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An empirical analysis on panel country data*

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Abstract

An empirical analysis is conducted on two panels of 18 OECD countries to test whether the elasticity of hourly productivity to working time is negative and decreasing with working time itself. If so, the decreasing returns on working time could be indicative of a fatigue effect that increases with working time. We find that the elasticity of productivity per hour to working time is negative and decreasing with working time, but its coefficient is not strongly significant. This study offers empirical support for the hypothesis of a fatigue effect that increases with working time, but with some reservations.

JEL Codes: J24, F01, O11, O47.

Key words: Productivity, Working time, decreasing returns.

Résumé

Une analyse empirique est conduite sur deux panels constitués de 18 pays de l'OCDE afin de tester si l'élasticité de la productivité horaire au temps de travail est négative et baisse avec le temps de travail lui-même. Si tel est le cas, cette baisse de l'élasticité avec le temps de travail pourrait indiquer un effet de fatigue croissant avec le temps de travail. Nous constatons que l'élasticité de la productivité horaire par rapport au temps de travail est effectivement négative et en baisse avec le temps de travail, mais le coefficient de cette baisse n'est pas très significatif. Cette étude offre un support empirique pour l'hypothèse d'un effet de fatigue qui augmenterait avec le temps de travail, mais avec quelques réserves.

Codes JEL : J24, F01, O11, O47

Mots clés : Productivité, temps de travail, rendements décroissants

1. Introduction

In all industrialized countries over the long run, average working time has decreased while the average productivity per hour worked has increased. Several empirical studies have shown that hourly productivity improvement could be explained in part by the decrease in working time (see, among others, Malinvaud, 1973, Gust and Marquez, 2000, 2004, Bélorgey *et al.*, 2004, Bourlès and Cette, 2005, 2007, McGuckin and Van Ark, 2005, or Dew Becker and Gordon, 2008). Worker fatigue effects could account for the decreasing returns on working time, reflected in a negative elasticity of hourly productivity with respect to working time. In this situation, the magnitude of the fatigue effect would outweigh that of fixed costs (for example, a fixed quantity of time necessary for workers to prepare their working places or to get instructions) from which increasing returns on working time originate.

The purpose of this study is to empirically assess whether or not the negative elasticity of hourly productivity with respect to working time could itself be decreasing. We posit that this may be due to a fatigue effect increasing with working time, and present a stylized theoretical model of such a decreasing negative elasticity of productivity with respect to working time.

The empirical analysis is conducted using economic estimations of simple relations on two panels of 18 OECD countries. The originality of the paper is twofold. First, we estimate the elasticity of hourly productivity with respect to working time on two different datasets, one of them being a long period dataset from 1870-2005, with long working times at the beginning. Second, we estimate a relation with thresholds of working hours.

The paper is organised as follows: Section 2 proposes a stylised model to characterize the impact of working time on hourly productivity; Section 3 presents the estimated relationship and Section 4 summarizes the data, Section 5 comments on the estimation results, and Section 6 concludes the study.

2. A stylised model

This stylised theoretical model characterizes the elasticity of productivity per hour with respect to working time. This model applies to a representative firm. We assume that workers are homogeneous and that working time H is composed of a productive part H_P and an unproductive part H_{NP} with $H = H_P + H_{NP}$. The unproductive part is a fixed cost, corresponding for example to a fixed quantity of time necessary for a worker to prepare his working place or to get instructions. Due to a fatigue effect, the returns of the productive working time H_P are supposed to decrease, and at a faster rate after certain thresholds. To simplify, we consider only one threshold H_T with $H_{NP} < H_T$.

We assume a Cobb-Douglas function dependant on the working time. With respect to the length of the working time, two situations are distinguished: below and above the threshold.

- *If the working time is below the threshold* ($H_{NP} < H < H_T$), then:

$$Q = (H - H_{NP})^{\alpha 1} . F_1(X_i) \qquad (1)$$

X_i being the other production factors (among them employment, capital and technical progress) and with $0 < \alpha 1 < 1$.

And productivity per hour P_H is:

$$P_H = Q / H = \frac{1}{H} .(H - H_{NP})^{\alpha 1} . F_1(X_i) \qquad (2)$$

The elasticity of productivity per hour to working time is:

$$E_1 = \frac{H_{NP} - (1 - \alpha 1).H}{H - H_{NP}} = \frac{\lambda + \alpha 1 - 1}{1 - \lambda 1} \qquad (3)$$

with $\lambda = \frac{H_{NP}}{H}$. For plausible values of λ ($0 \leq \lambda < 0.15$) and α1 ($0.4 < \alpha 1 < 0.8$) we have $E_1 < 0$. If there is no unproductive part in working time (which means $H_{NP} = 0$, $H = H_P$ and $\lambda = 0$) then $E1 = \alpha 1 - 1 < 0$. But for possible extreme and rare values of λ (here, for example, $\lambda > 1 - \alpha 1$) we get $E_1 > 0$, this property coming from the existence of an unproductive part of working time (here $H_{NP} > 0$).

