Received: 1 June 2023 | Revised: 18 July 2024 | Accepted: 31 July 2024

DOI: 10.1111/meca.12482

ORIGINAL ARTICLE

METROECONOMICA
INTERNATIONAL REVIEW OF ECONOMICS

WILEY

A simple comparative model of worker-managed and capital-managed digital platforms

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Abstract

We develop a simple model to study the comparative statics of worker-managed (WM) and capital-managed (CM) app-based labor platforms. The model assumes that algorithmic management makes free-riding and collective decision-making costs negligible and highlights different pay policies as the distinctive feature differentiating WM and CM platforms, in an environment where workers are financially constrained and capital markets are imperfect. With very simple algebra, we show that WM platforms may show greater cost efficiency and may be better able to benefit from network effects with respect to CM competitors. Yet, viability of WM firms may be critically impeded by the extra-cost of the external capital, which enables CM platforms to pay a wage premium. The optimal pay policy of CM platforms is shown to vary depending on the intensity of network effects. Reported anecdotal evidence is compatible with main model's results.

KEYWORDS
app-based work, labor platforms, worker-managed firms

JEL CLASSIFICATION
J54, L22, P13

1 | INTRODUCTION

The last decade has seen the organization of firms changing dramatically. An increasing amount of non-standard types of service provision has emerged, commonly referred to as the "platform economy," including various forms of crowdwork and service-on-demand app-based. Estimates of the number of individuals who work in the platform economy come to touch upon dozens of millions worldwide and report exponential growth rates (Abraham et al., 2017; Harris & Krueger, 2015; Katz & Krueger, 2019; Smith & Leberstein, 2015). Sectors of activity cover (and are not limited to) delivery, home services and transportation. Well-known companies operating through labor platforms are Uber, Lyft, TaskRabbit, Care.com, Amazon Mechanical Turk, Crowdsource, Clickworker, Foodora, Deliveroo, among many others.

From an economic perspective, there is a key ingredient that makes a platform-based firm different from traditional forms of organization. Thanks to digitalization and algorithmic management, platform technologies allow thousands (or even hundreds of thousands) of workers to meet with as many different customers through standardized and largely homogenous interactions whilst keeping the physical infrastructure relatively narrow (Cramer & Krueger, 2016). As a result, unlike conventional firms, labor platforms exhibit very low marginal costs and are able to show dramatic increases in their workforce in very short periods of time. For instance, in the United States, Uber has grown from a base of near zero active drivers in mid-2012, to 100,000 in mid-2014 and to over 400,000 a year later (Uber Newsroom, 2015).

A distinctive feature of workplace organization in the platform economy is that the use of digital technologies makes it possible to monitor the activity of the workforce very precisely, thereby preventing the workers to free-ride. Moreover, the nature of platform-based services typically requires homogeneous non-specialized workers to undertake fairly similar tasks, with algorithmic monitoring and management keeping cross-worker differences in effort per unit of time at minimum. In light of the literature on firm ownership, which points to worker heterogeneity, free-riding and collective decision-making costs as the main obstacles to worker ownership in the private business sector (Conte & Jones, 2015; Hansmann, 1996; Podivinsky & Stewart, 2007), it is therefore surprising that digital platforms are largely owned by capital input providers. Although some experiences of worker-managed labor platforms have been documented,[1] digital worker cooperatives remain rare and are much less diffused than one would expect absent the fundamental obstacles to labor ownership highlighted by the literature on ownership theory.

With this paper, we try to shed light on this puzzle, by investigating theoretically the issue of the ownership of a digital labor platform in a model where worker-managed (WM) and capital-managed (CM) platforms adopt different pay policies and the workers are financially constrained in an environment of imperfect capital markets.

