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# Cyclical Productivity and the Workweek of Capital

*By* MATTHEW D. SHAPIRO*

Standard specifications of the production function assume that an increase in labor given the stock of physical capital will reduce the capital–labor ratio. Since the stock of physical capital is quasi-fixed, the elasticity of output with respect to labor should be less than 1 as long as there are constant returns to scale. However, empirical studies of productivity typically find short-run increasing returns to labor. But the effective stock of capital should not be regarded as fixed if, when labor increases, it goes onto a previously inoperative shift. Labor that works the late shift will have at least as much capital as labor working days. Hence, for increases in labor that are accompanied by increases in the workweek of capital, there is no presumption of diminishing marginal product of labor.

This paper describes briefly a data set that provides a direct measure of the workweek of capital and then investigates its role in cyclical productivity. It finds that much of the apparent cyclicality of total factor productivity is accounted for by variation in the workweek of capital.

## I. Measuring the Workweek of Capital

The Census's Survey of Plant Capacity (SPC) asks questions about actual, preferred, and maximum practical output rates at manufacturing plants. The survey also asks about hours per day and days per week that the plant operates. I use these unpublished data to estimate the workweek of capital.

At the level of an individual plant, the workweek of capital, $S$, can be constructed as the product of hours per day and days per week. The data I have are aggregates of individual plants weighted by total production employment. Since plants with multiple shifts will have more workers, they receive a larger weight than single-shift plants in the Census's tabulations, even if they have the same amount of capital. It is possible to calculate an upper and lower bound on the industry-wide average work week of capital. In this paper, I use the average of those two extremes for $S$.

Across years and industries, the workweek of capital measured by these data averages 80.3 hours per week. The sample period 1977–1988 is centered on a major recession. As expected, the workweek of capital is highly procyclical. In the trough year of 1982, capital's workweek is 5.3 hours below the industry-effects-adjusted mean while for the peak year of 1988 it is 5.2 hours above the mean. In cyclical industries, such as motor vehicles, the swing in capital hours is as much as 50 percent over this sample period. The standard deviation of $S$ is 35.0 hours for the entire sample and 11.7 hours once industry-level means are removed.

Murray Foss (1984) uses historical figures from related Census surveys to study trends in capital hours and their contribution to growth. For cyclical measures, more attention has been given to using the fraction of workers on late shifts as a measure of capital's workweek (see Paul Taubman and Peter Gottschalk, 1971; Shapiro, 1986; Joram Mayshar and Gary Solon, 1993). Because day shifts tend to be larger than night shifts (see Shapiro, 1992), the fraction of workers at night will understate the workweek of capital. Which measure is appropriate de-

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pends on the theoretical framework and the source of the differences in intensity of work at night.

## II. Cyclical Productivity

Solow productivity accounting provides a framework for examining the role of the workweek of capital. Consider a five-factor model of real gross output, $Y = F(H, N, K, E, M)E^*$, where $Y$ is gross output, $H$ is production-worker hours, $N$ is non-production-worker employment, $K$ is net capital, $E$ is energy, $M$ is materials, and $E^*$ is the true level of total factor productivity. Share-weighted factor growth is conventionally measured as $\Delta x = \alpha_H \Delta h + \alpha_N \Delta n + \alpha_K \Delta k + \alpha_E \Delta e + \alpha_M \Delta m$, where $\Delta h$ and $\alpha_H$ are the percentage change and shares of production labor, and similarly for the other inputs. Capital's share is measured as 1 minus the sum of the shares of the other factors. The conventional Solow residual is $\Delta\varepsilon = \Delta y - \Delta x$, where $\Delta y$ is the percentage change in real gross output. This production function and Solow residual presume that capital's services are proportional to physical capital.

The most straightforward way to incorporate the workweek of capital into this analysis is to scale capital by its workweek, $S$.[1] Hence, the production function should be written as

$$Y = SF\left(\frac{H}{S}, \frac{N}{S}, K, \frac{E}{S}, \frac{M}{S}\right)E^*$$

$$= F(H, N, SK, E, M)E^*.$$

This specification assumes that there are constant returns to scale, that all factors are spread evenly across operative shifts, and that only capital has increasing returns in the sense that no more of it is needed to operate a second or third shift at a plant.[2] The capital-hours adjusted total factor input is then $\Delta\tilde{x} = \alpha_H \Delta h + \alpha_N \Delta n + \alpha_K \Delta k + \alpha_E \Delta e + \alpha_M \Delta m + \alpha_K \Delta s$ where $\Delta s$ is the percentage change in capital's workweek. The capital-hours-adjusted Solow residual is $\Delta\tilde{\varepsilon} = \Delta y - \Delta\tilde{x}$, that is, the conventionally measured Solow residual minus the share-weighted change in capital hours.

This paper is certainly not the first to propose that capital be adjusted for utilization (see Thomas Abbott et al., 1988), yet it is the first to have truly appropriate data. Indeed, Robert Solow (1957) in his original paper measures capital hours as the physical stock times the employment rate of labor. John Tatom (1980) uses Federal Reserve Board capacity utilization, but the way those data are constructed makes them an unsatisfactory measure of capital utilization (see Shapiro, 1989).

The measured Solow residual contains a cyclical component indicative of short-run increasing returns. Robert Hall (1988, 1990) has recently reinterpreted this phenomenon as evidence of market power, possibly combined with increasing returns. Consider this standard empirical result in the panel of four-digit U.S. manufacturing industries from 1978 to 1988.[3] Using the convention-

[1] See Robert Lucas (1970) and Thomas Sargent and Neil Wallace (1974) for theoretical discussions of these issues. While their work is motivated by overtime, their logic applies to shift work.

