WP/03/128

IMF Working Paper

Capital Operating Time and Total Factor Productivity Growth in France

Luc Everaert and Francisco Nadal De Simone

INTERNATIONAL MONETARY FUND

 WP/03/128

IMF Working Paper

European I Department

Capital Operating Time and Total Factor Productivity Growth in France

Prepared by Luc Everaert and Francisco Nadal De Simone[1]

Authorized for distribution by Robert Ford

June 2003

Abstract

Data on the weekly operating time of capital improve the measurement of effective capital input in production. The production function of the French business sector is found to be consistent with a Cobb-Douglas technology under constant returns to scale. Total factor productivity growth, estimated as an unobservable variable, has declined steadily since the late 1970s, but more slowly since 1994. During the 1990s, a secular increase in shift work raised the operating time of capital and began to contribute positively to growth, albeit only slightly.

JEL Classification Numbers: E32, E22, E24, E27

Keywords: Capital stock utilization, total factor productivity, labor organization

Authors' E-Mail Addresses: leveraert@imf.org and fnadaldesimone@imf.org

[1] We are grateful to the Banque de France for providing the time series on the duration of the workweek of capital, to Bob Ford and Marcello Estevão for stimulating comments, to Tam Bayoumi for his thoughtful discussion of an earlier version of the paper in an European I Department seminar, and to Jim Hamilton for a technical clarification. All errors and omissions remain the authors' sole responsibility.

Contents Page

I. Introduction 3

II. Production Function Specification, Measurements of Factor Inputs and Data Properties 4
- A. Production Function Specification 5
- B. Measures of Factor Inputs 6
- C. Data Properties 8

III. Econometric Estimation 10

IV. Changes in Shift Work 14

V. Concluding Remarks 15

Annex
1. Sensitivity of Coefficient Estimates of a Cobb-Douglas Production Function for the Business Sector to Adjustments to the Net Capital Stock, by Intensity of Use 16

References 17

Tables
1. Elliot, Rothenberg, and Stock Test for Unit Roots 9
2. Johansen-Juselius Maximum Likelihood Test for Cointegration 9
3. Parameter Estimates of the Cobb-Douglas Production Function with TFP as a Latent Variable 10
4. TFP Growth Estimates, 1980–99 12

Figures
1. Industry: Capital Operating Time and Capacity Utilization 6
2. Effective Capital Services 8
3. Business Sector: Estimated Total Factor Productivity Growth 12
4. Business Sector TFP Growth 13
5. Impact of Noncyclical Changes in Shift Work on Real GDP Growth 14

I. INTRODUCTION

Since the mid-1980s, research interest in economic growth has been rekindled, facilitated by the availability of the Summers-Heston dataset and spurred by the work of Baumol (1986), Romer (1986), and Lucas (1988). Although somewhat more sophisticated than in the past, the questions posed are still variants of what inspired Adam Smith's masterpiece: "Why do countries grow richer?" At the theoretical level, the analysis was freed from the pure neoclassical paradigm that long-term per capita growth depended only on the rate of an exogenously determined technological progress. Consequently, endogenous growth theories have been developed that allow for policy to influence long-run growth (e.g., Barro and Sala-i-Martin, 1995, and Aghion and Howitt, 1998), and empirical work has supported this conjecture (Easterly and Levine, 2001; Ahn and Hemmings, 2000; Temple, 2000). It has also been shown that factor accumulation, in particular of capital, does not account for the lion's share of *persistent* cross-country differences in per capita growth and that industrial countries appear to have experienced a slowdown in total factor productivity (TFP) growth. Empirical tests of theoretical concepts of TFP, such as the technology for combining factors (Grossman and Helpman, 1991), externalities (Romer, 1986), or efficiency (Harberger, 1998), are, however, not yet available.

As production technology is key for this analysis, much attention has been devoted to the definition and measurement of factor inputs. Early estimates of Cobb-Douglas production functions led to the apparent inconsistency of theoretically predicted diminishing returns to labor and procyclical movements in labor productivity and real wages in the data, prompting Lucas (1970) to argue that one possible reconciliation could lie in allowing for cyclical variation in the utilization of the capital stock.[2] This proposition gave rise to a considerable body of theoretical research: some models postulated depreciation in use to obtain a tradeoff between production and depreciation and thus explain underutilization of capital (Greenwood, Hercowitz, and Huffman, 1988), others relied on heterogeneity of firms facing idiosyncratic shocks and sunk investment costs (Cooley, Hansen, and Prescott, 1995), and still other models focused on the interaction between the intensity of capital utilization and labor supply (Dupaigne 1998, 2002) or shift work (Garofalo and Vinci, 2000). In parallel, empirical exploration of the links between the intensity of the use of capital, shift work, and productivity validated Lucas's insight. The omission of a measure of intensity in the use of capital in empirical work was largely responsible for the upward bias in estimated labor

[2] In the earlier studies, no adjustment was made for the utilization of the capital stock. Later, some (e.g., Jorgenson, 1966, and Solow, 1967) used the unemployment rate as a measure of the underutilization of capital. Griliches (1970) used the power utilization rate as a measure. Lucas (1970) modeled explicitly the supply of work effort to account for the absence of countercyclical real wage movements in the data, noting that as both hours worked and shift work are procyclical, they may be important in explaining cyclical fluctuations in the use of the capital stock.

shares and the procyclical character of total factor productivity (Tatom, 1980).[3] Recently, Finn (1995), Shapiro (1996), Dupaigne (1998), Baxter and Farr (2001), Rumbos and Auerheimer (2001), Horstein (2002), and others have convincingly argued that the intensity of the utilization of the capital stock is an important margin along which firms operate. Using different proxies for the intensity of the utilization of capital (capital operating time, energy use, material inputs) in simulations and growth accounting, this work removed most of the observed cyclicality of TFP in the United States.

