data. Moreover, from equation 2, the long-run value of actual output (Y) is capacity output (Y*). With an estimate of capacity in hand, we can then derive the rate of capacity utilization u = Y/Y* and the capital-capacity ratio v = K/Y*.

III. AN APPLICATION TO THE U.S. MANUFACTURING SECTOR

As a benchmark test of our methodology, we utilized the above cointegration framework to derive an econometric measure of the capacity utilization rate for the U.S. manufacturing sector. This was then compared to Shaikh's census-based measure, previously discussed at the end of section I. As Panel 1 shows, the close correspondence between the patterns of the two very different techniques provides a sense of the power of our methodology.[5]

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[5] Cointegration in levels of variables requires some choice of scale, which is usually accomplished by arbitrarily setting the cointegration coefficient of the first variable equal to one. An independent measure of the scale of economic capacity would be ideal. In the present case in which we are comparing our econometric measure of capacity utilization to an independent census-based measure, we can use the average level of the latter to define the scale of the former. But when making comparisons across countries for which no such independent measures are available, and in which some cointegration regressions were in log-levels and others in growth rates (first differences of log-levels), it is somewhat easier to define scale by using the highest growth rate peak over the period of observation. This is the procedure we adopt in the next section.

Panel 1: Census and Cointegration Measures of Capacity Utilization
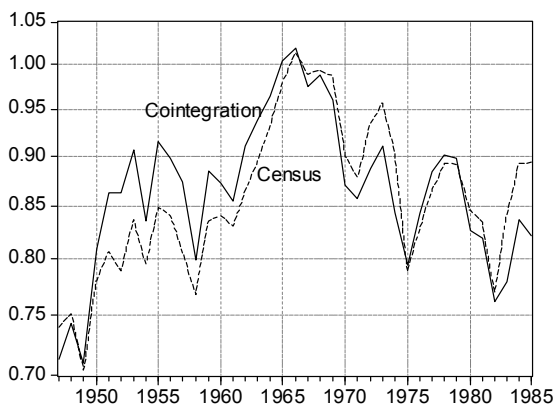
IV. EMPIRICAL MEASURES OF CAPACITY AND TECHNICAL CHANGE IN OECD COUNTRIES

Data on business sector real output and capital stock were obtained from the *OECD Economic Outlook 71* (June 2002) database. Given the relatively small sample sizes and the fact that the unit root tests have low power in such cases, we follow the literature by utilizing three different tests to gauge the order of integration[6]. In general, our final determination of the order of integration of the logs of each variable was based on agreement among at least two of the tests.

The levels of the logs of both output and capital stock were I(1) for Australia, Canada, France, Norway, Sweden, UK, and U.S., whereas they are I(2) for Austria, Germany, Japan, and Spain. In the former group of countries the Johansen cointegration test was carried out on the level of the variables, whereas in the latter group it was carried out on their first differences. In light of our previous discussion concerning scale (see footnote 5), we scaled the level of capacity by equating it to actual output in the year with the peak growth rate. The cointegration tests parallel the form of equation 4, in that they assume a linear deterministic trend in the actual data and an intercept in the cointegrating equation. Further details are provided in the data appendix.

The succeeding set of graphs in Panel 2 display our estimates of capacity and the rate of capacity utilization, the latter in comparison to corresponding estimates from the IMF. Two features are notable. First, our measures of capacity do not simply "thread-through" the actual level of output, as smoothed and filtered methods do. This is generally so, but is most evident in the case of countries such as Austria, Canada, and the UK. Secondly, the measures of capacity utilization derived from our cointegration method are generally very different from those provided by the IMF. It will be recalled

from Section I that the IMF defines potential output via an aggregate production function in which labor is assumed to be employed at the natural rate and capital is assumed to be utilized at the rate corresponding to the trend level of factor productivity. On the other hand, we measure potential output as the component of actual output that co-varies with the capital stock over the long-run. In principle, both measures should filter out short-run movements and highlight long-run ones. Since technical change is generally embodied at the margin through new investment, one would expect the capital-capacity ratio (the reciprocal of the "productivity of capital") to respond fairly smoothly to technical change. Our measure always exhibits this property, but it turns out that the IMF one often does not. Panel 3 displays the two such cases, for the U.S. and the UK. Considerations of space prevent us from exhibiting all of the relevant graphs.