- *If the working time is above the threshold* ($H_T < H$), then:

$$Q = (\frac{H}{H_T})^{\alpha 2}. F_2(X_i, H_{T1}, \lambda') \qquad (4)$$

with $0 < \alpha 2 < \alpha 1 < 1$ and with $\lambda' = \frac{H_{NP}}{H_T}$. The elasticity of productivity per hour to working time is:

$$E_2 = \alpha 2 - 1 \qquad (5)$$

and we have $-1 < E_2 < 0$. The difference between the two elasticities E_2 and E_1 is:

$$E_2 - E_1 = \frac{\alpha 2.(1 - \lambda') - \alpha 1}{1 - \lambda} \qquad (6)$$

We always have $E_2 - E_1 < 0$ and consequently $E_2 < E_1$, which means a decreasing elasticity of productivity per hour to working time.

3. Estimated relationship

The econometric model estimated is close to the one estimated by Gust and Marquez (2000, 2004), Bélorgey *et al*. (2004), Bourlès and Cette (2005, 2007), McGuckin and Van Ark

(2005) and Dew-Becker and Gordon (2008). In the following relationship (7), the dependent variable (Δph) corresponds to the rate of change of hourly labour productivity (PH)[1]:

$$\Delta ph = \beta 1.\Delta ER + \beta 2.\Delta h + \beta H_T.IH_T.\Delta h + \beta 3.gdpcap_{-1} + cte + u \qquad (7)$$

Where:

- The coefficient $\beta 1$ reflects the effect of a change in the employment rate (ΔER) on hourly productivity. *A priori* we expect: $-1 < \beta 1 \leq 0$ which means decreasing returns on hourly productivity with respect to the employment rate.
- The coefficients $\beta 2$ and βH_T reflect the effect of an increase in working time (Δh) on hourly productivity. Under a fatigue effect, the returns on working time would decrease, and at a faster rate after a threshold for working time represented by the variables IH_T, with IH_T being equal to 1 if the working time is equal to or above threshold H_T, and equal to 0 if it is below. Below threshold H_T, the elasticity of hourly productivity to working time, E1, is simply $\beta 2$, while the elasticity above the threshold, E2, is $\beta 2 + \beta H_T$. From the model proposed in Section 2, we expect $-1 < E2 = \beta 2 + \beta H_T \leq E1 = \beta 2 < 0$.
- Many other variables may affect labour productivity, but the use of these variables is constrained by the concern for consistency between the two datasets. The scarcity of available variables for the long dataset prevented the inclusion of certain variables used in the aforementioned studies, such as the capacity utilization rate, ICT production or investment, R&D spending, measures of human capital (e.g. the share of the population with primary or secondary education and the illiteracy rate), the share of the labour force working in agriculture, and the share of the population living in an urban environment.

[1] In this paper, Δ before a variable means a difference of the first order for the short dataset, and an average annual change for the long dataset, and variables in lower case correspond to their logs.

Ultimately, the lagged log of GDP per capita, $gdpcap_{-1}$,[2] is the only one of these variables used in the results presented here. This variable should capture a productivity catching-up process and we expect its coefficient $\beta 3$ to be negative, a higher initial level of GDP per capita being associated with lower productivity growth.

4. The data

The empirical analysis uses two datasets on 18 OECD countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United States, and the United Kingdom.

- The first panel (referred to as the "long dataset") starts in 1870 and ends in 2005, with only six observed years: 1870, 1913, 1950, 1973, 1990, and 2005. This gives five sub-periods: before WWI (1870-1913); from just before WWI to a few years after WWII (1913-1950), including the years of economic reconstruction and recovery to smooth out the most significant effects of the conflict on production capacities and economic structures; from some years after WWII until the first oil shock (1950-1973); from the first oil shock to 1990 (1973-1990); and finally from 1990 until the current period (1990-2005). In each of these five sub-periods, the variable changes used in the empirical analysis are the average annual changes within each period, and the variable levels are the levels of the initial year of the sub-period. All values of the variables in this dataset are from the Groningen Growth and Development Centre.[3] Data on country employment rates for the years 1870 and 1913 was unavailable, so for this dataset we used a proxy - the ratio of employment to the total country population (EPR), in contrast

[2] For the short dataset, gdpcap-1 is the value of the previous year. For the long dataset, it is the value from the beginning of the current sub-period.