This paper follows this literature and estimates a production function for the French business sector employing a measure of capital services that takes into account variations in the weekly operating time of equipment, as obtained from survey data. In line with findings in the literature for other countries (e.g., Shapiro, 1993), estimated labor- and capital-output elasticities are consistent with Cobb-Douglas technology under constant returns to scale and reflect the income shares as computed from national accounts, an encouraging result. The production function is estimated with TFP growth modeled as a latent variable. TFP growth is best described statistically as an autoregressive process of order one and is estimated to have declined from an average of 2 percent per year during the 1980s to 1.2 percent per year during the 1990s.

With capital operating time defined as the product of the number of labor shifts and the average duration of a shift, it reflects both cyclical developments and secular changes in shift or continuous work (Anxo and others 1995). The latter turn out to matter very little, however, as measured by the fraction of capital operating time that is orthogonal to capacity utilization, here used as a proxy for the business cycle. It was found that secular changes in shift work detracted marginally from growth during the 1980s and added a mere cumulative 0.6 percentage points to growth during the 1990s.

The paper is organized as follows. Section II defines the production function and the measurement of factor inputs, in particular of capital services. Section III presents the econometric estimates of the production function and TFP and discusses the robustness of the results. Section IV compares the results with traditional growth accounting measures of TFP, and provides an estimate of the effect of noncyclical changes in shift work on growth. Section V concludes.

II. Production Function Specification, Measures of Factor Inputs, and Data Properties

Production functions can be specified in a variety of ways for the purpose of growth accounting and the computation of TFP growth. The latter is most often obtained as the residual of GDP growth that cannot be attributed to changes in the volume of factor inputs,

[3] A regressor's measurement error makes ordinary-least-squares (OLS) estimates biased and inconsistent. The degree of the bias is directly related to the variance of the measurement error. See also Annex 1.

specifically labor and capital, weighted by their share of value added. Consequently, how factor inputs are measured matters a great deal for what TFP contains as well as for the econometric properties of the production function and any estimates of TFP.

A. Production Function Specification

The Cobb-Douglas production function adopted in this paper is defined in terms of the flow of services of the factors labor (N) and capital (Z). Labor services are represented by the total numbers of hours worked by the labor force ($L = N\,H_N$). The services of the capital stock are represented by the number of hours the capital stock is used ($K = Z\,H_Z$). Formally:

$$Y = A(NH_N)^{\alpha}(ZH_Z)^{\beta}, \tag{1}$$

where Y is output, and A is total factor productivity. When the factors of production are properly measured, A represents technical progress, including the level of efficiency in the utilization of the factors of production. In a competitive equilibrium, the exponents α and β represent the output elasticities of labor services and capital services, respectively. In the special case where $\alpha + \beta = 1$ the production function exhibits constant returns to scale, with α and β representing the income shares of labor and capital services.

Since Solow's (1957) work, a standard practice in the calculation of A has been, first, to compute α and β from national accounts as the shares of output accruing to the factors of production, or to estimate a Cobb-Douglas production function constrained to exhibit constant returns to scale. In either case, the residual has then been viewed as a proxy for total factor productivity, and has been dubbed the "Solow residual"[4]. The production function has usually been estimated in the first differences of the logarithms (with constant returns to scale imposed):

$$\Delta Y_t = \alpha\Delta\left(N_t H_{Nt}\right) + (1-\alpha)\Delta\left(Z_t H_{Zt}\right) + \varepsilon_t. \tag{2}$$

The use of first differences is justified on statistical grounds: although output and measures of labor and capital services often contain a unit root, they are not cointegrated, and estimation of equation (1) in the levels of the time series therefore cannot be justified.[5]

---

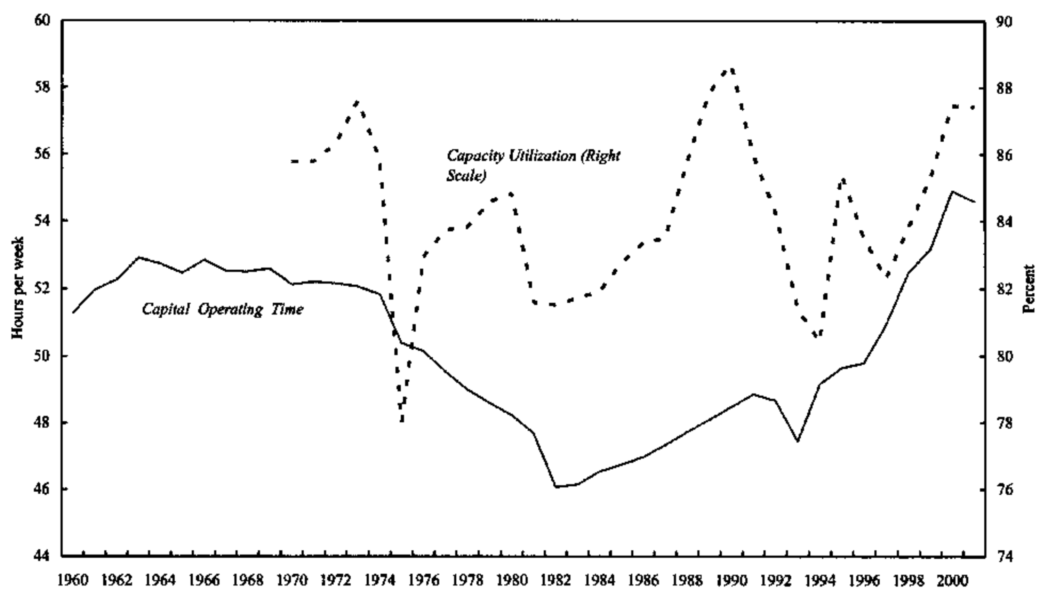
[4] In fact, Griliches (1996) argues that the credit for the earliest explicit calculation of total factor productivity is to be given to Tinbergen (1942).

[5] See Färe *et al.* (1994) for a detailed survey on production frontiers work, and Temple (1999) for a related survey on the empirical research on growth As discussed below, the measure of capital services used here also contains a unit root and is not cointegrated with labor hours and output. This suggests that the rejection of cointegration usually found in the literature may not hinge upon a regressor measurement error.