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[6] We used the augmented Dickey-Fuller (ADF), the Kwiatkowsky-Phillips-Schmidt-Shin (KPSS), and the Ng-Perron (NP) tests.

Panel 2: Output, Capacity, and Capacity Utilization Rate
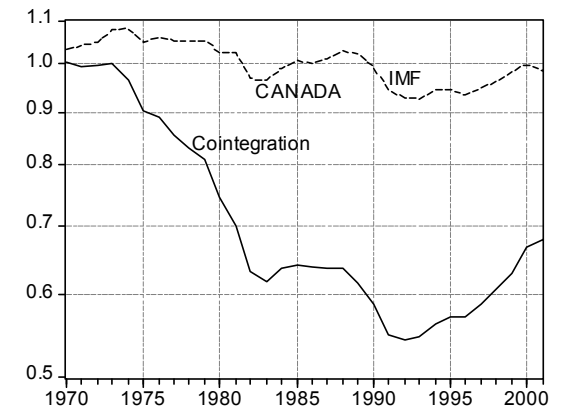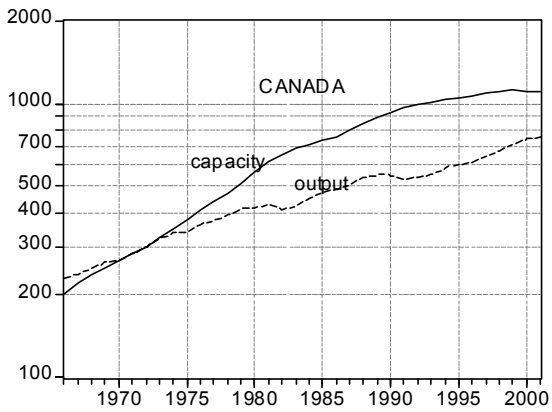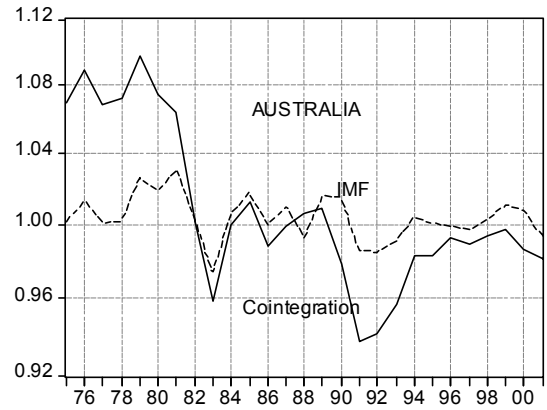