[2] Some nonproduction workers might also be similar to capital in that those already employed in day shifts might also be able to serve night production with little or no added cost or effort.

[3] The sample begins in 1978 to allow a percentage change in capital hours to be calculated. All variables except the workweek of capital are from Wayne B. Gray's total factor productivity data set. There are potentially 450 industries and 11 years, but because of missing data in the SPC tabulation, there are only 2,863 usable observations. The data on the workweek of capital refer to the fourth quarter, and the capital stock figures are end-of-year (lagged one year). Shares in revenue are calculated as two-period moving averages. The data reflect only factors at the plant level. In particular, they exclude central-office workers.

ally measured Solow residuals, there is evidence of short-run increasing returns in the following estimated equation:[4]

$$\Delta\varepsilon = \underset{(0.11)}{0.57} + \underset{(0.04)}{0.31}\Delta x + \Delta\varepsilon^*$$

(SEE = 6.3). The estimates replicate the well-known finding of short-run increasing returns. The coefficient of the change of input is substantially above zero and is estimated precisely.

Does the cyclicality of total factor productivity survive taking into account variation in capital hours? To answer this question, the above relation is reestimated using total factor productivity and inputs adjusted for capital hours. The estimated relationship is as follows:

$$\Delta\tilde{\varepsilon} = \underset{(0.13)}{0.45} + \underset{(0.04)}{0.05}\Delta\tilde{x} + \Delta\varepsilon^*$$

(SEE = 7.8). In capital-hours-adjusted data, there is little evidence of short-run increasing returns. The coefficient on total factor input is close to zero and again precisely estimated.

The specification in the previous estimate is based on a particular theory of the production function, that is, that the correct measure of capital services is the product $K$ times $S$. To evaluate this restriction, consider a regression of conventionally measured total factor productivity on conventionally measured total input and capital hours separately:

$$\Delta\varepsilon = \underset{(0.15)}{0.42} - \underset{(0.11)}{0.03}\Delta x + \underset{(0.39)}{1.35}\alpha_K \Delta s + \Delta\varepsilon^*$$

(SEE = 6.3). The result that there are no short-run increasing returns to conventionally measured inputs survives this relaxation of the specification. Under the theory that $S$ enters multiplicatively with $K$, the coefficient of $\alpha_K \Delta s$ should be 1. The point estimate is substantially larger than 1, but it has a large standard error. That it exceeds 1 suggests that the workweek of capital does more than just scale physical capital. Nonproduction workers might interact with capital hours if nonproduction workers already servicing day shifts can service night shifts with a less-than-proportional increase in their numbers.

In summary, the short-run increasing returns to inputs that have been found in many studies disappear when variation in the workweek of capital is taken into account. The finding is robust to freely estimating the elasticity of capital hours. Moreover, it is important to keep in mind that the data used to measure capital hours are completely independent of those used to measure output or other inputs. They are from an independent survey that directly measures capital hours. Other efforts to correct productivity for utilization often founder on the fact that "capacity utilization" is measured from production-worker hours, energy consumption, or output itself.

## III. Conclusions and Implications

When capital hours are taken into account, there appear to be no short-run increasing returns to conventionally measured total factor inputs. Further research is needed to refine this finding. In particular, the results in the previous section do not exclude the possibility that the elasticity of individual factors within $\Delta x$ have, individually, higher output elasticities than would be predicted by their shares. Additionally, the analysis is based on Annual Survey of Manufacturing data that count only factors employed at plants. Hence, the results show

[4] Estimation is by instrumental variables because of the joint determination of inputs and true productivity. The sample period 1978–1988 was dominated, however, by aggregate demand shocks, principally the Volcker deflation. This is known from the history of the period (see Christina Romer and David Romer, 1989) and from econometric evidence (see Shapiro and Mark Watson, 1988). I assume that *over this time period*, aggregate movements in productivity are *relatively* unimportant, so I use yearly dummies as instruments.

that hours of capital account for increasing returns at the plant level, but perhaps not at the firm or industry level.

Hall (1988, 1990) shows how short-run increasing returns imply that price exceeds marginal cost and also perhaps that there are increasing returns to scale. His empirical evidence is based on the coefficient of $\Delta x$ exceeding zero in equations such as those estimated above. It would be a mistake, however, to interpret the finding that this coefficient is zero when capital hours are taken into account as necessarily providing evidence against the basic message of Hall's research. Whether it does will depend on what the firm pays for increasing capital hours. The crux of Hall's argument is that if output elasticities exceed revenue shares, then price exceeds marginal cost. If firms bear little cost of extending the workweek of capital, the above results are perfectly consistent with Hall's insight.[5] Simple calculations based on average shift premia suggest that the incremental cost of using capital at night is quite low. If this is the case, then the share of capital hours in cost would be low.

On the other hand, firms might face a high shadow cost of increasing capital utilization. This could arise from, for example, a high marginal shift premium or from depreciation of capital in use. Other research (Roger Betancourt and Christopher Clague, 1981; Shapiro, 1992) investigates this shadow price. The implications of the regression in the previous section for market power and increasing returns depend on the definitive accounting of the costs of increasing capital utilization. Yet, the main findings of this paper are independent of the cost-side of the utilization margin. The cyclicality of conventionally measured total factor productivity results, in large part, from variation in the workweek of capital that accompanies increases in other inputs.

[5]Hence, absent evidence that increasing capital utilization is costly, these results do not support Abbott et al.'s (1988) critique of Hall.

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