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A Model for the Relationship between Working Time and the Intensity of Labour

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As Marx, but also Chapman and Robbins argued, working time and labour intensity are strongly and negatively correlated. Nevertheless, the models for this interaction presented so far don't integrate their ideas. We construct a model for the time – intensity relationship that is mainly based on the natural limitations of the human body and reflects Marx's main theses. We explore it's consequences on product, value and surplus value. Finally we find support for the basic assumptions of this model with the help of the results of contemporary ergo-metric experiments.

INTRODUCTION

Working time was a steadily declining economic variable since the beginning of the 20th century, reaching the level of 8 hours per day or even less. Therefore, there is even today a widespread perception that its declining trend is irreversible. However, since the mid-1980s there is growing evidence that this trend has actually been inverted, especially in the UK and the USA, despite variations due to economic cycles. In the other European countries, although trends are not uniform, the declining pace seems to reach an end (Schor, 1991; Leete and Schor, 1994; Bluestone and Rose, 2000). These developments restore attention on the working time and have significant theoretical consequences, which might surprise some economic theories. It will be argued that focusing on the crucial role of working time within the premises of the Labour Theory of Value enhances the explanatory power of the latter, particularly in the current era of economic turbulence.

We believe that despite its past declining trend, working time never stopped being a decisive factor of capital accumulation. Its theoretical depreciation could be attributed to a silent detachment of working time

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from the other dimension of labour-power expenditure: the intensity of labour. The correlation of these two variables can shed light to the historical evolution of working time and to the value-formation process as well.

After all, it was Smith and Marx, as well as influential neoclassical economists like Chapman and Robbins, who stressed the importance of the intensive dimension of labour. According to them, working time and labour intensity are inversely correlated in the real work-process. Furthermore, they argued that it is very possible a working time reduction to lead, through the corresponding rise of intensity, not to a decrease but to an increase of total output. However, it was rather impossible for them to prove this claim, since the time – intensity relationship was unquantifiable.

The quantitative determination of this relationship still remains a hard and yet unaccomplished task. A first step towards this direction is the theoretical description and the mathematical modeling of this relationship based mainly on Marx's ideas. This modeling is our first objective and it is conducted in comparison and sometimes in contradiction to the pertinent model offered by Barzel (1973). It appears that, under this formalization, there is a possibility of an increase in total product and surplus-value after a working time decrease, without assuming a negative marginal product of labour. The second goal of this article is to check out the main principles, upon which this model is based, with the help of an alternative method, using the results of ergo-metric experiments.

The paper is structured as follows. First, we present concisely the basic ideas of Marx and other influential economists on the time – intensity correlation and the workers' effort discretion. Then we describe a model that can incorporate the important features of this relationship, in comparison and some times contradiction to previously presented models. After this, we investigate its consequences to total product and surplus value, as well as the expansions and limitations of this approach. Finally we check the main assumptions upon which this model is based with the use of the results of ergo-metric experiments and conclude.

THE EVOLUTION OF IDEAS ON THE TIME – INTENSITY RELATIONSHIP

According to Nyland (1986), Smith argued that nature itself poses labour intensity in contradiction to labour time. This creates an inverse relationship between the two variables that employers tend to forget,

exhausting their workers, who in their turn demand the reduction of the labour hours. So he proposed to the employers to find the optimum combination of time and intensity, avoiding the exhaustion of their labourers.

Marx examined the relationship among the two variables in much more detail. In his surplus-value analysis he assumes that a change in working time leaves the intensity of labour unaffected. However, it is rather clear that this is a simplifying assumption at a high level of abstraction. In various parts of 'Capital' Marx points out the indisputable relation existing among these variables. The following arguments constitute, in our view, his thesis on the time – intensity relationship. First, it is the 'self-evident law that the efficiency of labour power is in inverse ratio to the duration of its expenditure' (Marx, 1990, p. 535), describing the negative correlation between working time and labour intensity. Marx justifies the above 'self-evident law' on the secular limitations that nature poses to human bodies and minds, which make it impossible for the labour-power to be expended for long times at a high intensity.

