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**Philippe Askenazy**
*Centre Maurice Halbwachs-CNRS-ENS-PSL and IZA*

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**IZA – Institute of Labor Economics**

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

# ABSTRACT

## Worker Surveillance Capital, Labour Share and Productivity

This paper proposes a basic model with two types of capital: productive capital directly involved in the production process and capital devoted to monitoring workers. Surveillance capital intensifies workers' job strain, while wage recognition encourages their engagement. Firms face a double trade-off between the two types of capital and between incentives and labour costs. Under simple assumptions, up to a certain threshold, technological innovation improves productivity, wages and profits at the same pace, leading to a flat labour share in income. Then, once the threshold is breached, profit-maximization initiates a transfer from productive capital to monitoring tools. This progressive shift generates a decline in the labour share and a productivity slowdown, despite greater job strain. The model suggests the possibility of a third phase in which productivity and wages recover.

**JEL Classification:** O33, O40, J20, J30

**Keywords:** declining labour share, productivity slowdown, effort-reward imbalances, surveillance

**Corresponding author:**
Philippe Askenazy
ENS
48 bd Jourdan
75014 Paris
France

E-mail: philippe.askenazy@ens.psl.eu

# 1 Introduction

The widespread decline of the labour income shares, especially in most OECD countries including the United States, has attracted an extensive treatment in the literature and significant political attention (ILO, 2019; Ciminelli et al., 2018). The OECD estimates the weighted average decline for member countries as a whole to be at least 3 percent over the past decades, driven mainly by the business sector (Pak et al., 2019). Some works stress that the labour share declines among low-skilled workers but increases among the high-skilled (Saumik, 2020). Numerous channels have been explored, both theoretically and empirically: biased technological change and decline in the relative price of investment goods may have eliminated routine middle-skilled jobs and increased capital intensity (Karabarbounis and Neiman, 2014); globalisation may have challenged exposed firms with the highest share of labour income (Böckerman and Maliranta, 2012); financialisation and rising shareholder power may have fuelled pressure to attain higher profit targets (Hein and van Treeck, 2010); welfare state retrenchment and labour market policies may have reduced workers' bargaining power (Fichtenbaum, 2011). Recent evidence also highlights the potential role of market concentration (De-Loecker et al., 2020) and especially of superstar US firms (Autor et al., 2017).

In the late 2000s, some researchers proposed an additional technological mechanism (Bental and Demougin, 2010): improvements in surveillance technology that reduces moral hazard (shirking) and the associated wage premium, lead to an erosion of the labour share. Despite the lack of comprehensive longitudinal statistics, a large literature provides evidences of the expansion of technological monitoring of workers including location tracking, biometrics, cameras, electronic reporting, email surveillance or e-monitoring of remote staff (Ball, 2010; Moore et al., 2018); recent surveys conducted by consulting companies also support that employers were increasing their efforts to monitor employee productivity (Blackman, 2020). The Fourth European Company Survey includes new questions on datafication at work: in 2019, one out of four EU establishments with 10 to 49 workers, and about 35% of larger establishments, use data analytics to monitor employee performance.

However, this line of investigation has received limited attention, probably because these surveillance models also predict an acceleration in productivity. In fact, the labour share of income declines because monitoring technology boosts productivity with no wage increases. Now, this prediction is inconsistent with a second key stylized fact[1]: most OECD countries have experienced substantial productivity slowdown over the past twenty years.

Here, we revisit the generic hypothesis of heightened surveillance by building a model with two types of capital: productive capital and capital committed to monitoring workers. Our model predicts two phases. First, innovation initially generates profits, productivity and wage gains at the same steady pace. Second, afterwards, when technological improvement breaches a certain threshold, its dynamics become the driver of a trade-off between the two types of capital. The firm devotes capital to surveillance as a substitute for pay incentives; the reduction of the capital directly involved in the production process hampers productivity but unitary labour costs are lower. Innovation becomes associated with both a smaller labour share and a productivity slowdown, but with expanding profits and higher job strain. A numerical illustration can replicate the magnitudes of the observed declines in the US labour share and productivity.

