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The decreasing returns on working time: 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

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1. Introduction

In all industrialized countries over the long run, average working time has decreased while the average productivity per hour worked has increased. The productivity improvement comes from numerous factors, chiefly innovation, and abundant empirical literature exists that evaluates their relative contributions. Several empirical studies have also 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 a stylized theoretical model of such a decreasing negative elasticity of productivity with respect to working time is proposed.

The empirical analysis is conducted on two panels of 18 OECD countries. These countries are: 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" in this paper) is a dataset with long sub-periods, starting in 1870 and ending in 2005, with only six observation years: 1870, 1913, 1950, 1973, 1990 and 2005. This provides five sub-period developments:

1870-1913, 1913-1950, 1950-1973, 1973-1990 and 1990-2005. All of the variables used in this dataset are from the Groningen Growth and Development Centre. The second dataset (referred to as the "short dataset" in this paper) starts in 1950 and ends in 2005, with annual observations. All of the variables in this dataset are taken from the OECD. The methodology consists in econometric estimations of simple relations on these two datasets. One of the relations will use thresholds on the working time to test the hypothesis of a decreasing elasticity of hourly productivity with respect to working time.

The originality of the paper is twofold. The first characteristic is to estimate the elasticity of hourly productivity with respect to working time on two different datasets, one of them being a long period dataset, with long working time at the beginning (to our knowledge, this has never been done before). The second characteristic is to estimate a relation with thresholds, which, to our knowledge, is also a novelty.

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

2. A stylised model

In this section, we propose a stylised theoretical model to characterize what could be 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 are supposed to decrease, and at a faster rate after certain thresholds. To simplify matters, we consider only two thresholds, H_{T1} and H_{T2} with $H_{NP} < H_{T1} < H_{T2}$.

We make the assumption of a Cobb-Douglas function depending on the working time. Three situations have to be distinguished, depending on the length of the working time: below the first threshold, above the first threshold and below the second one or above the second threshold.

- *If the working time is below the first threshold* ($H_{NP} < H < H_{T1}$) then we have:

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

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:

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

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

- *If the working time is above the first threshold and below the second one* ($H_{T1} < H < H_{T2}$)

then we have:

$$Q = \left(\frac{H}{H_{T1}}\right)^{\alpha 2} . F_2(X_i, H_{T1}, \lambda 1') \qquad (4)$$

with $0 < \alpha 2 < \alpha 1 < 1$ and with $\lambda 1' = \frac{H_{NP}}{H_{T1}}$. The elasticity of productivity per hour to working time is:

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

and we have $-1 < E2 < 0$. The difference Δ_{21} between the two elasticities E_2 and E_1 is:

$$\Delta_{21} = E_2 - E_1 = \frac{\alpha 2.(1 - \lambda 1') - \alpha 1}{1 - \lambda 1} \qquad (6)$$

We have always $\Delta_{21} < 0$ which means $E2 < E1$.

- *If the working time is above the second threshold* ($H_{T2} < H$) then we have:

$$Q = \left(\frac{H}{H_{T2}}\right)^{\alpha 3} . F_3(X_i, H_{T1}, \lambda 1', \lambda 2) \qquad (7)$$

with $0 < \alpha 3 < \alpha 2 < \alpha 1 < 1$ and with $\lambda 1' = \frac{H_{NP}}{H_{T1}}$ and $\lambda 2 = \frac{H_{T1}}{H_{T2}}$. The elasticity of productivity per hour to working time is:

$$E_3 = \alpha 3 - 1 \qquad (8)$$

and we have $-1 < E3 < 0$. The difference Δ_{32} between the two elasticities E_3 and E_2 is:

$$\Delta_{32} = E_3 - E_2 = \alpha 3 - \alpha 2 \qquad (9)$$

and we always have $\Delta_{32} < 0$, which means $E3 < E2$.

The stylised model proposed above shows that $E3 < E2 < E1$, which means a decreasing elasticity of productivity per hour to working time. More precisely, the elasticity of productivity per hour to working time decreases after each threshold H_{T1} and H_{T2} of the fatigue effect. We always have $-1 < E3 < E2 < 0$, which means that above the first threshold H_{T1}, the returns of working time are always decreasing. In usual situations we have $-1 < E1 < 0$, which means that below the first threshold H_{T1}, the returns of working time are decreasing. But in very rare cases (here $\lambda1 > 1 - \alpha1$) we can get $0 < E1$, which means that below the first threshold H_{T1}, the returns of working time could be increasing, this property coming from the existence of an unproductive part of working time (here $H_{NP} > 0$).

3. Some stylized facts

Over the period 1870-2005 (henceforth referred to as the “long period”), we observe some significant changes in productivity per hour and annual working time for the 18 industrialized countries included in this study[1].