Secondly, the inverse ratio obviously refers to the maximum magnitudes that the two variables can jointly take. If for a given magnitude of working time there exists a maximum magnitude for labour intensity, all the smaller magnitudes of labour intensity are feasible too. However, Marx offers many examples where the reduction of working time has led to increases in labour intensity (Marx, 1990, pp. 533-542) and generally considers each variable as binding for the other. His thesis was that the factory discipline had already made the workers work near their physical limits, so only a decrease in worktime could lead (and finally would lead) to an intensity increase. He supports this argument by referring to the extended use of machines and their effect on workers discipline. Marx didn't focus on the intra – day reduction of labour intensity. Instead, he focused on the accumulation of fatigue from one working day to the other that makes mutually exclusive the long working days and the high labour intensities. He even extended the accumulation of fatigue to the whole lifespan of the worker (see Ioannides and Mavroudeas, 2010).

Marx's description of the time – intensity relationship has an important advantage. It incorporates, as we aim to prove, the possibility that a decrease in working time can lead to an increase in total output, through the subsequent increase in labour intensity.

Marx's main argument is that the time – intensity relationship is based on 'objective' factors, that is, the human body and mind limits.

Of course he refers to 'consciousness' factors like the social determination through class struggle or other social processes, but in our opinion he poses the materialist factor of human limits above factors like individual or collective will (see Ioannides and Mavroudeas, 2010).

Interestingly enough, influential neoclassical economists shared a common view with Marx on this subject. Chapman (1909) points out that the use of machines has intensified the labour process:

> *And decade by decade, with the speeding up of machinery, we should expect to find more nervous strain accompanying the process of production.*
>
> *(Chapman, 1909, p.355)*

He mentions that there are examples of output increase after a working time reduction. He also claims that the probable reduction of output as a result of the increasing working time is not observed inside the limits of one working day, but in a broader period of time.

Robbins (1929) points out that the day after day repeated nature of labour and the accumulation of workers fatigue are responsible for the decrease in workers productivity after a working time increase. He also extends this result to the workers of mind and calls naïve the assumption that a lengthening of the working day necessarily increases output or that a curtailment diminishes it (Robbins, 1929, p.26). His conclusion is that there is an optimum length of the working day that leads to output maximization.

Despite these references, the existence of an interaction between working time and work intensity is rather problematic for the neoclassical framework. As Contensou and Vranceanu (2000) show, the possibility of a market determination of both the number of workers and their individual working time is cancelled when intensity depends on working time. For all that, there are recent neoclassical writings that investigate the time – productivity relationship. Felstein (1967) questioned the 'homogeneity assumption', that is the assumption that labour has the same impact on total product independently of its' internal composition (number of workers and hours of work). He argued that the number of workers and their working time cannot be just multiplied in the production function. He proposed a generalised production function where the number of workers and their working time enter the production function independently and in general not multiplicatively.

Barzel (1973) and Ehrenberg (1971) were also among the first contemporary writers who recognised the economic importance of the time – intensity relationship and proposed a mathematical modelling.

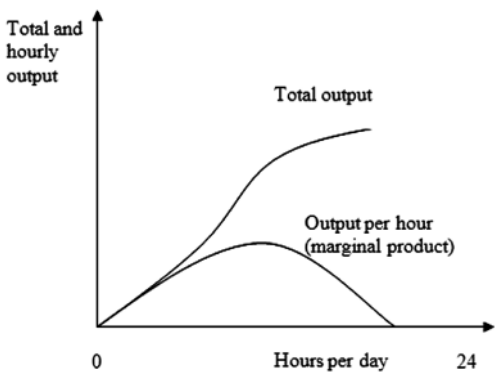
Their main thesis is that working time has an inevitable impact on productivity of labour. This impact is mainly based on the physical boundaries of the human body and mind.

Following a different path, many writers who also recognised the importance of workers' effort in the labour process, attributed it on motives or pressures and other 'subjective type' elements. Among them, Leibenstein (1979) described the remarkable effort discretion that workers enjoy which can lead to a firm behaviour deviating from the standard neoclassical paradigm. The efficiency wage theory also detects the role that motives (mainly wage) play in the determination of effort (see Akerlof, 1976, 1982). From a more social point of view, Green (2001) refers to a social process of intensity determination, among the workers or through class struggle. This was Marx's idea as well, who spoke of an 'average social labour' (Marx, 1990, p. 435). We argue that the above lines of thinking, which recognize the primary significance of worker's will on the determination of effort, are not in contradiction, neither incompatible with the more objective approach that was presented earlier and this compatibility we aim to develop further. Further, we will maintain that the determination of the 'humanly possible' time – intensity relationship can provide a solid ground for the investigation of the aspect of worker's discretion.