Our mechanism of endogenous changes in productivity trend thus completes the substantial literature that explores the causes and consequences of its deceleration (for a review, see Askenazy et al., 2016). "Techno-optimists", who see this phenomenon as a transitory phase before the emergence of artificial intelligence and related technologies (e.g. Brynjolfsson and McAfee, 2014), oppose "techno-

[1] Schneider (2011) attempted to test directly for a co-movement between productivity growth and the labour share. They find no substantial evidence of correlation and conclude that there is a lack of "strong support for pure technology-based theories of the productivity-compensation divergence".

pessimits" (e.g. Gordon, 2016). Some authors have specifically connected the declining labour share and the productivity stagnation. Grossman et al. (2017) build a neoclassical growth model with endogenous human capital accumulation and capital-skill complementarity; in this framework a productivity slowdown can be responsible for the decline in the labour share. But, contrary to our model, the slowdown is exogenous. Their calibration of the key parameters from US data suggests the reduction in the growth rate of per capita value added can account for about one half of the observed decline in labour share. Aghion et al. (2019) consider the impact of an exogenous fall of firm-level costs of spanning multiple markets. The firms with largest markups, assumed as the most efficient, spread into new markets. By composition effect, the aggregated markup rises and thus the labour share in national income declines. But within-firm markups plummet because innovating on a line where the incumbent firm is highly efficient generates lower profits than when the incumbent firm is poorly efficient. Eventually, the incentives to innovate are reduced leading to falling long-run (productivity) growth.

Labour market reforms are also suspected of altering both wages and productivity. For example, the 0-hour jobs in the UK or a new status of independent contractors in France have fuelled low-income/low-productive jobs. However, since such changes in labour market institutions have concerned only selected countries, this channel cannot explain why the productivity slowdown has been observed across OECD countries.

Our investigation is also related to the literature treating the changes in working conditions observed during the past decades. Research in sociology, economics, management, epidemiology, psychology or ergonomics converges to confirm a third key stylized fact(for a review, see Paškvan and Kubicek, 2017): an intensification of work, dissemination of job strain and occupational stress associated with work imbalances. Now, in our framework, lower labour share in income and more stringent surveillance should exacerbate effort-reward imbalances. With a specification ensuring that labour participation requires a minimum reward relative to the effort, the model exhibits a third phase in which the trends of the second phase are reversed in the long run.

This paper is organised as follows: The main components of the model are presented in Section 2. The solutions of the model, the main predictions and a numerical illustration are given in Section 3. The third phase is explored in Section 4. We conclude in the last section.

## 2 Basic model

We consider a representative profit-maximizing firm with a given capital endowment $C$.[2] The firm employs one worker for production; the worker generates an effort $E$. The production function has a Cobb-Douglas form with decreasing returns in $E$ and productive capital $K$ devoted to the generation of output:

$$Y = AK^{\alpha}E^{\beta}, \tag{1}$$

where $\alpha$ and $\beta$ are positive and $\alpha + \beta < 1$. $A$ is the technological frontier. We assume hereafter that $A$ is growing at a constant pace $a$. The output is the numeraire.

The effort results from two perfectly substituable drivers. First, the worker's engagement $r$ is driven by her cash reward recognition. This mechanism can be interpreted as the seminal incentive wage. We assume the worker compares her wage $w$ to the technological level $A$, which provides a reference for the expected reward:

$$r = \gamma w/A, \tag{2}$$

where $\gamma > 0$ is a fixed parameter.

[2] Note that assuming that the firm accumulates capital by investing a constant share of its profits, would lead to heavy calculus including resolutions of non-linear differential equations, but qualitatively similar conclusions.

Second, the firm can devote a part of its capital $S = C - K$ to monitoring the worker, which increases her effort and job strain $s$, by task optimisation and organization, densification of working time (e.g., downtime reduction), detection of potential shirking, surveillance of behaviours, quality management, etc. This mechanism evokes, à la Stiglitz, the wage as a discipline device. In workplace psychology, $s$ can refer to job strain in the standard job demand-control model: Karasek considers two dimensions of labour (demand and autonomy). Greater demand associated with a lack of, or declining, autonomy results in job strain. A considerable literature demonstrates the adverse impacts of job strain on various dimensions of workers' health (e.g. Kivimäki et al., 2012, on cardiovascular diseases).

We assume that the surveillance is linear in the monitoring capital. The performance of this capital is increasing with the technological level, but at a pace that can be similar, slower or faster, but always proportional to $a$:

$$s = A^{\epsilon} S, \tag{3}$$

where $\epsilon > 0$ is a given parameter.