Improvements in productivity have varied greatly between countries. From 1870 to 2005, it increased by a factor of 5.8 in Australia and a factor of 38.1 in Japan (Figure 1). The productivity leader also changed during the period observed: while it was Australia until the First World War (WWI), it is currently Norway. At the other end of the spectrum, the lowest productivity level was observed in Japan until WWI and in Portugal after that. The most drastic annual productivity improvement sub-period is the interval between the two World Wars (in this study, the sub-period 1913-1950) for the United States and the interval between the Second World War (WWII) and the first oil shock (1950-1973) for the other countries. Over the last decades, we observe changes in the productivity trend: a slowdown in all countries after the first oil shock and a diversity of trend changes during and after the 1990s, more precisely an acceleration in the United States, almost no change in Australia, Canada and the United Kingdom, and a new slowdown everywhere else.

[1] Productivity data are in 2000 ppp dollars; working time is a yearly average for employees, in hours. See further the source of the data.

Few analyses are able to draw productivity comparisons between several industrialised countries over a century. The stylised facts stated above are similar to those put forward by Gordon (2003), Cette (2007), Van Ark et al. (2004), Maury and Pluyaud (2004) and Cette et al. (2009). Most of these studies also measure labour productivity growth over different sub-periods using real GDP, employment and working time estimates calculated by Maddison (2001, 2003, 2007) and the Groningen Growth and Development Centre[2]. Our results are also consistent with long run analyses on specific countries, including those of Dubois (1985) and Carré, Dubois and Malinvaud (1972) for France; Crafts (2004a, b and c) for the United Kingdom, Ferguson and Wascher (2004) and Gordon (2010) for the United States. The stylised facts over the last three decades are also consistent with those from many other studies, such as the OECD (2003), Jorgenson and Kuong (2005), Van Ark and Piatkowski (2004) and Van Ark et al. (2008).

Average working time has decreased significantly in every country over the long period considered in this paper (Figure 2). From 1870 to 2005, it has been divided by a factor of 1.7 in Finland to a factor of 2.1 in the Netherlands. The most dramatic sub-period of decreasing annual working time is the interval 1913-1950. France had longer working times than any other country in 1870, while it had one of the shortest working times in 2005. In contrast, Japan in 1870 had one of the shortest working times, while it had the longest working time in 2005. At every date considered here, the Scandinavian countries (Denmark, Sweden, and Norway) consistently have the shortest working times.

In this respect, few analyses are able to draw working time comparisons between several industrialised countries over an entire century. The aforementioned stylised facts are similar to those put forward by Gordon (2003), Cette (2007) or, by construction, Maddison (2001, 2003, 2007) and the Groningen Growth and Development Centre. Over the last three decades,

[2] The data from Groningen Growth and Development Centre June may be downloaded at the following address: http://www.ggdc.net.

they are also consistent with those from other studies, including, among others, Prescott (2004) and Dew-Becker and Gordon (2008).

In line with the trends described above, the country panel data displays a notable negative correlation between working time and productivity: the higher the productivity per hour, the lower the working time (Figure 3). At the beginning of the period, Japan had lower productivity and shorter average working times than the adjustment line. At the same time, but at the opposite end of the spectrum, Australia had longer average working times than the adjustment line.

The larger range of working times resulting from the inclusion of very long working times observed at earlier dates, mostly before WWII, will allow us to more easily estimate a decreasing elasticity of productivity to working time stemming from a fatigue effect.

4. Estimated relationship and data

4.1. Estimated relationship

The model estimated is similar 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 (10), the dependent variable (Δph) corresponds to the rate of change of hourly labour productivity (PH):

$$\Delta ph = \beta 1.\Delta ER + \beta 2.\Delta h + \sum \beta H_{Ti}.IH_{Ti}.\Delta h + \sum \beta j.Xj + cte + u \qquad (10)$$

Where:

- The coefficient $\beta 1$ reflects the effect of a change in the employment rate (ΔER) on hourly productivity. *A priori* we expect: $-1 < \beta 1 \leq 0$, $\beta 1 < 0$, which means decreasing returns on hourly productivity with respect to the employment rate. We were unable to locate data on country employment rates for the years 1870 and 1913 of the long dataset. In any case, approximating the working age population to the 16-65 year-old population in the short dataset is probably less relevant at the end of the 19th century and even at the beginning of the 20th century. For this reason, a proxy of the employment rate ER is used in the regressions on the long dataset. This proxy is EPR, the ratio of employment to the total country population, in contrast to only the working age population. Because EPR is not a good 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 coefficients $\beta2$ and βH_{Ti} reflect the effect of an increase in working time (Δh) on hourly productivity. Due to a fatigue effect, the returns on working time are supposed to decrease, and at a faster rate after certain thresholds represented by the variables IH_{Ti}, each variable IH_{Ti} being equal to 1 if the working time is equal to or above the threshold H_{Ti}, and equal to 0 if it is below. From the model proposed in Section 2, we expect *a priori*: $-1 < \beta2$, $\beta H_{Ti}, \beta2 + \sum \beta H_{Ti} \leq 0$. $\beta2, \beta H_{Ti}, \beta2 + \sum \beta H_{Ti} < 0$ signifies decreasing returns on hourly productivity with respect to working time. Initially, two thresholds were considered, but the results were not realistic so we finally decided to present and comment on estimations with no more than one threshold.
- There are many other variables X_j that 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 has also made it impossible to try to estimate the impact on productivity 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 (such as 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. Ultimately, the lagged log of GDP per capita $gdpcap_{-1}$ (the year before the current one for the short