THE TIME - PRODUCTIVITY RELATION

One of the most influential descriptions of the effect of the length of work on its intensity is provided by Barzel (1973). He acknowledges the fact that the productivity of the worker varies during the period of one working day. He claims that productivity is zero at the beginning

Diagram 1
Daily and Hourly Output



of the day (the moment that the worker is entering the work place) and rises fast to a maximum as worker is adapting himself to the work environment. This was later called the 'warming up effect'. His main argument is that after reaching this maximum, productivity follows a declining pace due to the exhaustion and fatigue that work causes to the worker ('exertion effect'). The diagrammatic presentation he offers is the one presented in diagram 1.

Barzel does not extents the marginal product curve under the horizontal axis, implying that it cannot become negative. The above variation of the marginal product (output/hour) is observed inside the limits of a single working day (although it requires a long term adjustment of the equipment and number of shifts as he mentions). Each point upon the marginal product curve is showing the output produced at a specific increment of time. The marginal and total outputs of the following working day are not affected by the working time of the previous day(s).

One assumption that Barzel made is that labour productivity is affected solely by workers' effort, keeping all the other factors that influence productivity constant. Under this assumption, the terms productivity and intensity of labour can (and will afterwards) be used equivalently, with the appropriate adjustment of measurement units.

Besides Barzel, Ehrenberg (1971) suggests a similar approach, where the contribution of each worker on output is measured by a g(h) function, where h is working time. Ehrenberg explicitly states that the marginal product cannot become negative, implying that as working time increases output will always increase.

As mentioned above, a critical feature of Barzel's time – intensity relationship is that the productivity curve of one working day is not affected by the working time of the previous day or days. Irrespective of the time one works today, tomorrow's time – intensity curve will be exactly the same as before. This means that the effect of working time on productivity (intensity) of labour is created by the mechanism of fatigue accumulation from the previous hours of labour and not from the previous days of labour.

One major limitation of this approach is that every increase in working time should lead to an output increase as well, unless we assume that the marginal product can become negative. The last implies that working beyond a point in time will lead to a destruction of the previously produced output. This is not indicated by references of very extended daily working times (reaching 24 hours a day occasionally). So, it is not justified to assume that the marginal product becomes

negative. This is probably the reason why very few authors make this assumption. But on the other hand, assuming always positive marginal productivity means that the above mentioned model cannot incorporate the possibility of an output increase after a working time decrease, which is the case that Marx, Chapman and Robbins described.

THE FEEDBACK RELATIONSHIP

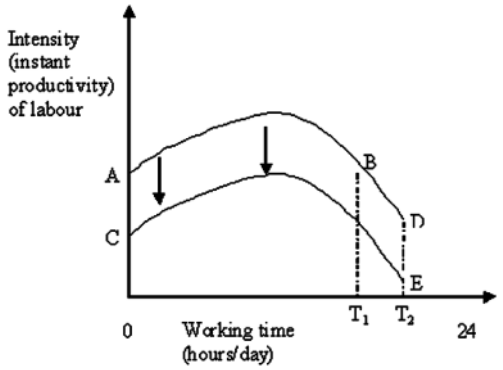
The above problem can be solved with the adoption of a broader view of the process of fatigue accumulation. As Marx indicated - and various contemporary studies prove (see for example Dawson and Fletcher, 2000) – the work process is not a 'daily paroxysm'.

> *Nevertheless, the reader will clearly see that we are dealing here, not with temporary paroxysms of labour but with labour repeated day after day with unvarying uniformity. Hence, a point must be inevitably reached where extension of the working day and intensification of labour become mutually exclusive so that the lengthening of the working day becomes compatible only with a lower degree of intensity, and inversely, a higher degree of intensity only with a shortening of the working day.*
>
> *(Marx, 1976, 533.)*

It is exactly this repetitive day after day nature that forbids the improvident spending of labour inside the limits of a single day. Fatigue is accumulated and transferred not only from one working hour to the following but also from one working day to the others. As a result, the extended working time of one day has a double effect. First, the intensity of labour is reduced for each extra working hour during that day. Second, the time – intensity relationship of the next day(s) will be affected in a way that the same time-point is corresponding to less intensity then the previous day. The first effect is the one described by Barzel (1973) and presented in Diagram 1. The second effect was not described by Barzel (1973), but in our opinion is the crucial one. According to this, an increase in working time will affect the time – intensity relationship for the whole day and not only for the time span of the increase.