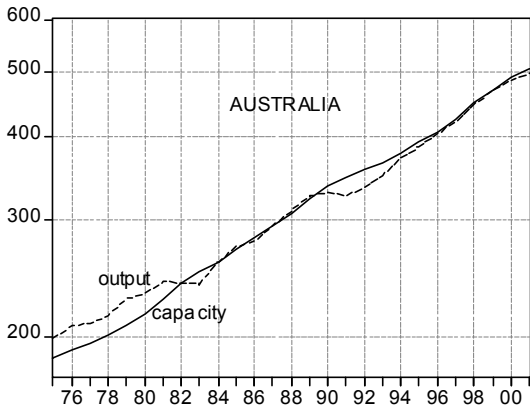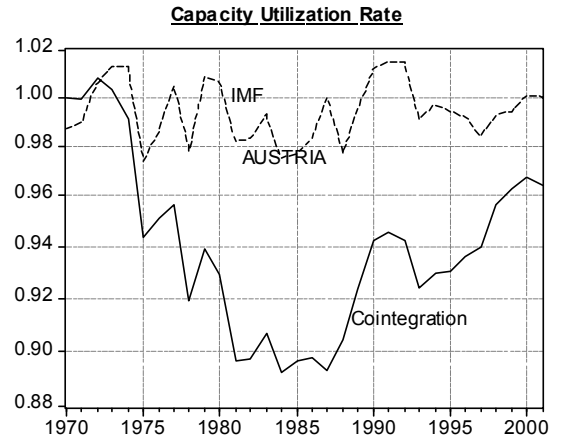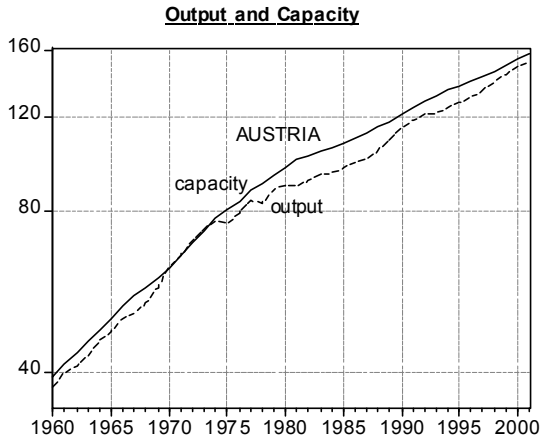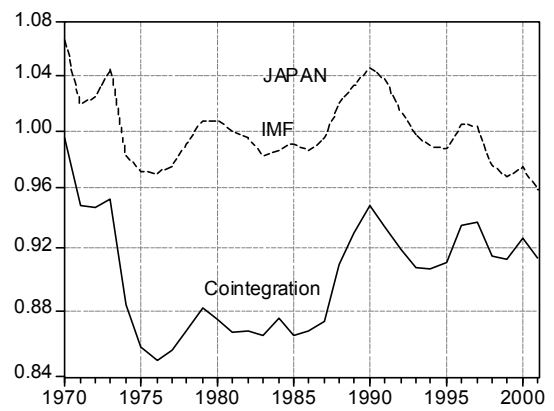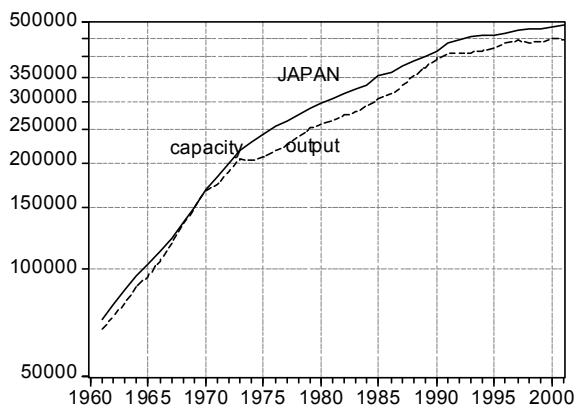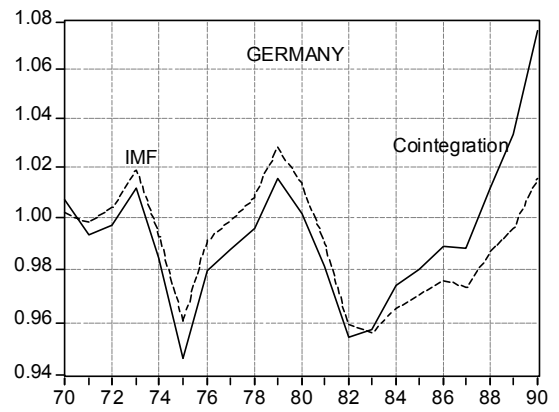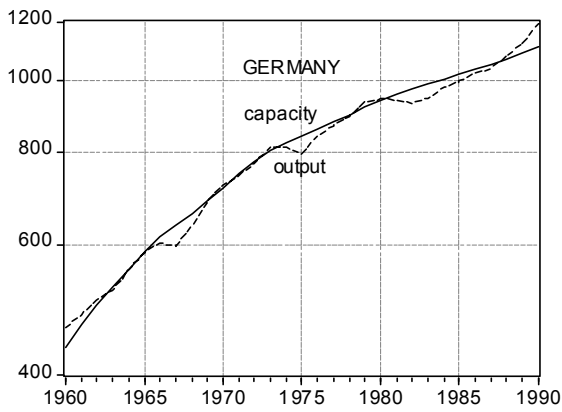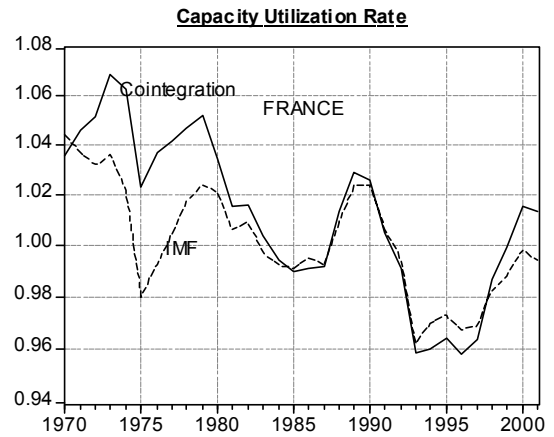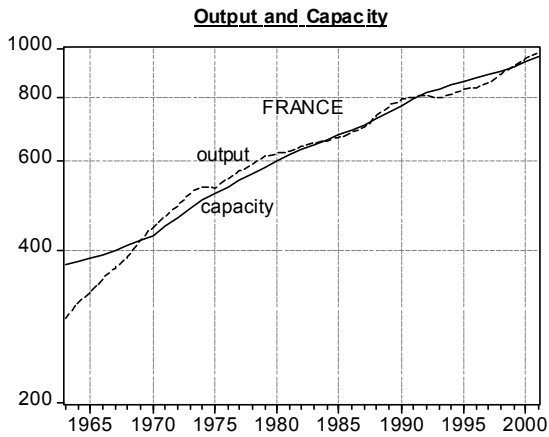
Output and Capacity