B. Measures of Factor Inputs

Annual data on real output, labor hours, and the capital stock for the business sector and the sample period 1970-2001 were taken from the AMECO database. Annual data on the weekly operating time of capital in industry were obtained from the Banque de France (Figure 1).[6] Clearly, capital operating time reflects cyclical developments, e.g. the downturns of 1982 and 1993, (compare with the rate of capacity utilization, including new hires, INSEE), but it also displays some longer-term behavior. In particular, it rose through the early 1960s, remained stable until the first oil price shock, and declined then dramatically through the early 1980s. Since then it has been trending upward again, rising during the second half of the 1990s to a historical maximum in 2000. That rise has been due to the development of shift work and continuous work (Banque de France, 2000).[7] Since 1995 on, the rise is reported to have resulted from changes in the organization of labor as well as from cyclical developments associated with a demand-driven rise in capacity utilization.[8]

Figure 1. Industry: Capital Operating Time and Capacity Utilization



Source: Banque de France and INSEE

---

[6] Since 1989 the Banque de France has conducted a survey specifically designed to assess capital operating time (Banque de France 2000) while Cette (1990) has constructed this indicator for 1957–1989.

[7] In 1989, about 43 percent (4.5 percent) of workers worked in (continuous) shifts while in 2000 about 48 percent (nearly 9 percent) worked in (continuous) shifts.

[8] Working in the opposite direction, the contractual workweek was reduced by law starting in 1998. The average workweek decreased from over 38 hours in 1998 to 36.5 hours in 2000.

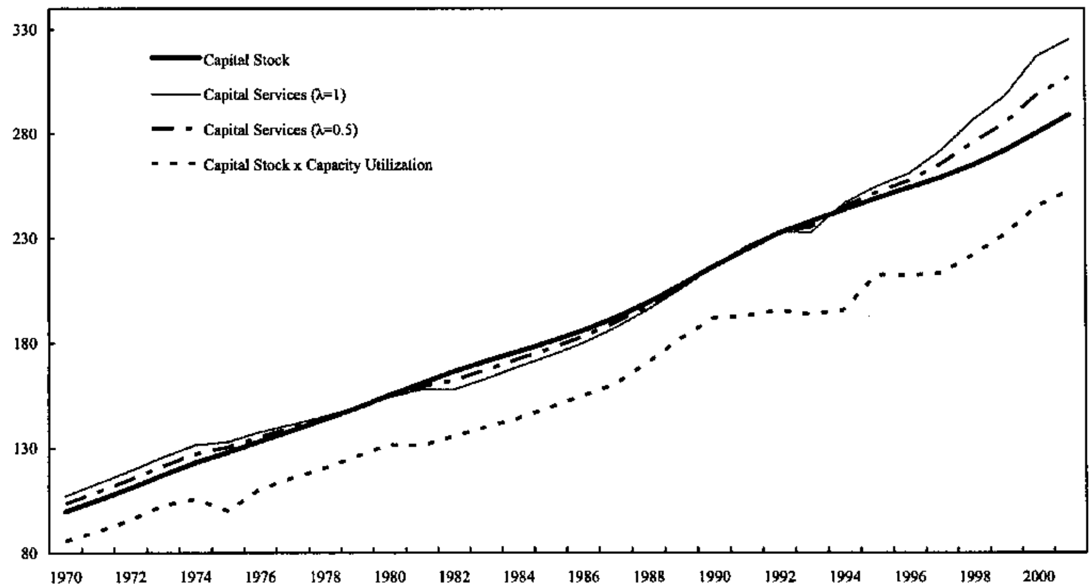
Given the difficulties involved in directly measuring the operating time of heterogeneous capital equipment, the survey conducted by the Banque de France computes capital operating time as the product of the number of hours worked per week per employee and the weighted mean of the number of shifts per week.[9] While the length of the contractual workweek and the organization of labor are the structural determinants of capital operating time, the latter also reflects the rate of capacity utilization (with and without new hiring). The rate of capacity utilization without new hiring proxies changes in the duration of the workweek over the cycle—through overtime and temporary lay-offs. The rate of capacity utilization with new hiring—when more or less machines are brought on stream—which do not necessarily affect the duration of the workweek or the organization of labor, will also be reflected in the measure of capital operating time.

Even though actual working hours of labor and capital are a good measure of effective factor inputs, they remain subject to limitations since they do not fully capture labor or capital effort. For labor, the well-known phenomenon of hoarding drives a wedge between the observed actual hours of work and their effort equivalent. For capital, a similar phenomenon exists for infrastructure, up to the point of congestion, and in industries that can vary the line speed (e.g., automobiles). In these cases, the amount of services derived from labor and capital varies without any observed equivalent change in the stocks of factors or their workweek.

Finally, the measure of operating time of capital, which is available only for industry, was applied to the business sector as a whole, but sensitivity analysis indicated that the results remained robust over a range of alternative assumptions. Formally, $K_t^B = \lambda Z_t^B H_t^B + (1-\lambda) Z_t^B$ with, λ=1. The resulting capital services indicator behaves quite differently from the capital stock estimate during the 1990s (Figure 2). On economic grounds, it is difficult to set a prior on whether changes in operating time of capital are synchronized between services and industry. Nonetheless, assuming λ close to 1 finds support in the fact that industry's share of the capital stock is higher than that of services and that, at the margin, fluctuations in industrial activity are responsible for the overall business cycle (Corrado and Mattey, 1997). More importantly, the estimation results are not much altered even when it is assumed that only one tenth of the net capital stock in the business sector is subject to the same operating time as industry (λ=0.1).

[9] The mean is weighted by the number of workers involved in shift work.

Figure 2. Effective Capital Services
(Capital stock in 1970=100)



Sources: AMECO and IMF staff calculations.