As it is shown in Diagram 2, if working time is T_1, the time – intensity relationship is described by curve ABD. The curve is similar with the one presented by Barzel (1973), with the difference that productivity is not zero at the beginning of the day, which we think as a rather extreme assumption. Since ABD is the instant intensity (which is equal to instant productivity) curve, output can be estimated by the appropriate integral and is represented by the area $0ABT_1$.

Diagram 2
Feedback Curve (Instant)



If working time is extended from T_1 to T_2, the productivity from time T_1 until time T_2 will fall according to Barzels' analysis and this decline is represented by the declining part BD. But the second effect, upon which we insist, requires that the time – intensity relationship will change as a whole and not only for the part from T_1 to T_2. Productivity at time 0 (the beginning of the day) will not be *A*, but will be reduced to *C*. For every point in time, productivity (intensity of labour) will decline, not necessarily at the same degree. There is a new curve indicating this new relationship between working time and intensity, the *CE* curve. This new curve is similar with the one corresponding to working time $0T_1$, but has been shifted downwards.

The new time – intensity relationship is the outcome of fatigue transfer to the following day. The increase in working time in 'day one' will accumulate more fatigue to the worker and this will result to a lesser productivity for the whole of the following day and not only for the part from T_1 to T_2. This effect is very probable to be continued for a number of days following 'day one', shifting the time intensity relationship down for each day, but lesser for every remote day. Eventually a new equilibrium relationship will emerge, and the time – intensity relationship will stabilize according to the new working time T_2. This new equilibrium relationship among working time and intensity is presented in Diagram 2 by curve *CE*.

As it is clear, the establishment of a new relationship among working time and work intensity cannot occur inside the narrow limits of a single working day. When working time rises from T_1 to T_2, the intensity for the previous part of the day cannot decline, since this work is already done. The decline of intensity as a whole due to the worktime increase

cannot take place before the next day or even next days come. So the phenomenon needs a time period to become visible. Nevertheless, if we assume that this time period will certainly pass we can abstract from the realization mechanism and claim that a working time increase is affecting the intensity not only of the added hours but of the previous hours as well. So, a feedback phenomenon is observed, after which we name the described working time – intensity relationship as 'feedback' relationship.

We maintain that the feedback relationship captures Marx's main arguments on the time – intensity relationship. However, this relationship between working time and intensity can be utilized not only in Marxist, but in neoclassical (or any other) economic paradigm as well. As we mentioned before, any interaction between working time and intensity is problematic for the neoclassical framework, since it cancels the possibility of the labour market to determine both the number of workers and their working time (for an analytical proof see Contensou and Vranceanu, 2000). What are the effects of the feedback relationship in the neoclassical framework remains a matter for further investigation. In the following chapter we will examine some basic effects of the feedback relationship for the Marxist theory of surplus value.

CONSEQUENCES TO OUTPUT AND SURPLUS VALUE

Important consequences concerning total output arise from adopting the feedback relationship. Before addressing them, the relationship among working time, intensity and output has to be determined. The terms 'work intensity' or 'labour intensity' are sometimes connected with the notions of workers' performance, efficiency or skills. In order to distinguish the notions, Green (2001) analyses the performance of each worker as a function of his skills and effort. The notion of the effort that a worker expends during the labour process is called by Marx intensity of labour and is connected, according to him, to the rate of expenditure of the labour-power. Green (2001) argues that the intensity is connected to the velocity that the workers' movements are executed as well as with the pores of the working day. In fact one of the four ways (for a review see Green, 2001) that has been used to measure the intensity of labour (the PUL method proposed by Bennet and Smith-Gavine, 1987) is using workers' movements' velocity to measure intensity. Under this definition the intensity of labour is attached more to the rhythm of the labour process rather to the energy expenditure of the worker. But of course, these concepts (rhythm of labour process and energy expenditure) are closely interrelated as various studies prove

(see for example Brouha and Maxfield, 1962). Under this definition of labour intensity, which we adopt, we argue that the intensity of labour and the output are analogous quantities (i.e. their relationship is linear). This means that an increase in labour intensity will lead to a proportional increase in output. This will of course occur under the assumption that all the other factors affecting output (mainly the technology of production and the organization of the labour process) remain stable. The above statement concerning output and labour intensity can be formally represented as:

$$Q(t) = \alpha \cdot \varepsilon(t) \cdot t \tag{1}$$

Where $Q(t)$ is a function for output, $\varepsilon(t)$ is the (daily average) intensity, t is working time per day and α is a constant that reflects differences in measurement units, or other exogenous factors.