[3] Address: http://www.ggdc.net.

to only the working age population. Because EPR is not an accurate measurement of the employment rate, the estimated value of its coefficient can be expected to be biased toward zero, compared to a coefficient estimated using a better measurement of the employment rate.

- The second dataset (referred to as the "short dataset") consists of annual observations from 1950 to 2005. All values of the variables in this dataset are from the OECD.[4]

For our econometric estimations, three thresholds were alternatively introduced for both datasets:

- The first threshold is 1,825 hours,[5] which is slightly above the first third of the observations in the long dataset and slightly below the median of the short one;
- The second threshold is 1,925 hours, which is close to the fourth decile of the long dataset and the sixth decile of the short one;
- The third threshold is 2,025 hours, which is slightly below the sixth decile in the long dataset and corresponds to the third quartile of the short one.

5. Empirical results

The estimation results may be subject to a simultaneous causality bias, as explained in Bourlès and Cette (2005), mainly for the coefficient of the employment rate change. To correct for this, this study uses the instrumental variables method.[6] Belorgey *et al.* (2004) use the generalized method of moments (GMM), but their estimates are made on a country panel dataset with a larger number of countries. Different tests are used to assess the quality of

[4] Address: http://stats.oecd.org/WBOS/index.aspx.

[5] We do not have a sufficient number of observations in the long dataset to use a threshold below 1,825 hours or above 2,025 hours. For consistency, we use the same thresholds on both datasets.

[6] The first stage estimation results of this IV estimate can be asked to the authors.

adjustment: the Sargan test (1958), as developed by Schaffer and Stillman (2006), which assesses the overall relevance of the instruments, and the Davidson and McKinnon test, as developed by Baum and Stillman (1999), to ensure that the instruments are exogenous.

The estimated coefficient of $gdpcap_{-1}$ is always significant, with the expected negative sign and a plausible value. The estimated coefficient of the employment rate changes is, in the short dataset, close to the one also estimated using instrumental variables by Bourlès and Cette (2005, Table 5, and 2007) and Dew-Becker and Gordon (2008, Table 5), but higher (in absolute terms) than the one estimated using GMM by Bélorgey *et al*. (2004, Table 1). It suggests that a one percentage point increase (decrease) in the employment rate would result in a decrease (increase) in productivity per hour – all other things held constant – of around 0.5%. In the long dataset, this estimated coefficient is not significant and unrealistic, which can be explained, as above, by the use of an imperfect proxy of the employment rate for this dataset.

In the short dataset, when the interaction term coefficient is significant (columns [6], [7] and [8]), the estimated coefficient for changes in working time is equivalent to the one also estimated with instrumental variables by Bourlès and Cette (2005, Table 5, and 2007) and the one estimated using GMM by Bélorgey *et al*. (2004, Table 1). In the long dataset, when this coefficient for changes in working time is significant (column [8]), it is equivalent to the one estimated in the short dataset.

In the long dataset, the coefficient on the interaction term always has a negative and plausible value, but is never significant for any of the threshold values. These non-significant estimate results likely from the imprecision of the data for this dataset, particularly for the older sub periods. In the short dataset, the coefficient of the interaction term is significant for the thresholds of 1,925 and 2,025 hours at respectively 15% and 10%, with the expected negative sign and a plausible value. Thus, the elasticity of hourly productivity with respect to working time is always negative (signifying decreasing returns on working time) and higher (in absolute terms) for longer working times. These results imply that the returns on working time decrease sharply with long working hours (when working time is above the threshold): a 1% increase in working time would lead to a decrease in productivity of roughly -0.9 % for the threshold of 1,925 hours and of 1% for the threshold of 2,025 hours. This also suggests that, given the very high initial levels of hours worked, the reduction in output stemming from decreasing working time would be mostly offset by the productivity gains associated with the decrease in working time.

6. Concluding remarks

The results of the empirical estimations provide some initial evidence for the existence of decreasing returns on working time and offer a partial confirmation of the hypothesis that these returns diminish with working time. Nevertheless, the statistical significance of this decline is not very high. This study offers some empirical support as a starting point for the hypothesis of a fatigue effect that increases with working time, but not yet enough evidence to stand on its own. These results would need to be verified by other analyses, ideally on a more micro-level using individual firm data.