We trace a broad distinction among various types of ownership according to whether ownership is shared among workers who equally divide residual profits or all control rights and rights to residual profits are allocated to capital suppliers who pay workers a variable wage determined after deducting an overhead commission from the price charged by the workers themselves, as private contractors, to final consumers. We then study the comparative viability

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[1] Examples include: *Green Taxi Cooperative* in the peer-to-peer transportation, *Loconomics* in home care and handyman, *Fairmondo* in ethical goods and services, *Stocksy United* in artistic products and photography.

of the WM ownership of a digital platform relative to a CM structure, with WM and CM firms competing over workers and workers being free to choose whether to be employed in a CM firm or to become members of a WM firm depending on which organizational model maximizes their payoffs.

We model the app-based platform as a digital infrastructure through which a homogenous service is provided to customers on-demand. Due to the technological characteristics of labor platforms, the fixed costs of providing the service and those of organizing workers can be assumed not to vary with the size of the workforce in the short-run. Consequently, for both CM and WM platforms, profits and per-capita earnings, respectively, are increasing in the size of the business until an equilibrium level of demand is reached. Hence, under an initial assumption that WM organizations maximize only per-capita earnings, the optimal size of CM and WM platforms is shown to be the same, in the presence of a competitive market for membership. Given the size of the market, we show that WM platforms maximize per-capita incomes over a middle range interval of firm size. If the number of workers is too low, fixed costs effects will bite relatively more, thereby making WM dividends lower than a capitalist salary; if workers-members are too many with respect to the maximum number of available customers, dividends will be diluted more than the fixed costs. At the equilibrium size, the extra-costs of the external capital for WM platforms may allow CM firms to set the commission fee at a level which enables CM firms to make non-negative profits, whilst creating a positive wage premium for the workers in CM firms.

Based on these ingredients, the model helps understanding some of the distributive consequences of CM versus WM ownership. When workers are concerned with employment, CM firms need to reduce the overhead fee to compensate for the fact that workers place value on higher employment levels. On the other side, the net worker payoff under WM ownership increases when network effects matter significantly. The intuition behind this latter finding is simple. When a CM firm does not pay fix wages but retains an overhead on the revenues raised by the workers, an increase in the revenues, due to network externalities (or to any other productivity improvement), accrues to workers only partly, while, in a WM platform, it is entirely captured by the workers-members. As a result, the overhead applied by capitalist owners being equal, the disadvantage of WM platforms reduces when network externalities are stronger.

The contribution of this paper is twofold.

On the one hand, we contribute to the economic literature on platforms, as reviewed by Spulber (2019). We deal with the issue of the ownership of digital labor platforms, by integrating standard analysis of WM firms with the specific features of the platform sector. Although the question of whether WM platforms are viable in the digital platform sector is new, the main answer to such question, as modeled in our paper, is centered on what is a well-known limit to WM firms viability in traditional industries, namely the cost disadvantage in raising external capital for financially constrained workers (Bowles & Gintis, 1994). Even if the expansion of the production capacity is typically associated with small cost variations in the digital platform sector, thereby reducing capital cost intensity at larger volumes of activity with respect to traditional (particularly, manufacturing) sectors, the initial fixed costs of the platform may bite significantly. This points to the importance of designing alternative (innovative) fund raising methods, if one is interested in finding ways to support worker-owned digital platforms. As it will be showed more formally in the paper, once established WM platforms may show greater efficiency compared to CM firms, in terms of average costs, and also a better ability to introduce quality improvements and to deal with worker preferences for employment levels and stability.

From this point of view, our study may also contribute to the current debate on the future of worker ownership in the platform economy. There is an increasing attention by policy-makers and, to a larger extent, the public opinion on how better wages and improved working conditions on the job may be sustained for platform workers (Smith & Leberstein, 2015). The extension of standard employment protection institutions, such as statutory rights to minimum wage and unemployment insurance, is at the heart of an active debate, involving both public policy and legal issues (Harris & Krueger, 2015; Krueger, 2018). We add to this discussion, by introducing some elements for an economic analysis of a market-based solution, based on an endogenous reallocation of ownership rights. Doing so, incidentally, we also touch the literature on the relationship between worker ownership and organizational resilience in the so-called "disconnected capitalism era" (Brown et al., 2019).