Naturally, working time and labour intensity are affecting output in a manifold way. On the other hand, labour intensity is a function of working time too, according to the feedback relationship. By adjusting measurement units (i.e. putting the constant $\alpha = 1$) we take:

$$Q(t) = \varepsilon(t) \cdot t \tag{2}$$

Returning to Barzel's (1973) relation (Diagram 1), total output equals the area between the marginal product curve and the horizontal axis, from time 0 until the time worked. If working time increases the area will increase as well, albeit in a lesser degree. This means that under Barzel's (1973) relationship an increase (decrease) in working time will always lead to an increase (decrease) in output, so output is maximized only when working time is maximized.

Things are different under the feedback relationship. In Diagram 2, output equals $0ABT_1$ area when working time equals T_1. If working time increases from T_1 to T_2 this will increase output by the area T_1BDT_2, which represents the product manufactured in this extra time span, under the Barzel's assumption. But, simultaneously, a major change will occur. The output produced until time T_1 will not remain the same as before but will be reduced. This will happen because the time – intensity relationship changed as soon as working time has changed. This is indicated by the downward shift of the curve in Diagram 2. If working time is T_1, total product equals $0ABT_1$ area. If working time increases to T_2, output equals $0CET_2$ area. There is no guarantee that total product will increase after the increase in working time. This will depend on the comparison among the new output manufactured in the additive time and the output lost from the intensity decline for all the previous working time.

An analogous effect is expected when working time decreases. In this case we move backwards from T_2 to T_1 and there exists the possibility of an output increase following a working time decrease.

What will really happen to output when working time is changing is a quantitative matter. As mentioned before, when working time changes, two different effects are in action. The one is the output gained or lost during the extra or cut time. The other effect is the one on overall intensity through the change of the time – intensity relationship. If the first effect is greater, output will follow the path of working time. If the second effect is dominant, output and working time will move towards opposite directions.

The above modeling of the time - intensity correlation has repercussions not only in output but in value and surplus-value as well. Since working time and labour intensity are moving towards opposite directions, absolute and relative surplus value are simultaneously present and opposite as well.[1] This means that an increase in absolute surplus-value will lead to a decrease in relative surplus-value and vice versa. This is true if the other factors determining surplus value and specifically the value of labour power are assumed to remain constant and this is a reasonable assumption at a high level of abstraction. This correlation of absolute and relative surplus-value creates a complicated and non-monotonic relationship among working time and surplus-value in general. It cannot be taken as granted that an increase in working time will necessarily lead to an increase in surplus-value, nor that a working time decrease will lead to a decrease in surplus-value. The possibilities are now extended, making the working time – surplus-value relation more complex and providing a broader basis for the investigation of the working time consequences and evolution. This is an important outcome that requires further investigation, but this is beyond the purpose of this paper.

EVIDENCE FROM ERGO-METRIC EXPERIMENTS

The idea of a feedback relationship between working time and intensity finds support in a field other than economics. We refer to the large research effort aiming to explore human's organism capabilities on work, with the use of ergonometric experiments. These experiments reconstruct in laboratory environment specific types of work processes and measure organism's reactions under different conditions. They use variables like the frequency of labour movements, the intensity of labour, the acceptable workload and the duration time, just to mention some of them. They investigate aspects of workers health and injuries

at work, as well as aspects of the intensity and the duration of the labour process.

Inside this extended bibliography we find experiments that measure the intensity of labour and its various effects both on the workers health and on the time they can sustain work process. All the relevant experiments exhibit an interesting similarity with the model presented above, although these scientists were probably not aware of Marx's thesis upon the matter.