Capacity Utilization Rate

Panel 2 (continued):

Output and Capacity

Capacity Utilization Rate

FRANCE

output

capacity

Cointegration

FRANCE

IMF

GERMANY

capacity

output

GERMANY

IMF

Cointegration

JAPAN

capacity   output

JAPAN

IMF

Cointegration

Panel 2 (continued):

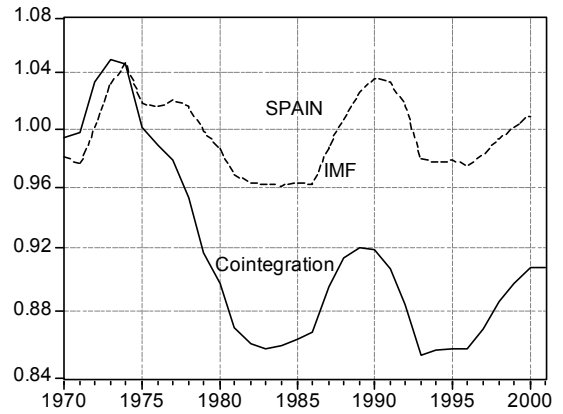**Output and Capacity**   **Capacity Utilization Rate**

Panel 2 (continued):

Output and Capacity
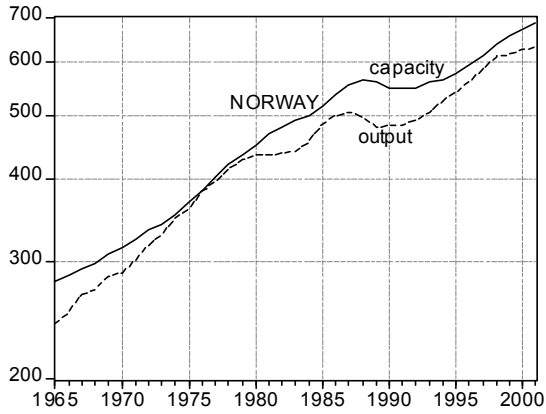
Capacity Utilization Rate