On the other hand, we contribute to the long-standing literature on worker-managed firms (see Bonin et al. (1993) and Dow (2003) for a general survey), which has focused on specific aspects of WM firms creation (including the influence of the business cycle (Kalmi, 2013; Pérotin, 2006; Russell & Hanneman, 1992; Staber, 1989, 1993), fund raising and sectoral characteristics (Podivinsky & Stewart, 2007) and agglomeration externalities (Arando et al., 2012)), but has never addressed the issue of app-based forms of worker-managed labor organizations, so far. In particular, we unveil the role played by network effects as a possible factor facilitating the viability of WM organizations, which has been generally overlooked by related literature focusing on traditional sectors (e.g., Dow and Putterman (2000), Belloc (2017)). We show that both user-side and worker-side network effects may improve WM platforms viability, by inducing higher monetary payoffs for workers-members vis-à-vis workers in CM firms. We also show that, in WM platforms, profit-sharing mechanisms are likely to induce product quality improvements, in the presence of worker-side externalities. Indeed, digital technologies strongly reduce the cost of collaborative effort (such as information sharing, through on-line systems), thereby improving the power of group incentive mechanisms activated by profit-sharing. Moreover, we consider the wage paid by CM firms (i.e. the outside option of WM firms' workers) to be endogenous, being it modeled as a function of the final service unit price. This generates some additional relevant differences between our framework and standard comparative analyses of worker cooperatives (see Dow (2018) for a technical survey).

The paper is organized as follows. In Section 2, we present our basic framework, where we derive the optimal size and optimal pay policies of WM and CM platforms under the assumption that WM firms maximize per-capita earnings. In Section 3, we introduce additional differences between CM and WM platforms: namely, employment level concerns and the ability to gain from network effects. In Section 4, we provide a simple analysis of comparative statics, discuss the main implications of our model about the viability of WM platforms, and report some available anecdotal evidence. Concluding remarks are in Section 5. The proofs of our propositions are relegated in the Appendix.

2 | BASELINE MODEL

2.1 | Setting

Consider a monopolistically competitive industry where platform-based firms produce a final service which is provided to customers on-demand. The service is differentiated across firms but it is homogenous for the customers of a same firm. App-based platforms may have two possible ownership structures: CM or worker-managed (WM).[2] The platform can be thought of as a digital infrastructure that allows organizing the division of labor across (possibly many) workers (also on a time or geographical basis), to meet customers, and to monitor the quality of the service provided by each worker.

The platform is costly. While capitalist entrepreneurs do have enough liquidity to buy the platform from an external programmer, the workers are financially constrained and need to raise funds on the capital market to afford the price of the platform.[3] Let us denote with I the initial sunk investment for the platform provision (equal for both workers and capitalist entrepreneurs) and with i the interest rate for the workers who decide to buy their own platform to start a WM firm.[4]

Assume that organizing the workers and monitoring the quality of service provision through the platform is costly. Assume also that organizational and monitoring costs are fixed because they depend on the structure of the platform technology and do not change significantly over the short-term when the volume of a firm's activity varies. This can be justified by considering that digital monitoring devices have a fixed cost and the quality of their functioning does not depend on the volume of activity, within a reasonably high level of employment. Hence, to keep notation simple, such costs can be included in the initial fixed investment I (I can be considered as inclusive also of the cost of any other physical assets needed for providing the service).

Assuming that a given app-based labor platform is suited for providing a given homogenous service through a given organization of work, the platform itself can be stylized as a combination of I and r, with $r > 0$ denoting the revenues per unit of service.[5] We assume that, in the short-run, the unit price r is given. In particular, r clears the market at $\bar{c}$, with c being the supplied number of units of service (we assume that each unit of service corresponds to one customer). The assumption that r is given for the firm may be justified in this context by the fact that labor platforms commonly set a minimum fare and then leave their workers free to compete over prices, as independent contractors. Hence, even if the platform covers the market monopolistically, the product price is determined through a competition-like mechanism among workers.[6] Alternatively, the firm offers a new service for which there are $\bar{c}$ potential

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[2] More generally, WM structures here may also include partnerships.