dataset and the beginning of the current sub-period for the long dataset) is the only one of these variables used in the results presented here. This variable ($gdpcap_{-1}$) should capture a productivity catching-up process and we expect its coefficient to be negative, a higher initial level of GDP per capita being associated with lower productivity growth.

The results presented and commented on below correspond to the estimation of the following relation:

$$\Delta ph = \beta 1.\Delta ER + \beta 2.\Delta h + \beta H_T.IH_T.\Delta h + \beta 3.gdpcap_{-1} + cte + u \qquad (11)$$

Below the threshold H_T, the elasticity of hourly productivity to working time is $E1 = \beta 2$, and above the threshold it is $E2 = \beta 2 + \beta\ H_T$. We expect $-1 < E2 = \beta 2 + \beta\ H_T \leq E1 = \beta 2 < 0$.

4.2. The data

As indicated in the introduction, 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 long dataset, beginning in 1870 and finishing in 2005, with only six observation 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 the five sub-periods of this longer dataset, the variable changes used in the empirical analysis are the average annual changes, and the variable levels are the levels of the initial year of the sub-period. Because of 2 missing data, for econometric estimations, this dataset contains 83 observations (5 sub-periods * 18 countries – 2 missing data). All the values of the variables in this dataset are from the Groningen Growth and Development Centre[3].

- The short dataset, beginning in 1950 and finishing in 2005, with annual observations. Because of 354 missing data, for econometric estimations, this dataset contains 636 observations (55 yearly changes * 18 countries – 299 missing data). All the values of the variables in this dataset are from the OECD[4].

The variables used in the empirical analysis are presented in Box 1.

Some descriptive statistics on working time with regard to the two datasets are given in Table 1. It appears that long working hours are observed only in the long dataset, and they correspond to the beginning of the relevant long period. For example, more than 25% of the working hours in the long dataset are higher than the longer working hours in the short dataset.

As regards estimations, we decided to use the same alternative thresholds for the two datasets. Three thresholds were alternatively introduced in the estimates:

- The first threshold is 1,825 hours, 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.

We do not have a sufficient number of observations in the long dataset to choose a threshold below 1,825 hours or above 2,025 hours.

[3] Address: http://www.ggdc.net.
[4] Address: http://stats.oecd.org/WBOS/index.aspx.

Box 2

Variables used in the study

. ER: Employment rate;

. EPR: Ratio of employment to the total country population, and not only to the working age population;

. GDPCAP: GDP per capita;

. H: Average annual hours worked;

. H_{Ti}: Threshold i on the length of H;

. IH_{Ti}: Dummy variable, equal to 1 if working time H is equal to or above the threshold H_{Ti}, and equal to 0 if it is below;

. ILLIT: Illiteracy rate;

. IR : Investment rate;

. PH: Hourly labour productivity;

. PH_{1}: Lag of hourly labour productivity;

. POP: Population of the country;

. PRIM: Percentage of population enrolled in primary school;

. URBAN: Urban population, as a percentage of total;

. WORAG: Percentage of labour force in agriculture;

. Δ before a variable means a difference of the first order for the short dataset, and an average annual change for the long dataset;

. Variables in lower case correspond to their logs.

5. Empirical results

We successively comment on the results obtained from the estimation of relation (11) without any working time thresholds, by the ordinary least squared (OLS) method (5.1.) and the instrumental variables (IV) method (5.2.). We then comment on the results obtained from the estimation of relation (1) with working time thresholds, using the OLS method (5.3.) and the IV method (5.4.). In the first two steps, we compare our results with previous studies, in particular those which also use panel country data: 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).