First of all, there are articles describing the fatigue transfer from one day to the following(s) (see for example Dawson and Fletcher, 2000) that are similar with the arguments made by Marx on this subject. Fatigue is considered accumulated and transferred from one day to those following. The duration and also the proximity of work and rest periods are entering a decay function that measures the effect of one day's work to the following days. The findings prove that there is unambiguously a fatigue transfer from every day of work to those following.

Regarding the issue of the definition of intensity, in these experiments it is approached with the use of velocity or the frequency by which the predetermined movements are executed (see for example Bonjer, 1968, Asfour, Tritar and Genaidy, 1991, Hsin and Mao, 2002). This velocity or frequency has a (verified and quantified) relationship with the physiological stress and fatigue of the worker as well as with the output produced. This finding provides additional verification of the connection between labour intensity and the velocity of work that we made above.

Another semantic outcome of this bibliography is the fact that it is feasible for the human organism to sustain a stable rhythm of work (stable intensity) throughout the working day (whatever its magnitude is). When a working day of a stable intensity begins, critical biometric characteristics, such as the relative heart rate and the relative oxygen uptake[2] start to increase for the first minutes of work, compared to their pre – work magnitudes. But after the passing of few minutes the above indicators stop increasing and stabilise for the rest of the working day. This is a clear indication of human organism adaptation to the working process. Only after the passing of a long period of time (which extends to several hours) the values of these indices start rising again. This is a phenomenon observed at the end of the shift and is considered as an indication of fatigue (Saha, *et al*., 1979, Rodgers *et al*., 1986, Hsin and Mao, 2002). The above findings (verified from the ergo-metric experiments) provide an unquestionable proof of the human capability

of sustaining a stable rhythm of work (with the appropriate breaks of course). This befits with the labour process organisation found in many work environments, especially the factories, where a stable intensity of labour is required. This is a case described thoroughly by Marx, when he assessed the role of machines in the intensification of labour in the factories. The above finding is a verification of the assumption made before, that the critical intensity fluctuations are not the ones occurred inside the limits of a single day, since intensity can be held constant for a whole working day.

The above mentioned ergo-metric experiments also prove that the magnitude of the intensity of labour that can remain stable during a working day is in inverse relationship with the working time for which this intensity is sustainable. In other words, a bigger labour intensity is compatible only with a smaller working duration and a lower intensity can be sustained for a longer period of time.[3]

Both the setting of these ergo-metric experiments and their outcomes provide strong support for the features of the feedback relationship, presented earlier. They back the position that the crucial influence of time on intensity is not the intra day variations of intensity, since they conduct the experiments adopting stable intra–day intensity (Rodgers *et al*., 1986, Hsin and Mao, 2002). In other words, it is not mainly the 'warming up effect', or the 'exertion effect' that connect working time to intensity. It is the fact that a longer time of work is compatible only with a smaller intensity for the whole of the working day.

They also prove the proposition of an inverse relationship between working time and maximum labour intensity. Finally, they provide a mathematical determination of the relationship between labour intensity and the maximum time that this intensity is sustainable. This relationship differs among the researchers but shares a common feature: it predicts that there is a possibility of an output increase following a working time decrease (Rodgers *et al*., 1986, Hsin and Mao, 2002). This is the thesis that was first maintained by Marx (followed by Chapman and Robbins) and is encountered in the feedback model presented above.

NECESSARY CONDITIONS AND EXPANSIONS OF THE MODEL

The above model explores the maximum capabilities of humans' nature, (i.e. the combination of maximum possible working time with maximum possible intensity). As mentioned before, it was in the spirit of Marx (as well as Chapman and Robbins) that, with the help of the machines and advanced systems of labour control, workers are forced to their limits. Nevertheless, it can be argued that this is only half of the

story. Since in many jobs labour intensity cannot be fully controlled by the management, one could argue that workers' effort discretion plays a decisive role in labour intensity determination. Towards this direction, the efficiency wage theory (see for example, Akerlof, 1982) explores the 'elasticity' of labour effort towards wages and other benefits provided to the workers. *X* – efficiency theory (see Leibenstein, 1979) explores the firm environment that motivates employees to determine a specific value for their effort. In an environment of effort discretion and organizational entropy, each worker chooses his effort point according to peer or hierarchical influences and this point is expected to be lower from his maximum abilities.