[3] The creation of the platform software from outside the firm is common practice, particularly for WM organizations. App-based cooperatives in peer-to-peer transportation and home care of the type mentioned above, for example, outsourced the production of the platform software to external programmers.

[4] The assumption that capitalist entrepreneurs do not raise external capital may seem restrictive. However, it can be relaxed, without affecting our model set-up, by simply normalizing the cost of external capital for capitalist entrepreneurs to zero and assuming that workers pay an extra-cost of capital equal to i, which reflects the costs of asymmetric information between an external financer and the insider workers-members. It is well-known that, when financing requirements are large and the capital market is imperfect, workers may encounter problems when seeking loans to finance firms (Stiglitz & Weiss, 1981).

[5] The model allows for different product quality across platforms. Assuming that product quality increases monotonically with the initial fixed investment, platforms that require larger investments will be also offering services with higher value and unit revenues. In our static comparative analysis, we will consider WM and CM platforms showing a same $\{I, r\}$ set, but cross-platform differentiations over these variables, including product quality, are compatible with the model.

[6] Angrist et al. (2017) present a model of compensation of *Uber*'s drivers, where the hourly wage rate (modeled as gross unit revenues) is taken as given. Related to this, they report that, after a change in the number of drivers in the Boston cab market, average drivers' revenues remained essentially unchanged.

customers, each with the reservation price r, so that the firm faces a horizontal demand curve at a unit price r up to a maximum total demand of $\bar{c}$ units.

We also assume that the workers have similar abilities. The possibility that heterogeneous workers sort endogenously among types of firm is thus excluded in this model. In particular, the workers are assumed to be unskilled and they can enter or exit the labor relationship freely, without frictional costs.

Finally, we denote with n the number of workers and with $(1-\alpha)r$ the amount that, in a CM firm, employers pay to a worker for each unit of service provided (with $\alpha \in [0, 1]$ being an overhead commission parameter and αr the total commission that the worker must pay to the platform owner; this reflects the practice of most companies operating in the platform economy).[7]

To keep things simple, we also normalize the units of service supplied by one worker to 1, so that $n = c \ \ \forall \, n \in [0, \bar{c}]$, while, for $n > \bar{c}$, additional workers will not find corresponding additional customers. Let us also normalize the disutility of working effort to 0 and assume (as a participation constraint) that there is an interval $[\underline{n}, \overline{n}]$, with $\underline{n} < \bar{c} < \overline{n}$, for which the total revenues are larger than the total costs for both WM and CM firms. Both CM and WM firms treat I, r, i and $\bar{c}$ as parametric, while n and α are choice variables. Specifically, CM firms can take separate decisions over the employment and the commission fee, while WM firms are allowed to vary only the number of workers-members and worker pay variation follows mechanically from size adjustments.

Note that variable operating costs in this framework consist only of the workers' pay. This assumption is largely compatible with the cost structure of many real platforms and allows us to emphasize the differences between app-based businesses and traditional (standard) production firms. Alternatively, the marginal cost of production can be assumed to be constant and normalized to zero. In any case, if marginal costs besides worker salaries are positive and similar across WM and CM platforms, the results of our comparative statics remain substantially unchanged.

In a CM labor platform, we assume to have only one owner (who is not also a worker of his firm).[8] In the short-run, her profits are:

$$\pi_{CM} = \begin{cases} rc - n(1-\alpha)r & \text{if} \quad n \leq \bar{c}, \quad \text{with} \quad c = n \\ r\bar{c} - (n_c r + n_0 r_0)(1-\alpha) & \text{if} \quad n > \bar{c}, \quad \text{with} \quad n_c + n_0 = n \end{cases} \tag{1}$$

where, if $n > \bar{c}$, n_c are workers who meet customers (and raise positive revenues $r > 0$) and n_0 are workers who do not find corresponding customers and raise $r_0 = 0$.