5.1. OLS estimation results without thresholds (Table 2)

For each dataset, we report the estimation with only country fix effects (see Table 2, columns 1 and 2 for the long dataset and columns 5 and 6 for the short one) and the estimation with both time and country fix effects (Table 2, columns 3 and 4 for the long dataset and columns 7 and 8 for the short one). The results of the regressions are as follows (see Table 2):

- The coefficient of the lagged log of GDP per capita ($gdpcap_{-1}$), one of the control variables, is significantly non-zero only when we add the time fix effect to the country fix effect in the long dataset, whereas it is always significantly different from zero in the short dataset even when we ignore the time effect. In both datasets, the coefficients of the lagged log of GDP per capita ($gdpcap_{-1}$) are negative, suggesting a productivity convergence process;
- For the short dataset, the estimated coefficient of employment rate changes (ΔER) is close to those also estimated using OLS by Bourlès and Cette (2005, Table 4 and 5) and by McGuckin and Van Ark (2005, Table 3). We find that without the control by the lagged log of GDP per capita (columns 5 and 7), a one percentage point increase (decrease) in the employment rate is associated with a decrease (increase) in

productivity per hour – all other things held constant – of 0.31% for the country fix effect to 0.16% if we add the time fix effect to the country fix effect. The sign and the significance of the employment rate do not change after controlling by the lagged log of GDP per capita. For the long dataset, however, the estimated coefficient differs from that of previous studies in that it is unrealistically high (in absolute terms). This is most likely due to the difference in the measure of employment rate changes (ΔEPR): in this dataset, the proxy for the employment rate is the ratio of employment to the total population and not, as is the case in the short dataset, the ratio of employment to the working age population. While Gust and Marquez (2000, 2004) use the same proxy for the employment rate, their dataset covers a shorter period and fewer countries than the one used in this study. Furthermore, their specification contains more control variables, but their estimated coefficients are generally not significant;

- In both datasets, the estimated coefficient of the growth rate of working time (Δh) is close to the one also estimated with the OLS method by Bourlès and Cette (2005, Table 4). In the long dataset, a one percentage point increase (decrease) in working time is associated with a decrease (increase) in productivity per hour - all other things held constant - of 0.81% when we consider only the country fix effect (columns [1] and [2]). The coefficients are significant at 10%. After adding the time fix effect, the coefficient on working time is no longer significant when the initial GDP per capita is excluded from the equation (column [3]). In the short dataset, all the working time estimates are negative and significant at least at 5%. After controlling by the GDP per capita (columns [6] and [8]) a one percent increase (decrease) in the working time results in a decrease (increase) in productivity per hour of 0.59% for the country fix effect and 0.69 when we add the time fix effect to the country fix effect.

5.2. IV estimation results without thresholds (Table 3)

The estimation results discussed above 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[5]. 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 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 estimate results using instrumental variables are very close to the OLS results (see Table 3). The important difference is observed on the estimated coefficient of the employment rate change, which is now higher (in absolute terms) on the short dataset. This coefficient for the short dataset is close to the one also estimated using instrumental variables by Bourlès and Cette (2005, Table 5), Bourlès and Cette (2007) and Dew-Becker and Gordon (2008, Table 5), but 50% higher (in absolute terms) than the one estimated using GMM by Bélorgey et al. (2004, Table 1). The estimates with control variables in the short dataset (columns [6] and [8]) suggest 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 0.46% when we take into account only the country fix effect and 0.43% after including also the time fix effect. In the long dataset, the estimated coefficient is very different and unrealistic, which can be explained, as above, by the use of an imperfect proxy of the employment rate for this dataset.

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[5] The first stage estimation results of this IV estimate are presented in Appendix 1.

Our estimates of the coefficient for changes in working time are close to the OLS estimates of the preceding section, and are slightly higher (in absolute terms) than the ones also estimated with instrumental variables by Bourlès and Cette (2005, Table 5), Bourlès and Cette (2007) and the ones estimated using GMM by Bélorgey et al. (2004, Table 1). This slight difference could be explained by the fact that even in the short dataset, the longer overall period of 55 years results in more instances of long working times in comparison to the previously quoted papers, which use shorter and more recent time periods. If we suppose that this coefficient is higher (in absolute terms) for longer working times, the difference could be considered as a coherent result. The following estimates with thresholds confirm this hypothesis.

5.3. OLS estimation results with thresholds (Table 4)

The estimations are reported in Table 4. We include here both the time and the country fix effects except in columns [4] and [8] where we take respectively into account only the time fix effect for the long dataset and the country fix effect for the short dataset. Results are close to the ones in Table 2 columns [4] and [8] except for the coefficient on working time, which is no longer significant in the long dataset. When we exclude the country fix effect in the long dataset (column [4]) the estimations are not affected, and when we only consider the country fix effect in the short dataset (column [8]) we observe that the coefficients on the employment rate and on working time are lower in absolute terms. The coefficients on the interaction (Ix.Δh) between the threshold variable (Ix) and working time (Δh) are never significant in both datasets and in different specifications.