C. Data Properties

Tests for stationarity and cointegration imply that a first difference specification of the model is preferable for the purpose of estimating the production function. While the levels of all time series (output, labor and capital services) are found to be nonstationary when a constant and a time trend are included in the alternative hypothesis, the rates of changes are stationary when the alternative hypothesis includes a constant (Table 1).[10] The cointegration tests, corrected for small sample bias (Cheung and Lai, 1993), reject the null hypothesis of no cointegration at the 95 percent confidence level. However, the trace and λmax statistics yield conflicting results, with the former suggesting that there is one cointegrating vector and the latter that there are two (Table 2). If there were only one, full identification of the model would require two common trends (i.e. two weakly exogenous variables). While a test for weak exogeneity accepts that labor and capital services are weakly exogenous, a test of exclusion from the cointegration space accepts that none of the variables belong to the cointegration space. If in contrast, there were two cointegrating vectors, the weak exogeneity test rejects weak exogeneity for all variables, causing the model to be improperly identified.

[10] The unit root test is the augmented Dickey-Fuller test proposed by Elliott, Rothenberg, and Stock (1996).

Table 1. Elliot, Rothenberg, and Stock Test for Unit Roots[1]
(Statistics for ρ= 0, 1970–2001)

Levels[2]			First differences[3]		
Variables	Lags	$\Delta FGLS^{\tau}$	Variables	Lags	$\Delta FGLS^{\tau}$
GDP	1	-2.45	GDP	1	-2.65*
Labor hours	1	-1.51	Labor hours	1	-1.95*
Capital stock	1	-2.54	Capital stock	1	-2.93*
Capital services	1	-1.70	Capital services	1	-2.88*

Source: IMF staff estimates.

[1] All variables are measured in natural logarithms. Lags are determined according to Schwarz information criterion and checking that the residuals are white noise.

[2] The $DFGLS^{\tau}$ has a null of unit root with a constant and a linear trend. The 5 percent critical value is -2.89.

[3] The $DFGLS^{\tau}$ has a null of unit root with a constant. The 5 percent critical value is -1.95.

Table 2. The Johansen-Juselius Maximum–Likelihood Test for Cointegration
(1970–2001)

Eigen values	Lags	λ max	Trace	$H_0 : r$[1]	λ max 95%[2]	Trace 95%[2]
0.5537	3	23.40*	43.88*	0	19.51	40.83
0.4581		17.77*	20.48	1	15.98	21.32
0.0893		2.71	2.71	2	5.34	5.34
Exclusion[3]	$\chi_2^2 = 5.99$	GDP: 14.87*	Labor: 15.61*	Capital: 8.90*		
	$\chi_1^2 = 5.99$	GDP: 3.64	Labor: 3.35	Capital: 1.74		
Weak exogeneity[4]	$\chi_2^2 = 5.99$	GDP: 19.52*	Labor: 17.12*	Capital:10.16*		
	$\chi_1^2 = 5.99$	GDP: 5.63*	Labor: 3.02	Capital: 1.79		
Residuals normality[5]	$\chi_6^2 = 6.96$ (0.32)		Serial correlation	LM(1)[6]	$\chi_9^2 = 13.45$ (0.14)	
				LM(4)[6]	$\chi_9^2 = 8.60$ (0.47)	

Source: Fund staff estimates.
Notes: The models include a drift term in the variables but not in the cointegration space.
[1] Column r refers to the number of cointegrated vectors.
[2] The λ max and the trace statistics critical values are corrected for small samples using Cheung and Lai (1993).
[3] This is a test of long-run exclusion of the relevant variable from the cointegration space. It is distributed as a chi square variable with r degrees of freedom.
[4] This is a test of weak exogeneity of the relevant variable. It is distributed as a chi square with r degrees of freedom.
[5] It is a multivariate version of the Shenton-Bowman test for normality of individual series.
[6] The LM are Lagrange multiplier tests. The p-values are between parentheses.

III. Econometric Estimation

The production function is estimated in the first differences of the logarithm of the series, with total factor productivity specified as a latent variable:

$$\Delta Y_t = \Delta A_t + \alpha \Delta L_t + \beta \Delta K_t + \varepsilon_t . \tag{3}$$

The unobserved variable ΔA_t is assumed to follow an autoregressive process of order one. Thus, shocks to total factor productivity growth would have transitory effects. Formally:

$$\Delta A_t = \rho \Delta A_{t-1} + \nu_t , \tag{4}$$

where $\rho < 1$ in the case of the AR(1) process.[11]

Equations (3) and (4) are estimated in state-space form using the maximum likelihood estimator based on the prediction error decomposition generated by the Kalman filter (Table 3).

Table 3. Parameter Estimates of the Cobb-Douglas Production Function with TFP as a Latent Variable (1970–2001)

Log likelihood	Variables	Estimates	Standard errors	K-S levels[1]	K-S squared[1]	Tests
Model 1: Unconstrained parameters and TFP growth as an AR(1) process						
Unadjusted net capital stock						
86.32	Labor	0.93	0.16	0.15	0.27	
	Capital	0.48	0.36			
	Autoregressive	0.95	0.02			
Intensity-of-use adjusted net capital stock						
86.97	Labor	0.80	0.19	0.15	0.28	0.58 [2]
	Capital	0.26	0.13			0.64 [3]
	Autoregressive	0.95	0.01			
Model 2: Constrained parameters and TFP growth as an AR(1) process						
86.85	Labor	0.75	0.14	0.15	0.27	0.24 [4]
	Capital[5]	0.25	--			
	Autoregressive	0.95	0.01			

Source: Fund staff estimates.
[1] The Kolmogorov-Smirnov statistic is 0.31 at the 10 percent level.
[2] Chow test using a dummy variable equal to one from 1992 onward and zero otherwise distributed as an F statistic with 3,14 degrees of freedom. The 95 percent critical value is 3.34.
[3] Chow test using a dummy variable equal to one until 1991 and zero otherwise distributed as an F statistic with 3,14 degrees of freedom. The 95 percent critical value is 3.34.
[4] The value of the likelihood ratio test that the unrestricted and restricted models are equal is 2.71 at the 90 percent confidence level.
[5] The sum of the coefficients in the Cobb-Douglas production function is restricted to one.