Eventually, the effort verifies:

$$E = r + s = \gamma w / A + A^{\epsilon} S. \tag{4}$$

Taken together, the conjunction of the reward and surveillance mechanisms mirrors a second fundamental model in occupational psychology: the Siegrist's reward-effort imbalance framework. This stress-theoretical model of a health-adverse, psycho-social work environment is based on the principle of justice in the exchange. Social reciprocity lies at the core of the job contract, which defines conditions of subordination in exchange for rewards (compensation, career opportunities...). In this framework, failed reciprocity generates negative emotions, driving stress and eventually (long-term) health disorders. Here again, a large epidemiological literature tends to validate this model (Siegrist and Wahrendorf-(eds.), 2016).

Continuing along this line, we assume workers only apply for positions that guarantee minimal work balance between rewards and constrained efforts: $r$ must be at least $\omega s$, where $\omega > 0$. Note that such a constraint can also derived from a worker's utility $U(r, s) = r - \omega s$.

Alternative participation constraints are briefly discussed in section 4.

# 3 The dynamics of the model

By construction, profit $\pi$ is given by:

$$\pi = Y - w = A^{1-\beta} K^{\alpha} (\gamma w + A^{1+\epsilon} S)^{\beta} - w. \tag{5}$$

The firm maximizes its profits by allocating its capital $C$ between productive capital $K$ and surveillance capital $S$, and by setting wages. It thus faces two trade-offs. First, reinforced surveillance requires a reduction of the capital directly engaged in the production process. Second, higher wages increase the cost burden, but they strengthen the worker's engagement. We assume in this section that the participation constraint is not binding.

## 3.1 Profit maximization and internal condition

If $K$ is non-positive, profits cannot be positive, and thus the optimal value of $K$ is always strictly positive. We assume first the level of $A$ leads to an internal optimum i.e., $S > 0$.

The first-order condition for $S$, $\partial \pi / \partial S = 0$, implies $\partial \ln Y / \partial S = 0$ and so:

$$\frac{\alpha}{C - S} = \frac{\alpha}{K} = \frac{\beta A^{1+\epsilon}}{\gamma w + A^{1+\epsilon} S}. \tag{6}$$

The optimum reward is given by:

$$\frac{\partial \pi}{\partial w} = 0 = A^{1-\beta} K^{\alpha} \gamma \beta (\gamma w + A^{1+\epsilon} S)^{\beta - 1} - 1. \tag{7}$$

Eliminating $\gamma w + A^{1+\epsilon} S$ in these two equations gives the optimal value for $K$:

$$K = \phi A^{-\mu}, \tag{8}$$

where $\mu = \epsilon(1-\beta)/(1-\alpha-\beta) > 0$, and $\phi = (\alpha^{1-\beta}\beta^{-\beta}\gamma)^{\frac{1}{1-\alpha-\beta}} > 0$.

We can then deduce the condition for an internal solution $S > 0$ i.e., $K < C$: $A$ must be greater than the threshold $\underline{A} = (\phi/C)^{1/\mu}$. We therefore have to separate the study of the economic dynamics above and below this threshold.

## 3.2 Two first phases

This subsection studies the dynamics of the economy around the technological level $\underline{A}$.

**Phase 1:** $A < \underline{A}$. The global technological level is too low to make monitoring capital sufficiently efficient for use. The firm thus devotes its whole capital endowment to direct production $K = C$, in which case we have the very standard Cobb-Douglas framework. The wage (share) satisfies $w = \beta Y = \beta A^{1-\beta} C^{\alpha} (\gamma w)^{\beta}$. Therefore,

$$w = A[\beta \gamma^{\beta} C^{\alpha}]^{\frac{1}{1-\beta}}. \tag{9}$$

This result leads to the following property:

**Property 1** *When the technological level is below $\underline{A}$, wage, output and profits increase at steady rate a. The wage share is flat equal to $\beta$.*

**Phase 2:** $A$ **is above** (but not too far from) $\underline{A}$.

The technology becomes sufficiently mature to make investments in monitoring capital profitable: $S > 0$. From the equation (8), $K$ declines at a pace $-\phi a$, as $S$ grows mechanically. For a given $w$, the profit-maximizing capital mix is also the optimal productive combination. By contrast, the introduction of monitoring tools alters the balance in the reward-labour cost trade-off. It weakens the incentive mechanism because the firm procures effort from the worker via increased job strain. This weakening incentive and the erosion of $K$ generate a decoupling of innovation and labour productivity dynamics. More precisely, the output grows during the second phase at a constant pace that is strictly lower than $a$.