References

- C. F. Baum and S. Stillman (1999), DMEXOGXT: Stata module to test consistency of OLS vs XT-IV estimates, Statistical Software Components S401103, Boston College Department of Economics, revised 18 June 2003.

- N. Belorgey, R. Lecat and T. Maury (2004), "Déterminants de la productivité apparente du travail", *Banque de France Bulletin*, January.

- R. Bourlès and G. Cette (2005), "A Comparison of Structural Productivity Levels in the Major Industrialised Countries", *OECD Economic Studies*, No. 41, pp. 96–138.

- R. Bourlès and G. Cette (2007), "Trends in Structural Productivity Levels in the Major Industrialized Countries", *Economic Letters*, Vol. 95.

- I. Dew-Becker and R. J. Gordon (2008), "The role of labour market changes in the slowdown of European productivity growth", Discussion Paper Series, CEPR, No. 6722, February.

- Gust, C. and J. Marquez (2000), "Productivity Developments Abroad", Federal Reserve Bulletin, October.

- Gust, C. and J. Marquez (2004), "International Comparisons of Productivity Growth: The Role of Information Technology and Regulatory Practices", Labour Economics, Vol. 11.

- R. McGuckin and B. Van Ark (2005), "Productivity and Participation: an International Comparison", Research Memorandum, University of Groningen, Groningen Growth and Development Centre, August.

- Malinvaud, E. (1973), "Une explication de la productivité horaire du travail". *Économie et Statistique* 48 (September).

- J. Sargan (1958), "The Estimation of Economic Relationships Using Instrumental Variables", *Econometrica*, 26(3).

- M. E. Schaffer and S. Stillman (2006), XTOVERID: Stata module to calculate tests of overidentifying restrictions after xtreg, xtivreg, xtivreg2, xthtaylor, Statistical Software Components S456779, Boston College Department of Economics, revised 04 Oct 2007.

Table 1

Estimation results for relationship (7) - IV Method

Explanatory variables	Long dataset				Short dataset			
	Time and country fix effect			Time fix effect	Time and country fix effect			Country fix effect
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
$gdpcap_{-1}$	-0.019	-0.018	-0.017	-0.015	-0.034	-0.033	-0.033	-0.022
	(3.52)***	(3.61)***	(3.50)***	(6.31)***	(2.90)***	(2.86)***	(2.80)***	(6.97)***
ΔER					-0.450	-0.436	-0.449	-.485
					(2.53)**	(2.46)**	(2.55)**	(3.05)***
ΔEPR	1.053	1.077	1.079	-0.221				
	(0.72)	(0.75)	(0.76)	(0.20)				
Δh	-0.383	-0.365	-0.463	-0.559	-0.742	-0.679	-0.685	-0.570
	(0.72)	(0.80)	(1.09)	(1.68)*	(10.21)***	(10.33)***	(10.52)***	(8.38)***
I_{1825}. Δh	-0.347				0.177			
	(0.58)				(1.34)			
I_{1925}. Δh		-0.492		-0.167		-0.304		
		(0.90)		(0.40)		(1.54)°°		
I_{2025}. Δh			-0.409				-0.497	-0.440
			(0.75)				(1.75)*	(1.50)°°
Constant	0.154	0.148	0.144	0.148		0.346	0.339	0.236
	(3.94)***	(4.02)***	(3.90)***	(7.52)***		(2.97)**	(2.91)***	(7.64)***
Δh + Ix. Δh	-0.73	-0.857	-0.872	-0.726	-0.565	-0.983	-1.182	-1.01
F-statistic	(1.15)	(1.21)	(1.11)	(5.08)***	(5.98)***	(6.08)***	(6.04)***	(26.76)***
Sargan test								
Statistic	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
P-value	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Davidson McKinnon test								
Statistic	5.760	5.733	5.996	1.811	0.871	0.795	0.930	4.652
P-value	0.019	0.02	0.018	0.18	0.35	0.37	0.34	0.03
Number of observations	83	83	83	83	636	636	636	636
Adjusted R^2	0.69	0.69	0.68	0.05	0.38	0.39	0.39	0.24

The numbers in brackets beneath the coefficients are the absolute value of the t-student statistic.
°° : significant at 15% ; * : significant at 10% ; ** : significant at 5% ; *** : significant at 1%.
* We use the fisher test to test the null hypothesis under which the variable Δh + Ix. Δh is equal to zero.

List of instruments:
[1] to [8] : Investment rate ; $gdpcap_{-1}$; Δh ; I_{1825}. Δh

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