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[7] In most of the existing CM labor platforms, workers are not standard employees and interact with the platform owners through non-standard forms of employment (see Hagiu and Wright (2019) for a theoretical discussion). As for the pay policy, the ability of CM platform firms to exert wage-setting power arises from the monopsony position of employers in the platform sector. Monopsony power may arise due to a small number of employers for a given on-platform job type, together with the absence of bargaining (Dube et al., 2020) and contract incompleteness issues (partly mitigated by online reputation mechanisms (Benson et al., 2015)).

[8] This assumption may be relaxed by considering a multi-owner structure, with $s \in [1, \infty]$ being the number of shareholders and with per-shareholder profits being the maximand of CM platforms. However, as long as the number of shareholders is independent from the number of workers, having $s > 1$ only introduces a rescaling effect in the CM firm's profit function without changing the model's result. Hence, to keep things simple, we will continue by assuming CM firms to have a single shareholder.

In a WM labor platform structure, we have possibly many workers-owners. Per-capita earnings in a WM organization are:

$$\pi_{WM} = \begin{cases} \dfrac{rc - Ii}{n} & \text{if} \quad n \leq \overline{c}, \quad \text{with} \quad c = n \\[2ex] \dfrac{r\overline{c} - Ii}{n} & \text{if} \quad n > \overline{c} \end{cases} \tag{2}$$

From Equation (1), it is straightforward to observe that $\partial\pi_{CM}/\partial n > 0$ if $n < \overline{c}$, while $\partial\pi_{CM}/\partial n = 0$ if $n > \overline{c}$. From Equation (2), we observe that $\partial\pi_{WM}/\partial n > 0$ if $n < \overline{c}$, while $\partial\pi_{WM}/\partial n < 0$ if $n > \overline{c}$ (with $\lim_{n\to\infty} \pi_{WM} = 0$). All in all, the key difference between a CM and a WM organization, in this baseline setting, is due to the payoff policy, that is, WM firms redistribute net revenues equally to all workers-members, whilst, in CM firms, the capitalist owner retains all the residual profits after the workers are given a baseline pay, which is a function of the unit revenues. Clearly, this is a simplification. In many real WM platforms, workers may not share profits equally and may be paid according to a convex combination of dividends and some share of the revenues that they raise individually. Real WM platforms adopt various compensation polices, with some degree of flexibility, and many WM platforms are more similar to producer cooperatives than to worker cooperatives. To simplify the mathematics and to emphasize the key contribution of our argument, in the model we trace a strong distinction in the pay policy used by WM and CM platforms, with the former sharing profits equally and the latter using a commission-based remuneration. The possibility for WM firms to combine the two types of compensation schemes would simply rescale the quantitative significance of our results, without changing the qualitative implications. Here, we are not assuming that workers inherently value democratic participation in a WM organization. In order to make non-negative profits, a CM platform must charge workers with $\alpha > 0$.

With this very simplified framework, we can study the possible emergence of app-based WM labor platforms, under the assumption that the workers choose whether to work as contractors for a CM firm or to organize themselves in a WM structure only depending on the relative per-capita payoff they will be able to get from the two alternative employment (i.e., ownership) solutions. In doing this, we implicitly assume that CM workers may switch to a (potential) WM counterpart and viceversa, without costly frictions. We also assume that workers-members of a WM organization have equal shares. For now, we do not consider the possibility that workers are concerned also with employment levels and job or income stability. We consider, finally, workers and capitalists as equally able to have an initial entrepreneurial idea and to commission a job platform to an external programmer.[9]

Next, we determine optimal levels of platform size and worker pay in order.

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[9] Notice that this model does not require full employment. The mechanism of firms competing over workers only requires non-null and (between platforms) symmetric elasticity of labor to wages. Since, in our setting, the worker payoff is for one unit of service provided and not for one unit of full-time equivalent labor, the model is compatible with underemployment of the type documented by Bell and Blanchflower (2019).