[11] An AR(2) process for TFP growth resulted in an order-two coefficient insignificantly different from zero.

Estimates of the model with capital services taking into account the operating time of capital yield results consistent with constant returns to scale technology and output elasticities of capital and labor in line with factor income shares. In the unrestricted model, these elasticites are 0.80 and 0.26, respectively, and their sum is not statistically different from one. When restrictions are imposed, the coefficient on labor falls to 0.75. The level and the square of the residuals are white noise. Chow tests for the stability of the coefficients in the unrestricted model indicate that the parameters are stable over the sample period.

These result confirm Lucas' (1970) insight and subsequent findings in the literature on the importance of taking into account variations in the intensity of capital utilization and contrast sharply with estimates in which capital services are measured by the capital stock only. In this case, the elasticity of labor services is 0.93, somewhat above the maximum of the range often found in other empirical work. As in Mankiw, Romer, and Weil's (1992) seminal paper, the elasticity of capital services is much higher than what is implied by the share of capital in national accounts and the estimated elasticities suggest increasing returns to scale.[12] On the other hand, using human capital proxies instead of better measures of capital services as an alternative was found in the literature to yield "too low" physical capital shares.[13]

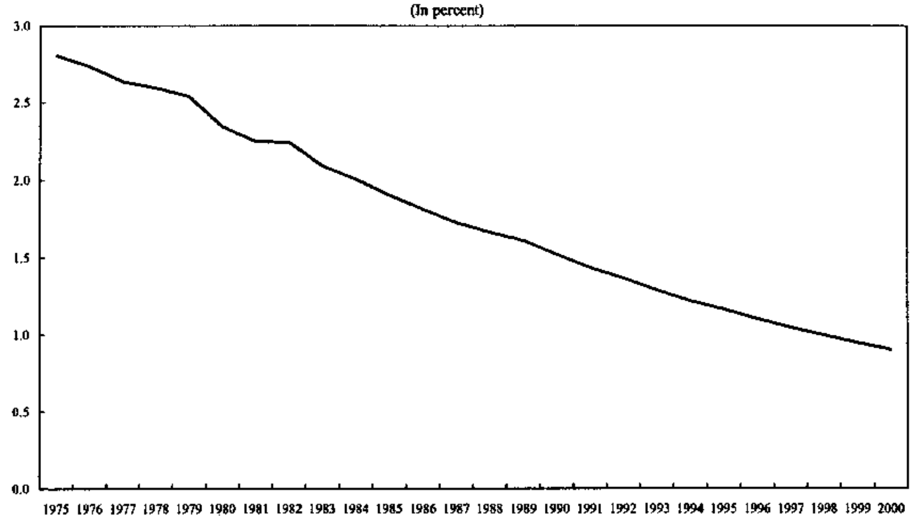
Total factor productivity growth is estimated to be an autoregressive process and to have declined steadily over the sample period from about 2.8 percent per year to 0.9 percent per year (Figure 3 and Table 4). The autoregressive coefficient of 0.95 is highly significant, suggesting persistence in total factor productivity growth. The coefficient and its variance are statistically the same whether the model is restricted or not. Given that a likelihood ratio test cannot reject the null that the unrestricted and the restricted models are statistically identical, in what follows, the discussion focuses on the estimates of the restricted model unless otherwise indicated.

---

[12] This finding led Mankiw *et al* (1992) to consider a variant of the Solow model in which human capital as well as physical capital is accumulated.

[13] Bernanke and Gürkaynak (2001) test a Solow growth model with human capital using the Summers-Heston database, and find in a cross-country framework that although the coefficient on human capital takes on reasonable values (between 0.3 and 0.4), the coefficient on physical capital becomes unreasonably low, and sometimes even insignificantly different from zero. While providing support for several of Mankiw *et al*'s key conclusions, Hamilton and Monteagudo (1998) find that investment in human capital has no ability to account for *changes* in growth rates over time.

Figure 3. Business Sector: Estimated Total Factor Productivity Growth
(In percent)



Source: IMF staff calculations.

Table 4. TFP Growth Estimates, 1980–99

	Business Sector		
	TFP AR(1) Operating Time	Solow Residual Operating Time	Solow Residual Capital Stock
1980–84	2.19	2.12	1.85
1985–89	1.74	2.08	2.29
1990–94	1.37	0.54	0.68
1995–99	1.05	0.79	1.28
1980–99	1.59	1.38	1.52

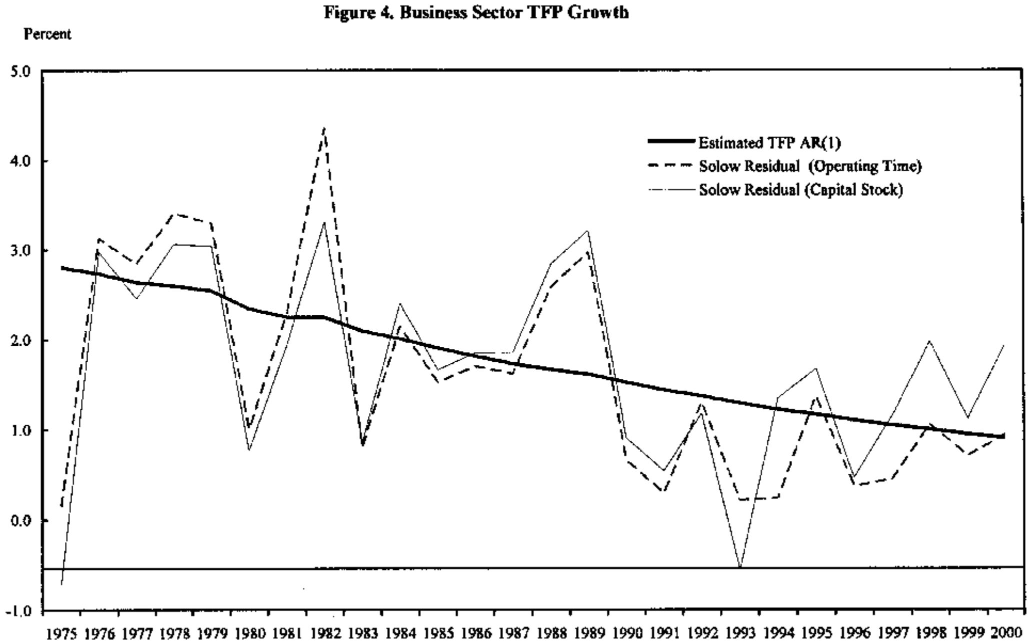
Source: IMF staff calculations.