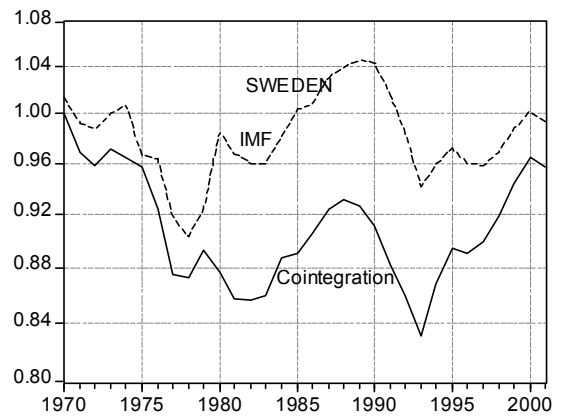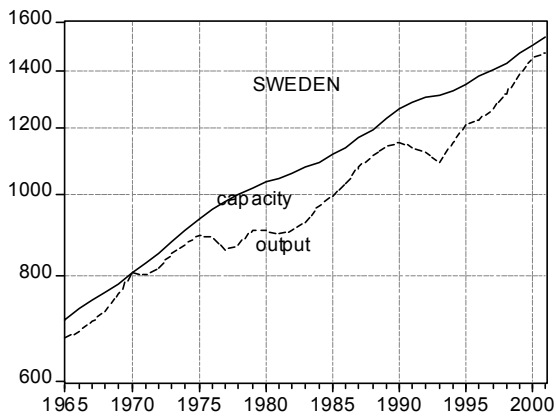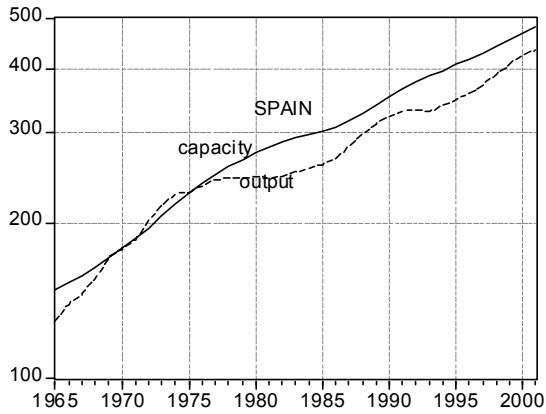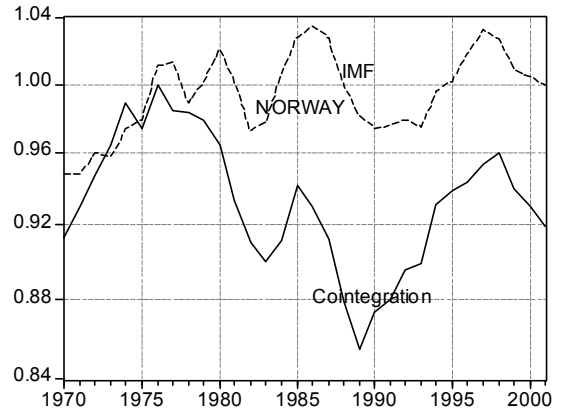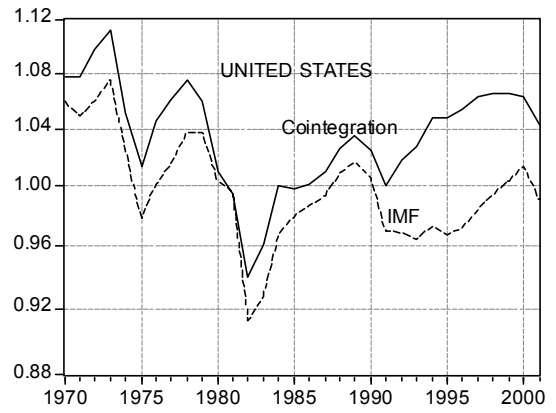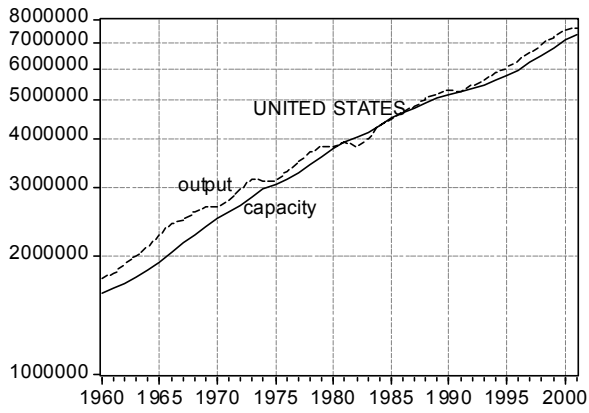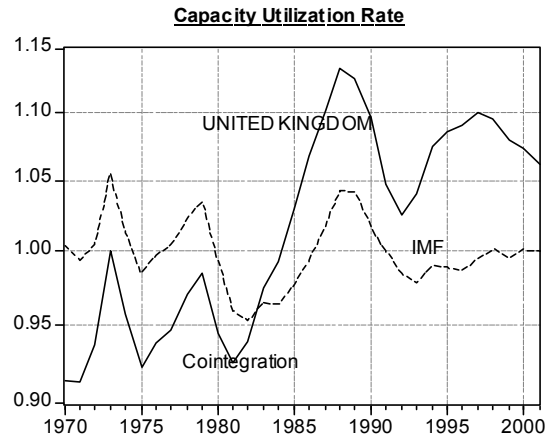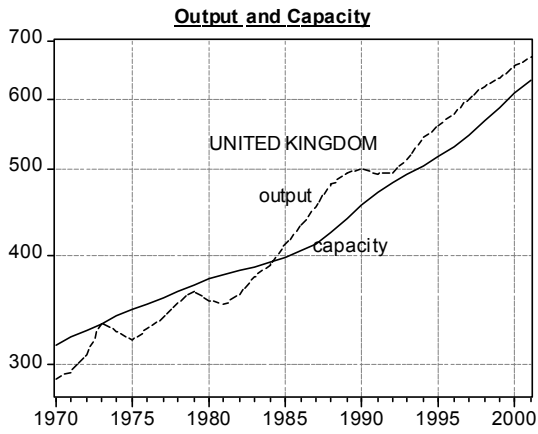
The results for several of the countries show that our measure tends to exhibit a wider range of variations in comparison to the IMF measure which is usually quite damped.