2.2 | Optimal size

CM and WM platforms choose the optimal size by maximizing, respectively, Equations (1) and (2) with respect to n, that is:

$$n^*_{CM} \equiv \underset{n}{argmax}\, \pi_{CM} \quad \text{and} \quad n^*_{WM} \equiv \underset{n}{argmax}\, \pi_{WM} \tag{3}$$

From Equation (3), it is straightforward to obtain that the income maximizing size of the firm is the same in a CM and in a WM platform, and precisely:

$$n^*_{WM} = n^*_{CM} = \bar{c} \tag{4}$$

For CM platforms, profits are maximized at any size $n \geq \bar{c}$ (as variable labor costs do not increase above $\bar{c}$). However, we assume that a CM platform chooses the smallest size compatible with profit maximization (in order to minimize possible additional operating costs not included in the model) and Equation (4) holds.[10]

Equation (4) says that the optimal size for both CM and WM platforms is at a level equal to the size of the market (i.e., there is a tendency towards monopoly). The main intuition behind this is that in the cost structure of platform firms, as modeled in our framework, variable operating costs are negligible.[11] Equation (4) also equals to say that a per-capita income maximizing WM platform will choose employment levels, in practice, as a conventional profit maximizing firm. The reason is easy to see. If the final market is competitive, workers-members appropriate the entire surplus of the firm, with each worker receiving an equal fraction of the total surplus. Thus, an income maximizing WM firm will pursue maximization of total profits in order to expand per-capita earnings. To keep things simple, throughout the paper we will refer to a stylized WM firm in the platform economy as an income maximizing firm, even if its employment behavior is equivalent to that of a profit maximizing firm (in the next Section, we will show that an income maximizing WM platform may deviate from profit maximization in the direction of employment maximization, when its welfare function places some weight also on employment levels). Moreover, it is clear from Equation (4) that the optimal size of a CM platform does not depend on the pay policy (i.e. the level of α).

Related to the issue of size, our results differ from previous theoretical research on worker cooperatives in traditional sectors in at least two main ways (see Pencavel et al. (2006) as a representative reference).

First, we show that income maximizing WM platforms do not tend to employ a lower number of workers than their CM counterparts. Standard theory predicts that capitalist firms

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[10] Notice that Equation (4) holds under our implicit assumption of a horizontal demand curve in the product market. This is justified, given that common policy among platform firms selling a homogeneous product is to set a minimum fare and then leave their workers free to compete over prices, as independent contractors. CM and WM firms would choose a different optimal size if the demand curve was downward sloping (calculation can be provided upon request). Whilst a downward sloping demand curve is standard in textbook-style monopolistic competition contexts, it is less realistic in the platform economy sector.

[11] This is similar to the model of Rey and Tirole (2007) referred to cooperative undertakings in a context of substantial initial sunk investment, with zero variable operating costs, such as in credit card cooperatives. They show that, because shared among the users, fixed costs in cooperatives may give rise to "cost-sharing network externalities," thereby generating natural monopolies.

set employment at the level where the marginal product of labor equals the wage, while worker cooperatives set employment at a lower level, where the marginal product of labor equals income per-worker: because the maximized value of per-worker net revenues is no less than the wage, then employment in CM firms is not less than that in WM ones. In our framework, both WM income maximizing platforms and CM profit maximizing platforms choose to employ $n=\bar{c}$ workers, because at $n=\bar{c}$ they maximize per-capita earnings and profits, respectively.

Second, the relationship between the optimal level of employment of an income maximizing WM platform and unit price is different from usual theory of worker cooperatives. In our model, an increase in price may be associated with an increase in $\bar{c}$ (if due, for instance, to a positive demand shock) and thereby in n^*_{WM}. We also have that n^*_{WM} is not affected by variations in fixed costs. Instead, standard theory would predict that employment is higher when fixed costs are greater and that, if labor is the only input, increases in unit prices of the output reduce employment (this is the so-called "perverse supply response"; see, e.g., Steinherr and Thisse (1979)).[12]

While it is intuitive that a WM platform, if established, will expand to $n^*_{WM}=\bar{c}$, because at this size it will maximize per-capita earnings, $n^*_{WM}=\bar{c}$ it is also shown to be an equilibrium in the presence of a perfect (i.e. competitive) market for membership, where insider members would be willing to accept new members above n^*_{WM} upon payment of some price for membership.[13]

Proposition 1. *If CM platforms pay positive wages (i.e.,* $\alpha<1$) and the WM platform is income per-worker maximizing, in the presence of a competitive membership market, then $n^*_{WM}=\bar{c}$ is an equilibrium.