Estimated total factor productivity growth has several features that are consistent with findings in the literature in similar applications for other countries. The use of capital services reflecting the operating time of capital tends to generate a path of total factor productivity growth that is higher than with an unadjusted capital stock. This suggests that net capital stock measures understate excess capacity, generating unrealistically high input shares, and consequently, unrealistically low total factor productivity growth. Unobserved input movements such as changes in the intensity in the use of capital are bound to be interpreted as changes in total factor productivity growth.[14] These results accord well with Finn (1995), Shapiro (1996), Baxter and Farr (2001), and Chen (1997).

[14] The extent of the bias is large if we take the variance of the error in measurement as reflected by the difference in growth rates of the net capital stock unadjusted and adjusted. The variance is 2.8 with full adjustment of the capital stock, and 1.8 with an adjustment factor for the capital stock of only 10 percent of the workweek of capital.

The use of capital services reflecting operating time of capital can account for the observed cyclicality of total factor productivity growth without making reference to increasing returns to scale (Figure 4). For example, the correlation between capacity utilization (proxy for the business cycle) and the Solow residual is not statistically significant either when the capital stock is unadjusted or it is adjusted. Moreover, a regression of the Solow residual (calculated using the unadjusted capital stock) on the measure of the intensity in the use of capital transforms the residual into white noise.[15]

Figure 4. Business Sector TFP Growth



Source: IMF staff calculations.

Similarly, the volatility of the Solow residual is 1.2 (with adjusted capital services, and 1.1 unadjusted) while the volatility of the estimated total factor productivity growth is 0.6. This is a large reduction in volatility compared to, for example, reductions of between 15 to 23 percent for the industrial sector alone reported for Canada and the United States by Baxter and Farr (2001) using various proxies for capital services. On this metric, those proxies are further away from an effective measure of the use of the capital stock than the measure used in this study. Finally, the correlation between output growth and the estimated TFP growth is basically zero, whereas it is 42 percent (66 percent) with the Solow residual using capital services adjusted (unadjusted) for operating time.[16]

---

[15] The estimated regression is: unadjusted Solow residual$_t$ = 0.004 workweek of capital$_t$ + res$_t$, with a t-statistic for the slope of 7.71. The residual maximum gap with respect to the white noise alternative is 0.13 with a rejection limit of 0.31 for the null of white noise.

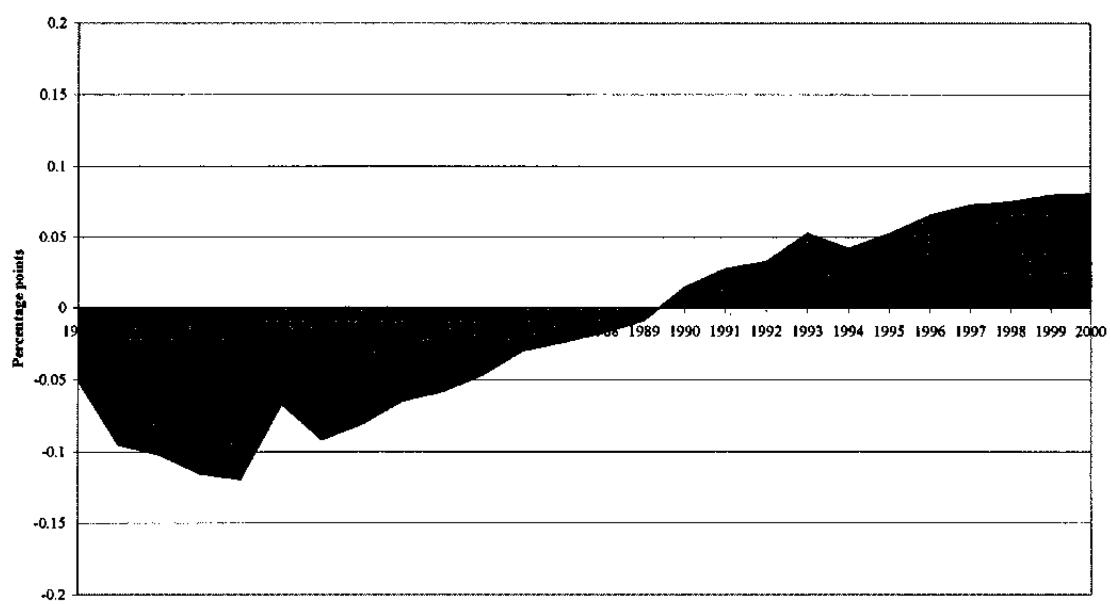
[16] Values above 44 percent are statistically significant for this sample.

IV. CHANGES IN SHIFT WORK

Capital operating time reflects cyclical and non-cyclical changes in shift work and the number of hours worked per shift. Consequently, TFP growth estimated using the capital service indicator is cleaned of the influence of both. It may nonetheless be important from a policy perspective to identify structural changes in shift work and hours per shift as they may influence trend growth.