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Panel 3: Capital-Capacity Ratios
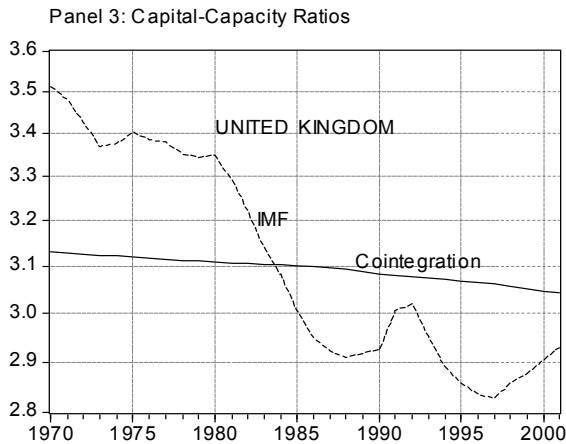
IV. CONCLUSION

In this paper, we provide a simple general method for estimating economic capacity. The
intuitive idea is that economic capacity (potential output) is the aspect of output that co-varies
with the capital stock over the long-run. We show that this notion can be derived from a general
model that allows for a changing capital-capacity ratio in response to partially exogenous,
partially embodied, technical change. Our method has several advantages. It only requires data
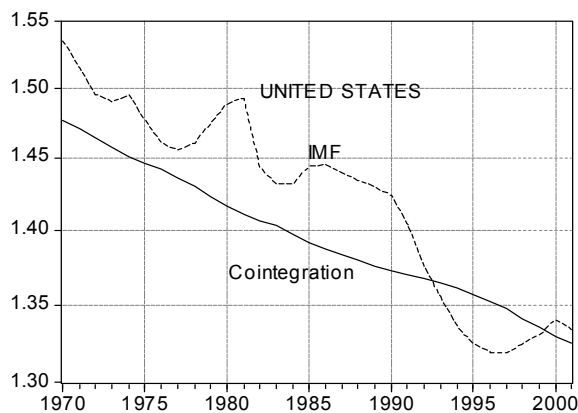on output and capital stock, which is widely available across countries, and even across
industries. It also closely replicates a previously developed census-based measure of U.S.
manufacturing capacity-utilization. Of particular interest is that our measures of capacity are
quite different from standard ones based on aggregate production functions, such as those
provided by the IMF. The two yield quite different patterns for capacity utilization and for the

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capital-capacity ratio (the reciprocal of the "productivity of capital"). In the latter instance, our measure always yields a smooth capital-capacity ratio, while the IMF measure often does not.