Proof See the Appendix. ■

An implication of Proposition 1 is that, under the assumption that workers are concerned only with per-capita earnings, expansion of a WM platform above size $\bar{c}$ is possible only if competing CM platforms retain all of the revenues raised by their workers, which equals to say that CM platforms pay zero wages. This paradoxical result is actually unsurprising. Theory of membership markets shows that expansion is desirable for per-capita income maximizing WM firms only if the value of the new members' marginal product exceeds the outside wage (see, e.g., Sertel (1987) and Dow (1996)). Here, new members who enter a WM platform of a size $\bar{c}$ do not find corresponding customers and, in fact, do not contribute to raise additional revenues. Hence, the new members' marginal product is zero, and so as to be the outside wage in a CM firm for Condition (A1) to hold.

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[12] Refinements of standard theory show that the downward sloping perversity of the supply curve happens only in a low price range, where the short-run fixed cost burden becomes severe due to low revenues (Miyazaki & Neary, 1983). Others have related the output supply elasticity of WM firms to the worker-partnership market (originally, this is due to Sertel (1987)) and showed that imperfect appropriation of current members from outsiders over the surplus generated by the firm yelds employment contraction in response to an increase in output price (see Dow (2018, Chapter 9) for an overview).

[13] As one can notice, we implicitly assumed that there is no entry fee for members up to $n=n^*_{WM}$.

2.3 | Optimal pay policy

It is now intuitive to observe that, given I, r and $\bar{c}$, taking i as exogenous, for each any level of n, the relative payoff of the workers across the two platform ownership structures depends on the overhead parameter α. Hence, profit maximizing CM platforms will choose the optimal level α^* so as to maximize Equation (1) at $n^*_{CM} = \bar{c}$, that is, recalling that α enters Equation (1) with a positive sign, they will choose the maximum level of α subject to $(1-\alpha)r > \pi_{WM}$ (because they need to be attractive to workers) and to $\alpha \geq 0$ (because they need to make non-negative profits). We assume that, when $(1-\alpha)r = \pi_{WM}$, WM platforms are preferred by workers.

Definition 1 Define

$$\alpha_E \equiv \underset{\alpha}{argmin}[(1-\alpha)r] \tag{5}$$

$$\text{s.t. } (1-\alpha)r \geq \pi_{WM}, \quad \text{at } n = n^*_{WM}, \tag{6}$$

that is, the threshold (maximum) level of α under which WM platforms are never convenient for the workers.

For an income maximizing WM platform of size $n = \bar{c}$, by using Equation (2) into Definition 1 (and recalling that $c = n$), we obtain that the level of α under which the workers are always better off as contractors for a CM platform is:

$$\alpha_E = \frac{Ii}{\bar{c}r} \tag{7}$$

When $\alpha < \alpha_E$, workers will prefer joining CM firms.[14] Hence, to the extent that $\alpha_E > \alpha_{\min}$, CM platforms will choose α^* just below α_E (say $\alpha^* = \alpha_E - \varepsilon$, with ε infinitely small), because this is the maximum α compatible with being attractive to workers with respect to an income-maximizing WM counterpart.