It turns out that secular changes in shift work have had limited effects, though the latter changed direction in the middle of the sample period. While exerting a small drag on growth between the mid-1970s and late 1980s, their contribution to growth became positive in the 1990s, reaching about 0.08 percentage points per year in 2000–2001 (Figure 5). This estimate was obtained using the component of the capital services indicator adjusted for operating time that was orthogonal to the rate of capacity utilization including new hiring, here used as a proxy for the cycle. Reassuringly, the econometric results are very much in line with those obtained from using capital operating time as a proxy for capital services, suggesting that the use of this alternative measure of capital services does not introduce econometric problems.[17]

Figure 5. Impact of Noncyclical Changes in Shift Work on Real GDP Growth



Source: IMF staff calculations.

[17] The unrestricted model estimated with the stock of capital adjusted for capacity utilization produced a labor coefficient of 0.67 and a capital coefficient of 0.26. The sum of coefficients was not statistically different from one. The level of the residuals was white noise, but the squared residuals displayed serial correlation.

In the French context during the 1990s, labor market developments are the most likely explanatory factor for increased use of shift work. Wage moderation that cannot be explained by changes in labor demand, taxes, and benefits, or composition effects, and that was particularly pronounced during 1996-2000 (Estevão and Nargis, 2002) fits the observed changes in shift work well. It is generally attributed to a shift in preferences or bargaining. Labor market policies are likely to have contributed as well. In the early 1990s, social security contributions were lowered first for part-time employees and subsequently for minimum-wage workers, a reduction that was gradually extended up the pay-scale to about 1.8 times the minimum wage in the context of the reduction of the maximum workweek from 39 hours to 35 hours. This reduction began in earnest only in 1997, but was further facilitated by the relaxation of restrictions on overtime, in particular the possibility to average overtime over the year rather than on a weekly basis.

V. Concluding Remarks

When capital services are measured by taking into account operating time—and labor is measured as hours worked—the estimates of the production function become more aligned to theoretical priors: output elasticities are close to the factor income shares and total factor productivity growth loses its procyclical properties. For the French business sector, a Cobb-Douglas technology under constant returns to scale is found to be a good approximation of the production technology.

Using a latent variable framework, TFP growth was estimated concurrently with the production function. An AR(1) process in the growth rate of TFP fits the data well. Estimated TFP growth declines steadily from the mid–1970s to the end of the sample period, although the rate of decline moderates somewhat in the second half of the 1990s. During 1993 to 2001, it averages about 1.1 percent.

Though there have been noncyclical changes in shift work that directly affect the operating time of capital, their impact on growth is estimated to have been very limited. Nonetheless, after exerting a drag during the 1980s, they have begun to contribute positively to growth in the 1990s. Wage moderation and cuts in social security contributions to promote part-time and low-paid work are likely to have contributed.

Sensitivity of Coefficient Estimates of a Cobb-Douglas Production Function for the Business Sector to Adjustments to the Net Capital Stock by the Intensity of its Use[1]

Sector/Capital	Model for TFP	Restrictions	TFP Range				Estimated Coefficients											
			Unadjusted	Factor = 1	Factor = 0.5	Factor = 0.1	LA	KA	AR(1)	LA F=1	KA F=1	AR(1) F=1	LA F=0.5	KA F=0.5	AR(1) F=0.5	LA F=0.1	KA F=0.1	AR(1) F=0.1
Capital stock																		
	AR(1)	Unconstrained	1.8-0.6				0.93	0.48	0.95									
	AR(1)	Constrained	3.7,1.5				0.94	0.06	0.96									
Capital services [2]																		
	AR(1)	Unconstrained		2.8-0.9	2.8-0.8	2.6-0.7				0.80	0.26	0.95	0.80	0.26	0.95	0.79	0.31	0.95
	AR(1)	Constrained		2.8-0.9	2.8-0.9	2.6-0.8				0.75	0.25	0.95	0.74	0.26	0.95	0.72	0.28	0.95

Note: Coefficients that are not statistically significant at least at the 90 percent confidence level are shown as zero.

[1] The factor of correction F took the values 1, 0.5 and 0.1. The capital stock series for the whole economy and for the business sector were adjusted consequently. The sensitivity of total factor productivity growth, the estimated input elasticities as well as the AR(1) coefficient was tested by running the same econometric model with the different meaures of capital services. The table shows that correcting the capital stock to measure better the services it provides to the production process is crucial to obtain elasticities and total factor productivity growth that accord with factual evidence on factor shares. The results are quite robust to the share of the net capital stock adjusted.

[2] The bias and inconsistency due to error in measurement in one regressor is directly proportional to the variance of the measurement error. If all the measurement error were corrected by the adjustment to the capital stock growth by using the intensity-of-use measure, the variance in measurement error would be 2.9 percent in case of full adjustment and 2.1 percent in case of adjustment by a factor of 0.1.

References

Aghion P., and P. Howitt, 1998, *Endogenous Growth Theory*, MIT Press.

Ahn, Sanghoon, and Philip Hemmings, 2000, "Policy Influences on Economic Growth in OECD Countries: An Evaluation of the Evidence," *OECD Econmics Department Working Papers*, Number 246.

Anxo, Dominique, Gerhard Bosch, Derek Bosworth, Gilbert Cette, Thomas Steiner, and Domique Taddei (eds.), 1995, *Work Patterns and Capital Utilization*, Boston, Kluwer Academic Publishers.

Banque de France, 2001, "La durée d'utilisation d'équipements: principaux résultats 1989-2000," *Bulletin de la Banque de France*, No 94, October 2001 pp 75-93.Barro, Robert, and Xavier Sala-i-Martin, 1995, *Economic Growth*, New York, McGraw-Hill.

Barro, Robert, and Xavier Sala-i-Martin, 1995, *Economic Growth,* New York, McGraw-Hill.

Baumol, W. J., 1986, "Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show," *American Economy Review*, 76:5, pp. 1072–85.

Baxter, M. And D. D. Farr, 2001, "The Effects of Variable Capital Utilization on the Measurement and Properties of Sectoral Productivity: Some International Evidence," *NBER* No. 8475.