5.4. IV estimation results with thresholds (Table 5)

The estimations are reported in Table 5. They are comparable to those in Table 3 column [4] for the long dataset and columns [6] and [8] for the short dataset[6]. For the long dataset the coefficient on the employment rate becomes insignificant, but the working time becomes more significant when only the time fix effect is taken into account (see column [4]). The coefficient on the interaction term is never significant for all threshold values. In the short dataset the estimates are very close to those without thresholds (Table 3 column [8]). The interaction term for the thresholds 1,925 and 2,025 is significant at respectively 15% and 10% with a negative sign. The estimated coefficients of the variables without (Δh) and with ($I_{x\%}.\Delta h$) thresholds confirm the hypothesis that the returns on working time decrease more drastically for longer working times. The elasticity of hourly productivity with respect to working time is always negative (which means decreasing returns on working time) and higher (in absolute terms) for longer working times. The 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 1,925 and of 1% for the threshold 2,025. 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 evidence the existence of decreasing returns on working time and offer a partial confirmation of the hypothesis that they decline with working time. More specifically, the elasticity of productivity per hour to working time is negative and

[6] The first stage estimation results of this IV estimate are presented in Appendix 2.

decreasing with working time. Nevertheless, the statistical significance of the elasticity coefficient is not very high. This study offers some empirical support for the hypothesis of a fatigue effect that increases with working time, but not yet enough evidence to stand on its own.

These results will need to be verified by other analyses, in particular on individual firm data, in order to confirm the hypothesis that the returns on working time decline more sharply for long working times than for shorter ones.

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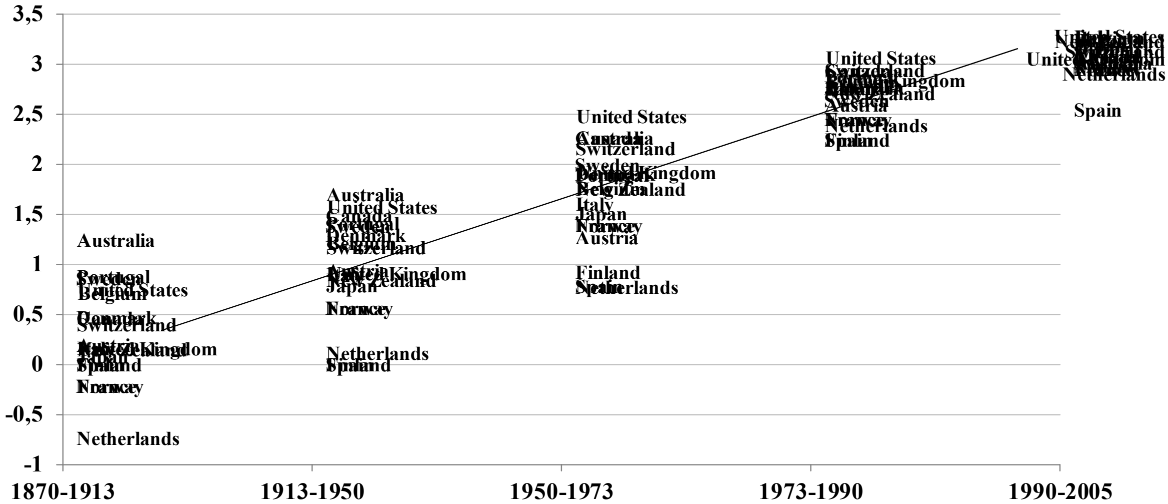
Figure 1
Productivity per hour
Levels (in log) for 18 OECD countries, in different sub-periods from 1870-1913 to 1990-2005
The levels are those at the beginning of each sub-period – 2000 ppp dollars