To answer the same question from a collective point of view, some authors (Green, 2001) refer to a social process of intensity determination that occurs among workers in the work place. This social norm of intensity determining a 'fair working day' is adjusting the length and the intensity of the working day so that workers won't be extra squeezed. If the working day is extended, the social norm of intensity will decrease in order to sustain the labour power. Class struggle in a more organized way (such as unions) can also influence the determination of the intensity of labour. After all, Marx referred to a socially determined usual intensity of labour, although he devoted many chapters of Capital describing the 'human boundaries' relation among maximum intensity and working time.

We maintain that all the above procedures of individual or collective determination of labour intensity are not incompatible with the 'material nature' of the feedback relationship, described earlier. Even more, we argue that the scientific description of human organism capabilities can provide a materialist ground upon which all other (social or not) procedures of intensity determination take place. If, for example, a social process of intensity determination takes place in the workplace, this process is very much compatible with the feedback relationship. This is because the social process of intensity determination is based on the principle of keeping a more or less stable rhythm of exploitation of the labour power, without driving it beyond the limits of human organism. But these limits are described by the feedback relationship, so we can argue that this social process is conducted upon the base of human limitations and that the trade off among intensity and working time must be similar with the one described by the feedback relation.

In other words, many theories which acknowledge workers' discretion as the decisive factor of intensity determination accept that there is a trade off between intensity and working time, although not

necessarily the one described by the feedback relationship. We maintain that the deeper reason for the existence of this trade off is that both working time and intensity are the two forms of consumption of the labour-power or, in other words, workers are willing to work less hard when they work long hours, because they are more exhausted when they work long hours. So we claim that the 'willingness based' trade off among working time and work intensity is founded on the 'human capabilities based' trade off, which is described by the feedback relationship.

There are many other important or less important outcomes of the above analysis, concerning the evolution of working time and its consequences. Under the feedback relationship, it can be true (and Marx insisted that it was true at his times) that a working time decrease can lead to an output increase. This provides a different base for the explanation of the historical evolution of working time. Capitalists, according to this explanation, may be in favour of a working time reduction, if they can be assured that by controlling and increasing intensity they can produce more product and surplus value, not less. This could be the case in many countries where mechanized labour was prevailing and the intensity of labour was more easily controllable. On the other hand, the political claim for reducing working hours as a means for reducing unemployment is not unquestionable if the feedback relationship occurs. In order to deal with these and many other issues arising from the feedback relationship it is necessary to calculate its' quantitative aspects. Only if this relationship is quantified we can estimate if a further reduction of working time can still lead to product increase, or if the limits of this process have already been reached, so that any further reduction can only lead to a decrease of the product. The task of estimating the exact relationship is a hard one, since the only credible method is the above mentioned ergo-metric experiments and no source of economic data seems to be of help. In any case this is beyond the scope of this paper.

CONCLUSIONS

One of the impressive events of our times is the disruption or even the reversal of the working time declining trend. Many theories may be surprised from such a development, but not the Marxian theory we believe. This is because inside this theory, working time has always been a decisive economic variable. We maintain that the key issue that can help us fully understand the role of working time is its correlation to the intensity of labour. The first step of exploring this correlation is

to construct a theoretical model that reflects the main ideas of Marx, as well as other economists, not necessarily Marxists. This model is described above and has some interesting features. The most important in our opinion is the possibility of a non – monotonic relationship that establishes among working time and total output and among working time and surplus-value. To be more specific, this model allows for the possibility to observe a product (or surplus value) increase following a working time decrease. Of course, the exact quantification of the relationship among working time and intensity still remains an unaccomplished task. Yet we maintain that the above model can help towards this direction, all the more that its main assumptions are compatible to the findings of a series of ergo - metric experiments.

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Notes

1. At this point we follow the classical definition of Marx, who classifies the working time increase in absolute surplus-value and the intensification of labour in relative surplus value (see Ioannides and Mavroudeas, 2010).
2. The 'relative heart rate' (RHR) is the heart rate (beats per minute) during work process compared to the heart rate in stable condition (not working). The 'relative oxygen uptake' (RVO_2) is the oxygen uptake of organism during work process compared to oxygen uptake in stable condition (see Hsin and Mao, 2002).
3. See for example Asfour, Tritar and Genaidy (1991), Hsin and Mao (2002).

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