To demonstrate this result, we first replace $K$ by its value $\phi A^{-\mu}$ in equation (6):

$$\gamma w + A^{1+\epsilon} S = \frac{\beta}{\alpha} K A^{1+\epsilon} = \frac{\beta}{\alpha} \phi A^{1+\epsilon-\mu}. \tag{10}$$

The equation (7) can then be rewritten:

$$Y = \frac{1}{\beta}(w + A^{1+\epsilon}\frac{S}{\gamma}) = \frac{\phi}{\gamma\alpha} A^{1+\epsilon-\mu}. \tag{11}$$

Consequently, the output $Y$ grows at a rate $(1+\epsilon-\mu)a$. Now,

$$1+\epsilon-\mu = 1+\epsilon - \frac{1-\beta}{1-\alpha-\beta}\epsilon = \frac{1-\beta-\alpha(1+\epsilon)}{1-\alpha-\beta}, \tag{12}$$

which is strictly less than 1, since $\epsilon$ is strictly positive. QED.

Note that if $\epsilon$ is large, then $1-\alpha-\beta(1+\epsilon) < 0$, and thus the output change may fall into negative territory; in this case, the labour productivity plummets during the second phase.

We can now determine the labour share in income. From the equation (7), the labour share is

$$\frac{w}{Y} = \beta - \frac{A^{1+\epsilon} S}{\gamma Y}. \tag{13}$$

Since $S$ is increasing, $A^{1+\epsilon}S$ is growing faster than $A$, which is not the case of output $Y$. Consequently, the labour share $w/Y$ is not only lower than $\beta$ (its share during the first phase), but is also declining over time.

Conversely, the profit share increases. In addition, the firm's choice of $S = 0$, $w = \beta Y$ would deliver profits $\pi = (1 - \beta)Y$, growing at rate $a$, as during the first phase. However, by construction this choice is sub-optimal. Therefore, the absolute value of optimal profits accelerates in comparison to the first phase.

By contrast, the decline of the labour share in value-added means decelerating rewards. But the absolute wage does not necessarily drop, at least at the beginning of Phase 2. Laborious but basic calculus proves that if $\epsilon$ is sufficiently small, labour compensation is increasing at the entry of the second phase. Intuitively, $S$ is too low to disable the incentives mechanism, while the firm enjoys positive productivity gains and can continue to deliver an optimal growing wage, years after the beginning of the second phase, as illustrated in the numerical simulation below.

To wrap up, we have the following property:

**Property 2** *When the technological level surpasses $\underline{A}$, capital shifts from the production process to the surveillance of workers, the wage share falls, and labour productivity decelerates below the rate of innovation $a$ despite greater job strain. In contrast, profits accelerate.*

Note that the decoupling of job strain and rewards in the model generates work imbalances à la Siegrist, which are suspected of having grown since the 1990s (Siegrist and Wahrendorf-(eds.), 2016). In additions, our findings are not inconsistent with the research on high-involvement workplace practices. There is a certain consensus that these management methods are associated with better productivity (e.g. Bloom and Reenen, 2011) and may improve dimensions of well-being at work (Böckerman, 2015). Yet, the use of surveillance technologies cannot be considered as a way to improve workers' engagement. By contrast, individual and collective performance pay, which are key components of the bundle of high-performance practices, can be classified in our framework as incentive-reward schemes.

### 3.3 A numerical illustration of the productivity slowdown and labour share erosion

This subsection provides a numerical illustration of the magnitudes of the changes in Phase 2. We set $\beta = 0.6$ i.e., a labour share during the first phase equal to 60% of the value added; $\alpha = 0.2$; an annual rate of innovation of about 2.5%, $a = 0.025$; $\epsilon = 0.5$, and $C = 1$. Using these values, Figure 1 represents labour productivity growth, wage growth and the labour share for the last 5 years of the Phase 1 and the first decade of Phase 2; the date $T = 0$ corresponds to the technological threshold $\underline{A}$.