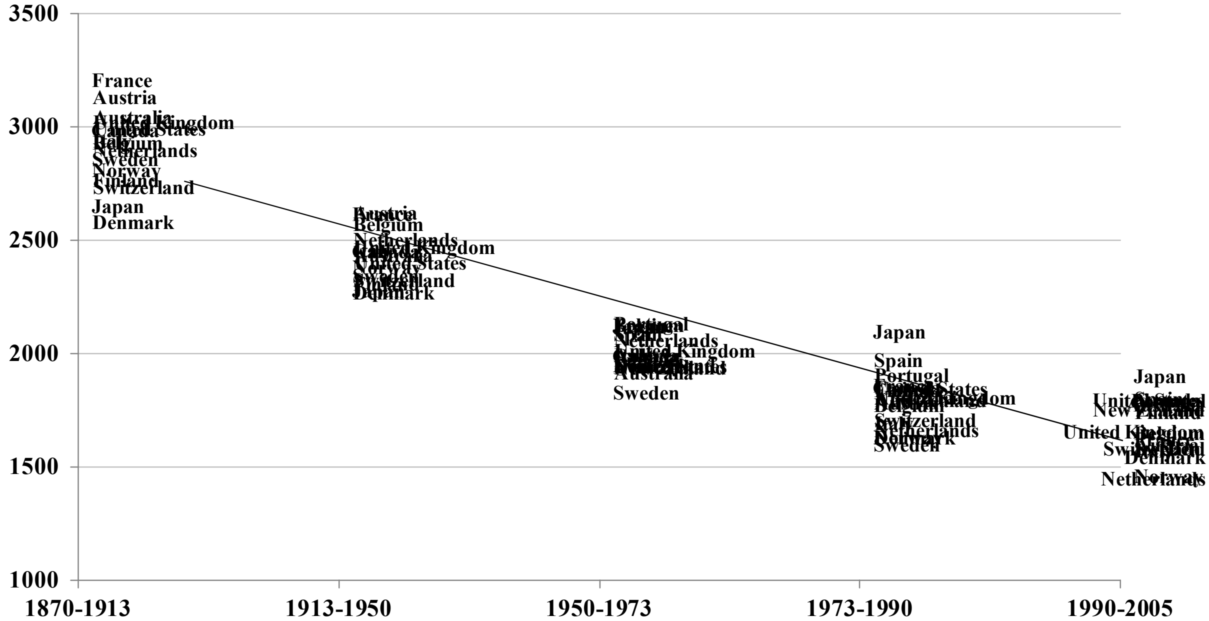
Source of the data: University of Groningen and OECD.

Figure 2

Annual average working time of employees

Levels for 18 OECD countries, in different sub-periods from 1870-1913 to 1990-2005

The levels are those at the beginning of each sub-period - hours



Source of the data: University of Groningen and OECD.

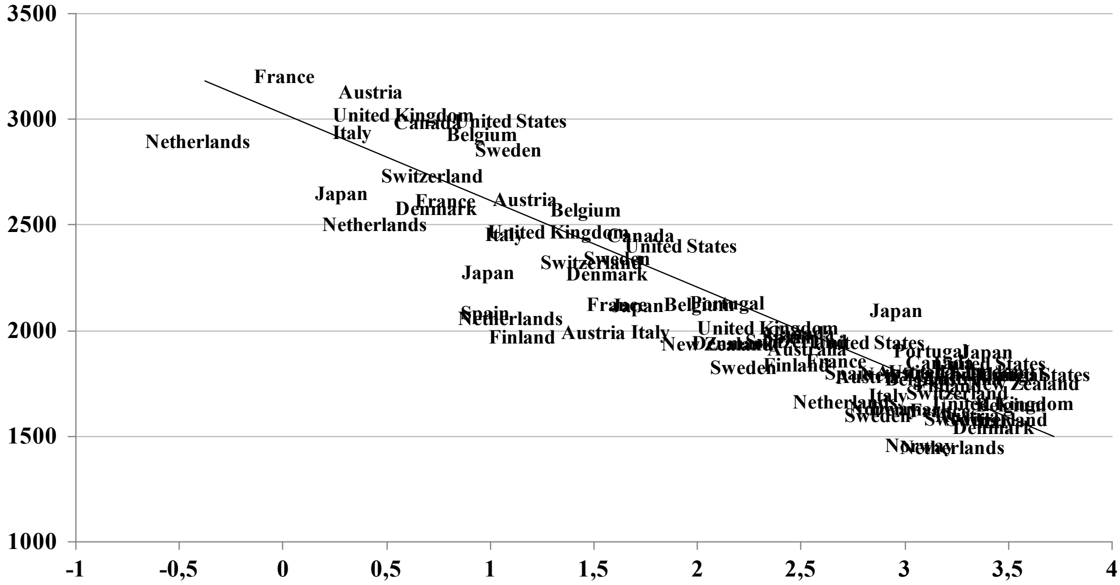
Figure 3

Annual working time of employees and productivity per hour

Levels for 18 OECD countries, in different sub-periods from 1870-1913 to 1990-2005

The levels are those at the beginning of each sub-period

In log and 2000 ppp dollars for productivity, in hours for working time



Source of the data: University of Groningen and OECD.

Table 1

Some descriptive statistics on average working hours per year in the two datasets

	Long dataset	Short dataset
Minimum	1,450.4	1,392.4
Decile 1	1,627.7	1,579.8
Quartile 1	1,793.0	1,712.1
Third 1	1,816.7	1,769.1
Median	1,974.4	1,833.7
Third 2	2,277.2	1,958.1
Quartile 3	2,454.6	2,027.5
Decile 9	2,887.1	2,128.8
Maximum	3,207.8	2,404.2
Mean	2,125.6	1,857.9
Standard Deviation	462.1	207.1
Nb. Observations	83	636