Bernanke, B. S. and R. S. Gürkaynak, 2001, "Is Growth Exogneous? Taking Mankiw, Romer, and Weil Seriously," *NBER* No.8365.

Burnside, C., Martin Eichenbaum, and Sergio Rebelo, 1995, "Capital utilization and returns to scale" NBER Working Paper 5125.

Cette, Gilbert, 1990, "Durée d'utilisation des équipements: l'inversion d'une tendance longue" *Économie et Statistique*, No. 231.

Chen, E. K. Y., 1997,"The Total Factor Productivity Debate: Determinants of Economic Growth in East Asia", *Asian Pacific Economic Literature* 18, pp. 313-328.

Cheung, Y. W. and K. S. Lai, 1993, "Finite Sample Sizes of Johansen's Likelihood Ratio Test for Cointegration," *Oxford Bulletin of Economics and Statistics* 55, pp. 313-328.

Cooley, T.F, G.D. Hansen, and Edward C. Prescott, 1995, "Equilibrium business cycles with idle resources and variable capacity utilization," *Economic Theory*, Vol 6, No. 1, pp 35-50.

Corrado, Carol and Joe Mattey, 1997, Capacity Utilization, *The Journal of Economic Perspectives*, Volume 11, Issue 1 (Winter), 151-167.

Doisy, S. (2002), "La Croissance Potentielle de l'Économie Française," *Revue Économique* 53, 3, pp. 611-624.

Dupaigne, M., 1998, "Capital Operating Time and Economic Fluctuations," *Recherches Économiques de Louvain* 64, 3, pp. 243-267.

———, 2002, "Travail posté et durée d'utilisation des équipements dans les fluctuations économiques," *Annales d'Économie et de Statistique*, Vol. 66, pp. 235-256.

Easterly, William, and Ross Levine, 2001, "It's not Factor Accumulation: Stylized Facts and Growth Models," *World Bank Economic Review,* Volume 15, No. 2.

Elliott, G., T. J. Rothenberg, and J. Stock, 1996, "Efficient Tests for an Autoregressive Unit Root," *Econometrica* 64, pp. 813-36.

Estevão, Marcello and Nigar Nargis, (2002), "Wage moderation in France," *IMF Working Paper* Number 02/151.

Färe, R., S. Grosskopf, and C. A. K. Lovell, 1994, Production Frontiers, *Cambridge University Press*, Cambridge.

Finn, M. G., 1995, "Variance Properties of Solow's Productivity Residual and their Cyclical Implications," *Journal of Economic Dynamics and Control* 19, pp. 1249-1281.

Garofalo, A. and C. P. Vinci, 2000, "Employment, Capital Operating Time and Efficiency Wages Hypothesis: Is There Any Room for Worksharing?", *Cahiers Economiques de Bruxelles* 168, 4ème trimestre, pp. 397-441.

Greenwood, Jeremy, Zvi Hercowitz, and G.W. Huffman, 1988, "Investment, capacity utilization, and the real business cycle," *American Economic Review*, Vol. 78, No. 3, pp 402-417.

Griliches, Z., 1970, "Notes on the Role of Education in Production Functions and Growth Accounting," in L. Hansen (ed.), *Education, Income, and Human Capital*, Columbia University Press, New York, pp. 71-115.

———, 1996, "The Discovery of the Residual: A Historical Note," *Journal of Economic Literature* XXXIV, pp. 1324-1330.

Grossman, G., and E. Helpman, 1991, "Quality Ladders in the Theory of Economic Growth," *Review of Economic Studies* Volume 58, No. 1, pp 43-61.

Hamilton, J. D. and J. Monteagudo, 1998, "The Augmented Solow Model and the Productivity Slowdown," *Journal of Monetary Economics* 42, pp. 495-509.

Harberger, A.C., 1998, "A vision of the growth process" *American Economic Review*, Volume 88, No. 1, pp 1-32.

Hornstein, A., "Towards a Theory of Capacity Utilization: Shiftwork and the Workweek of Capital," *Federal Reserve Bank of Richmond quarterly* 88, 2, pp. 65-86.

Jorgenson, D. W., 1966, "The Embodiment Hypothesis," *Journal of Political Economy*, 74, 1, pp. 1-17.

Larsen, Jens, Katharine Neiss, and Fergal Shortall, 2002, "Factor utilisation and productivity estimates for the United Kingdom," *Bank of England Working Paper* No. ???

Leamer, E. E., 1999, "Effort, Wages, and the International Division of Labor?" *Journal of Political Economy* 107, 6, pp. 1127-1162.

Lucas, Robert E. Jr., 1970, "Capacity, Overtime, and Empirical Production Functions," *American Economic Review*, Proceedings, Vol. 60 (2) pp 23-27.

Mankiw, N. G., D. Romer, and D. N. Weil, 1992, "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics* 107, pp. 407-437.

Romer, Paul, 1986, "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, Volume 94, No. 5, part 2, pp 1002-37.

Rumbos, B. and L. Auernheimer, 2001, "Endogenous Capital Utilization in a Neoclassical Growth Model," *Atlantic Economic Journal* 29, 2, pp. 121-134.

Shapiro, M.D., 1993, "Cyclical Productivity and the Workweek of Capital," *American Economic Review*, May Vol 83, No. 2, pp 229-233.

———, "Macroeconomic Implications of Variation in the Workweek of Capital," in *Brookings Papers on Economic Activity* 2, pp. 79-133.

Solow, R. M., 1967, "The Explanation of Productivity Change," *Review of Economic Studies*, 34, 2, pp. 249-283.

Temple, J., 1999, "The New Growth Evidence," *Journal of Economic Literature* XXXVII, 1, pp. 112-156.

———, 2000, "Summary of an Informal Workshop on the Causes of Growth," *OECD Economics Department Working Papers* No 260.

Tinbergen, J., 1942, Selected Papers, *North-Holland*, 1959, reprint in English.