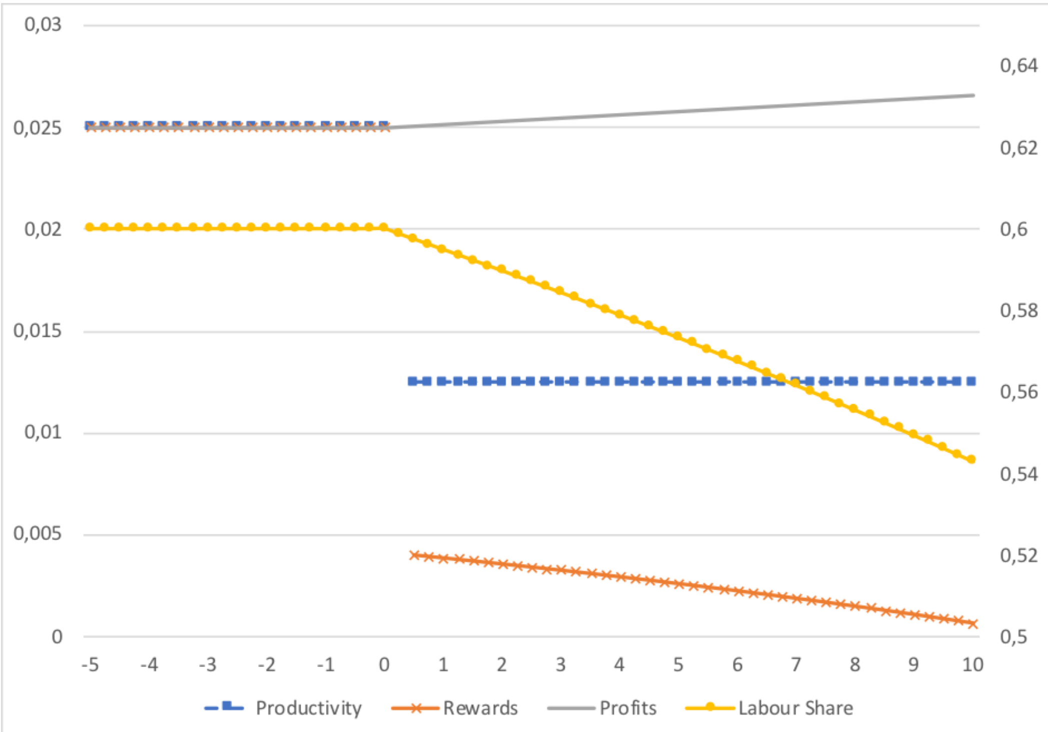


Figure 1: Numerical simulation, 5 last years of phase 1, and first decade of phase 2.

Left scale: ln growth of labour productivity, wages and profits; right scale: labour share in value-added.

Thus, for reasonable parameter values, the model is able to replicate labour productivity growth cut by half to about 1.3 percent a year in the second phase. This figure is broadly consistent with the observed productivity slowdown in both the US and the EU. According to the US Bureau of Labor Statistics (BLS, accessed Nov. 06, 2020), the average annual growth of hourly productivity in the US non-farm business sector was 2.6 percent from 1992 to 2003. It then dropped to an average of 1.5 percent from 2004 to 2019.

The wage is still increasing during the first decade of Phase 2, but at a far lower (and declining) rate than in Phase 1. From year T+12, the wage even begins to plummet. By comparison, profits progressively accelerate in Phase 2, leading to a clear decline in the labour share of value added. It falls from 60% to 54% in 10 years. Here again, this simulated magnitude of the decline in the labour share is not at odds with the observations. According to BLS data[3], the average US labour share in the non-farm business sector was 61.7% from 1992 to 2002. It then felt to an average of only 56.5 percent from 2010 to 2019.

# 4 Towards a recovery in productivity and a rebalance of the labour share?

Our specification of the workers' participation generates a third phase: because of the decoupling of rewards and efforts in Phase 2, the participation constraint will become binding. For instance, in our numerical simulation, for $\omega = 3$, the second phase lasts 22 years. Afterwards, firms' choices are constrained by the participation condition linking job strain and rewards; thus, so too are $S$ and $w$:

[3] Data from 1992 to 2002 come from Giandrea and Sprague (2017); the series is then expanded up to 2019 using the latest -U.S. Bureau of Labor Statistics, Nonfarm Business Sector: Labor Share- https://beta.bls.gov/dataViewer/view/timeseries/PRS85006173, -retrieved Nov. 06, 2020.