Table 2
Estimation results for relationship (11)
OLS Method – 18 countries

Explanatory variables	Long dataset				Short dataset			
	Country fix effect		Time and country fix effect		Country fix effect		Time and country fix effect	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
$gdpcap_{-1}$		-0.0003		-0.017		-0.034		-0.049
		(0.17)		(4.12)***		(16.76)***		(7.86)***
ΔER					-0.319	-0.164	-0.359	-0.283
					(4.64)***	(2.75)***	(5.71)**	(4.62)***
ΔEPR	-2.158	-2.113	-1.543	-1.471				
	(2.49)**	(2.31)**	(2.72)***	(2.93)***				
Δh	-0.812	-0.817	-0.195	-0.551	-0.717	-0.591	-0.636	-0.692
	(1.71)*	(1.70)*	(0.58)	(1.76)*	(9.05)***	(8.69)***	(9.20)**	(10.37)***
Constant	0.021	0.024	0.018	0.182	0.024	0.345	0.023	0.451
	(8.00)***	(1.53)°°	(6.04)***	(4.59)***	(28.76)***	(17.98)***	(2.75)**	(8.05)***
Number of observations	83	83	83	83	769	769	769	769
Adjusted R^2	0.13	0.13	0.71	0.77	0.13	0.37	0.47	0.51

In the long dataset, $gdpcap_{-1}$ corresponds to the value of gdpcap at the beginning of the relevant sub-period.
The numbers in brackets beneath the coefficients are the absolute values of the t-student statistic.
°° : significant at 15%; * : significant at 10%; ** : significant at 5%; *** : significant at 1%.

Table 3
Estimation results for relationship (11)
IV Method – 18 countries

Explanatory variables	Long dataset				Short dataset			
	Country fix effect		Time and country fix effect		Country fix effect		Time and country fix effect	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
$gdpcap_{-1}$		-0.002		0.990		-0.023		-0.034
		(0.89)		(0.71)		(7.17)***		(2.89)***
ΔER					0.637	-0.466	-0.508	-0.437
					(2.00)**	(2.92)***	(3.01)***	(2.47)**
ΔEPR	1.609	0.861	0.662	-0.018				
	(0.55)	(0.38)	(0.45)	(3.60)***				
Δh	-0.843	-0.863	-0.232	-0.607	-0.742	-0.586	-0.688	-0.698
	(1.55)°°	(1.66)*	(0.61)	(1.63)°°	(9.02)***	(8.72)***	(10.49)***	(10.78)***
Constant	0.019	0.037	0.018	0.147	0.018	0.242	0.012	0.350
	(5.61)***	(1.94)*	(5.36)***	(4.04)***	(18.48)***	(7.85)***	(3.36)***	(3.00)***
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	2.459	2.613	3.575	5.836	11.295	4.020	1.284	0.756
P-value	0.12	0.11	0 .06	0.02	0.01	0.05	0.26	0.39
Number of observations	83	83	83	83	636	636	636	636
Adjusted R^2	0.01	0.01	0.56	0.69	0.02	0.24	0.39	0.38

In the long dataset $gdpcap_{-1}$ corresponds to the value of gdpcap at the beginning of the relevant sub-period.
The numbers in brackets beneath the coefficients are the absolute values of the t-student statistic.
°° : significant at 15 %; * : significant at 10 %; ** : significant at 5 %; *** : significant at 1 %.

List of instruments:
[1] : IER ; Δh
[2] : IER ; $gdpcap_{-1}$; Δh
[3] : IER ; Δh
[4] : IER ; $gdpcap_{-1}$; Δh
[5] : IR; Δh
[6] : IR ; $gdpcap_{-1}$; Δh
[7] : IR ; Δh
[8] : IR ; $gdpcap_{-1}$; Δh

Table 4
Estimation results for relationship (11)
OLS Method – 18 countries

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]**
$gdpcap_{-1}$	-0.017	-0.017	-0.017	-0.014	-0.048	-0.049	-0.049	-0.033
	(3.83)**	(4.10)**	(4.05)**	(6.54)**	(7.76)**	(7.88)**	(7.85)**	(16.44)**
ΔER					-0.288	-0.280	-0.282	-0.163
					(4.70)**	(4.56)**	(4.61)**	(2.74)**
ΔEPR	-1.492	-1.443	-1.452	-1.488				
	(2.89)**	(2.81)**	(2.87)**	(3.40)**				
Δh	-0.612	-0.480	-0.456	-0.569	-0.755	-0.674	-0.690	-0.586
	(1.42)	(1.26)	(1.29)	(1.81)	(9.56)**	(9.50)**	(10.01)**	(8.36)**
I_{1825}. Δh	0.095				0.183			
	(0.21)				(1.47)			
I_{1925}. Δh		-0.145		-0.043		-0.114		
		(0.34)		(0.11)		(0.77)		
I_{2025}. Δh			-0.264				-0.023	-0.061
			(0.59)				(0.12)	(0.30)
Constant	0.180	0.183	0.181	0.142	0.447	0.452	0.451	0.344
	(4.25)**	(4.56)**	(4.52)**	(7.84)**	(7.97)**	(8.07)**	(8.04)**	(17.65)**
Δh + Ix. Δh	-0.517	-0.625	-0 .720	-0.612	-0.572	-0.788	-0.713	-0.647
F-statistic*	(0.59)	(0.59)	(0.67)	(2.72)*	(4.72)***	(4.75)***	(4.72)***	(31.31)***
Number of observations	83	83	83	83	769	769	769	769
Adjusted R^2	0.77	0.78	0.78	0.46	0.51	0.51	0.51	0.37