Several extensions of this paper are possible. The cointegration method itself could be easily applied at industry levels, since it only requires data on output and capital stock. In addition, the method itself could be deepened by testing for structural breaks in the cointegration equation. Finally, the method could be applied to variables other than output, such as employment and profit, so as to assess the long-term trends of technical change and profitability, respectively.

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DATA APPENDIX

As is well known, the power of unit root tests is rather low, especially when applied to relatively small sample sizes such as the current one. We have therefore decided to carry out three tests: the Augmented Dickey Fuller (ADF), the Kwiatkowsky, Phillips, Schmidt, and Shin (KPSS), and the Ng-Perron (NP) tests. For both the ADF and the NP tests the null hypothesis is the presence of a unit root while that for the KPSS test is that the variable is stationary. We decided on the order of integration of a variable on the basis of at least two of the tests. A decision based on at least two tests made us reasonably confident of our final specification with regard to the number of unit roots in each variable.

Table 1 summarizes the results of the unit root tests.

TABLE 1:

Country	Order of Integration, Type of Test, and Significance Level	
	Output	Capital Stock
Austria	I(2) KPSS*** & NP*	I(2) KPSS* & NP*
Australia	I(1) KPSS*** & NP*	I(1) KPSS** & NP*
Canada	I(1) ADF*, KPSS**, & NP*	I(1) ADF*, KPSS**, & NP*
France	I(1) ADF*, KPSS**, & NP*	I(1) ADF*, KPSS*, & NP*
Germany	I(2) ADF*, KPSS***, & NP*	I(2) ADF*, KPSS**, & NP*
Japan	I(2) ADF*, KPSS*, & NP*	I(2) ADF*, KPSS*, & NP*
Norway	I(1) KPSS** & NP*	I(1) KPSS* & NP*
Spain	I(2) ADF* & NP*	I(2) ADF* & NP*
Sweden	I(1) KPSS** & NP*	I(1) KPSS* & NP*
UK	I(1) KPSS*** & NP**	I(1) KPSS** & NP*
U.S.	I(1) ADF*, KPSS***, & NP*	I(1) ADF*, KPSS**, & NP*

* = significance at 1%, ** = significance at 5%, and
*** = significance at 10%

The Johansen cointegrating test was carried out for all the countries. In the case of those countries for which the variables are I(1), the regression was run on the levels of the variables. For those countries for which the variables are I(2) the cointegration test was performed on the first differences of these variables as these happen to be I(1). With regard to the second group of countries, the cointegration relationship allowed us to derive the growth rate of the capacity utilization rate. It was then assumed that in some peak year of output growth, the capacity utilization rate was at the normal level and was set equal to one. This base year value and the growth rate of the rate of capacity utilization were used to derive the level of this variable. *In order to obtain a consistent scaling method, for the I(1) countries capacity was scaled to make it equal to output in the year with the peak growth rate.*

The regressions were run by assuming a linear deterministic trend in the actual data and an intercept but no trend in the cointegrating equation. Table 2 below shows the coefficients on the right-hand-side of the long-run cointegration equations (t – statistics are in parenthesis). For the countries with I(1) variables the level of output is a function of the level of the capital stock while for those with I(2) variables the growth rate of output is a function of the growth rate of the capital stock.

TABLE 2:

	Constant	Coefficient on the Capital Stock
Country		
*Austria	-0.014	0.889 (7.27)
Australia	-0.145	0.955 (26.66)
Canada	-4.25	1.545 (6.7)
France	1.04	0.766 (31.56)
*Germany	-.0035	0.672 (7.04)
*Japan	-0.017	0.888 (12.52)
Norway	-0.71	1.014 (43.08)
*Spain	0.002	0.658 (3.14)
Sweden	0.434	0.818 (39.62)
UK	-1.439	1.043 (15.87)
U.S.	-2.088	1.112 (38.63)

* For these countries the long-run relationship is that between the growth rates of output and the capital stock.