$r = \omega s$. Output is then

$$Y = AK^{\alpha}(1+\omega)^{\beta}(A^{\epsilon}S)^{\beta} = A^{1+\epsilon\beta}K^{\alpha}(1+\omega)^{\beta}S^{\beta}. \tag{14}$$

Consequently, profits can be written as a function of $S$:

$$\Pi = A^{1+\epsilon\beta}K^{\alpha}(1+\omega)^{\beta}S^{\beta} - S\omega A^{1+\epsilon}/\gamma. \tag{15}$$

The profit-maximizing surveillance capital $S$ is given by the first-order condition:

$$[\beta S^{\beta-1}(C-S)^{\alpha} - \alpha S^{\beta}(C-S)^{\alpha-1}](1+\omega)^{\beta} = \omega A^{\epsilon(1-\beta)}/\gamma. \tag{16}$$

Since the term on the left of this equality is a decreasing function of $S$, and the term on the right is increasing in $A$, $S$ is declining over time. Intuitively, due to the improvement of the surveillance technology, the firm can achieve a same effort for a same wage but using less monitoring capital. There is thus a progressive reallocation of the capital endowment to the direct production process.

More precisely, since $A^{\epsilon(1-\beta)}$ is not bounded, $S$ will asymptotically converge to 0. In the long run, the left term of (16) is approximately equal to $\beta(1+\omega)^{\beta}S^{\beta-1}C^{\alpha}$. So, the first-order condition provides an approximate value for $S$:

$$S \approx_{Long-run} A^{-\epsilon}[\beta C^{\alpha}(1+\omega)^{\beta}\gamma/\omega]^{1/(1-\beta)}. \tag{17}$$

Therefore, output follows in the long run:

$$Y = AK^{\alpha}(1+\omega)^{\beta}(A^{\epsilon}S)^{\beta} \approx_{Long-run} AC^{\alpha}(1+\omega)^{\beta}[\beta C^{\alpha}(1+\omega)^{\beta}\gamma/\omega]^{\beta/(1-\beta)}. \tag{18}$$

Consequently, the productivity evolves at about the same rate as A: in the long run, productivity growth returns roughly to $a$, its level during the first phase.

This productivity recovery is associated with a revival of the wage dynamics.

The labour share can be derived easily from the first-order condition:

$$w = \beta Y - \alpha Y S/(C - S). \tag{19}$$

Since $S$ drops to 0, the labour share rises. It remains below, but it tends to converge on $\beta$, its initial level during Phase 1.

This strong result is obtained under a particular specification of workers' participation. Alternatively, if we assume that workers require a constant minimum wage or a minimal wage that is proportional to $A$, [4] the Phase 2 can last much longer and the labour share would still plunge during the third phase. But productivity will recover; Intuitively, since the employers are constrained in their capacity to lower wages, they can optimize the profits only by improving productivity.

# 5 Conclusion

Our model can replicate simultaneously three stylized facts observed in OECD economies from the late 1990s to the Covid-19 crisis: on the economic side, the declining labour share of national income, the slowing productivity rate; and on the side of work psychology, reward-effort imbalances. A numerical illustration with reasonable parameter values generates trends that are consistent with the observations drawn from the US economy.

The introduction into the model of a trade-off firms face between devoting their capital endowment directly to the production process and investing in surveillance tools, leads to results that contrast with the first generation of surveillance models that link the eroded labour share to an acceleration of productivity. Firms use surveillance capital to increase workers' job strain as a substitute for compensation incentives. Fundamentally, their profit-maximizing strategy is to lower the labour

[4] Such constraints can be, for example, derived from a utility depending only on income in an economy with out-of-work benefits

bill, at the expense of directly productive capital investment and eventually of productivity.

Our model also departs from the research that explores causal relationships between the declining labour share and the productivity slowdown. Both phenomena become the simultaneous consequences of the shifting technological frontier that determines when surveillance technologies become sufficiently profitable for firms to exploit.

An empirical validation of the mechanisms of the model would require identification of investment in monitoring technologies at the firm level. The inclusions of questions on data analytics in the last wave of the European Company Survey is a first step. Working conditions surveys can also include detailed questions about worker surveillance. The empirical issue here is to be able and authorized to merge such surveys with firms' accounting or fiscal data, especially in order to test some main predictions of the model: surveillance capital is associated with higher profits but no productivity improvements. Analysis at the industry level might provide first insights.

Finally, the model suggests that if workers require a minimal reward-effort balance, then the focus on surveillance could come to an end, and a recovery in productivity may occur in the long run. Such an evolution is hypothetical at best and can be delayed by exogenous shocks: the lock-downs and disruptions linked to the Covid-19 sanitary crisis are suspected to have boosted workplace and working-at-home surveillance practices. By contrast, our finding that the focus of firms on surveillance capital can hamper economic growth may complement the arguments for tougher regulations of surveillance technologies in the wake of the fears for the privacy of workers and more generally the growing concerns over 'surveillance capitalism' (Zuboff, 2019).

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