In the long dataset $gdpcap_{-1}$ corresponds to the value of gdpcap at the beginning of the relevant sub-period.
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 %.
Working hours thresholds: 1,825; 1,925; 2,025.
* We use the fisher test to test the null hypothesis under which the variable **Δh + Ix. Δh** is equal to zero.

Table 5
Estimation results for relationship (11)
IV Method – 18 countries

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

In the long dataset $gdpcap_{-1}$ corresponds to the value of gdpcap at the beginning of the relevant sub-period.
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] : IER ; $gdpcap_{-1}$; Δh ; I_{1825}. Δh
[2] : IER ; $gdpcap_{-1}$; Δh ; I_{1925}. Δh
[3] : IER ; $gdpcap_{-1}$; Δh ; I_{2025}. Δh
[4] : IER ; $gdpcap_{-1}$; Δh ; I_{1925}. Δh
[5] : INVEST; $gdpcap_{-1}$; Δh; I_{1825}. Δh
[6] : INVEST; $gdpcap_{-1}$; Δh; I_{1925}. Δh
[7] : INVEST; $gdpcap_{-1}$; Δh; I_{2025}. Δh
[8] : INVEST; $gdpcap_{-1}$; Δh; I_{2025}. Δh

Appendix 1: First stage 2SLS for Table 3

Explanatory variables	Long dataset				Short dataset			
	Country fix effect		Time and country fix effect		Country fix effect		Time and country fix effect	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
IER	-0.017 (2.83)***	-0.022 (3.86)***	-0.021 (3.65)***	-0.021 (3.61)***				
INVEST					0.086 (2.38)**	0.167 (9.38)***	0.149 (8.33)***	0.132 (7.96)***
$gdpcap_{-1}$		0.001 (3.55)***		ε (0.06)		0.019 (8.42)***		0.014 (3.34)***
Δh	0.048 (0.72)	0.070 (1.14)	0.055 (0.77)	0.056 (0.75)	0.113 (2.38)***	0.087 (1.92)*	0.019 (0.44)	0.021 (0.48)
Constant	0.008 (3.01)***	0.004 (1.33)	0.009 (3.57)***	0.009 (1.16)	0.018 (18.48)***	-0.225 (9.04)***	-0.026 (5.70)***	0.194 (2.91)***
Number of observations	83	83	83	83	636	636	636	636
Adjusted R²	0.123	0.24	0.28	0.28	0.03	0.07	0.05	0.15

The numbers in brackets beneath the coefficients are absolute value of t-student statistic.
°° : significant at 15 % ; * : significant at 10 % ; ** : significant at 5 % ; *** : significant at 1 %.

Appendix 2: Fist stage 2sls for Table 5

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]
IER	-0.020 (3.54)***	-0.020 (3.54)***	-0.021 (3.55)***	-0.013 (3.98)***				
Invest					0.109 (7.29)***	0.116 (7.52)***	0.127 (7.85)***	0.118 (7.86)***
$gdpcap_{-1}$	0.001 (0.48)	ε (0.12)	ε (0.04)	0.001 (1.03)	0.011 (3.18)***	0.011 (3.18)***	0.013 (3.28)***	0.014 (7.05)***
Δh	-0.041 (0.41)	-0.002 (0.02)	0.046 (0.55)	0.004 (0.06)	0.002 (0.04)	0.006 (0.13)	0.014 (0.32)	0.068 (1.50)
I_{1825}. Δh	0.148 (1.42)				0.057 (0.63)			
I_{1925}. Δh		0.115 (1.15)		0.126 (1.37)		0.179 (1.35)		
I_{2025}. Δh			0.026 (0.24)				0.211 (1.10)	0.197 (1.00)
Constant	0.006 (0.72)	0.009 (1.10)	0.009 (1.16)	0.002 (0.57)	-0.126 (3.65)***	-0.133 (3.66)***	-0.153 (3.78)***	0.236 (7.64)***
Number of observations	83	83	83	83	636	636	636	636
Adjusted R²	0.31	0.69	0.68	0.048	0.15	0.16	0.16	0.01

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%.