In practice, α_E is an informative parameter because reflects the feasible upper bound of the commission fee of CM platforms, thereby shaping their optimal pay policy and the distributive consequence of a CM ownership structure. In particular, from Equation (7) it is easy to observe that the optimal commission fee of a profit maximizing CM platform needs to decrease when the size of the market and when the unit revenues increase. As a result, when r increases (or in sectors where r is higher), the worker payoff in a profit-maximizing CM firm (i.e. $(1-\alpha^*)r$) will increase more than proportionally, because r influences the worker payoff both directly through r itself and indirectly through α^*. An intuition to explain this is that very small revenues relative to the fixed costs make WM firms' remuneration fall below the members' reservation income, thereby increasing the ability of CM firms to extract higher rents; notice that this is compatible

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[14] Equivalently, we may obtain α_E from considering the CM platform to pay workers by deducting an unconstrained commission fee α' reduced by an ex-post bonus transfer B (with $B = br$) which reflects the external opportunity cost of workers. The monetary payoffs of the workers under the two alternative ownership structures are equal when $(1-\alpha')r + br = \pi_{WM}$. At $n = n^*_{WM}$, the latter equation equals to $[1-(\alpha'-b)]r = \frac{r\bar{c}-Ii}{n}$, from which we obtain $\alpha' - b = \frac{Ii}{\bar{c}r}$. Then, α_E can be defined as $\alpha_E \equiv \alpha' - b$.

with standard theory of worker cooperatives (Brewer & Browing, 1982; Miyazaki & Neary, 1983).

Essentially, in our model, WM firms are required to always maximize per-capita income in order to attract workers, while CM platforms receive an additional degree of freedom in setting up $\alpha^* < \alpha_E$. This means that CM platforms have the freedom to not act as profit maximizers in order to capture the entire market, and they point to obtaining non-negative profits with WM firms being expelled from the market. Hence, our otherwise static model has clear implications for the dynamics of competition. In fact, once in a static setting CM platforms have set α^*, the market will result as being populated only by CM firms. Clearly, given entry costs I, the result is that CM firms may be able to reach a monopoly position more easily than WM firms, with possible consequences on the development of the market itself. In other words, our static framework may be seen as exploring one source (among possibly many sources) of market power in the digital platform sectors, at least for what concern the tension between CM and WM ownership structures. While we do not model such dynamic aspects, it is straightforward from our discussion that CM firms will set α^* anticipating the implication of their pay policy on the future market structure and therefore on their future profits.

2.4 | Viability of WM platforms

We can now study the conditions under which WM platforms are viable.

If $\alpha_E > 0$, there is always a wedge, no matter how small, allowing CM platforms to make $\alpha_E > \alpha^* > 0$, thereby providing workers with a higher payoff in CM firms without CM firms making negative profits. In this case, WM platforms are not able to attract workers and only CM firms will emerge in the market. At the optimal size n^*_{CM}, we have that $c = \bar{c}$. Hence, $\alpha_E > 0$ when $\frac{Ii}{cr} > 0$, that is, $i > 0$. Phrased differently, absent any other source of differentiation in the cost structure between CM and WM platforms, in equilibrium CM firms will crowd WM firms out only when the extra-cost of capital for WM firms is positive.

Substituting Equation (7) into Equation (1) we obtain the equilibrium profit level of CM platforms, that is,:

$$\pi^*_{CM} = Ii \tag{8}$$

which is always positive when $i > 0$. Related to this, one may wonder why capital owners should opt for starting a business rather than lending capital to a WM platform thereby obtaining Ii as a compensation. In our static comparative exercise, we do not consider possible outside options for capital and do not address this issue. In any event, there are a number of reasonable arguments that may explain why capital owners may prefer direct production than lending. In particular, specialized risk neutral entities (e.g. banks) may be available in the financial market, possibly providing capital to WM firms at a lower cost than undiversified capital owners. If i reflects the cost of capital for WM firms at these diversified financial firms, capitalist entrepreneurs would be uncompetitive in the financial market when required to ask an interest rate higher than i for accommodating undiversification; this would leave CM firms with no outside option for their capital. Alternatively, financial firms and capitalist entrepreneurs name the same price for capital, but the mechanism of financial intermediation is more costly to undiversified capital owners by an amount of transaction costs $T > 0$, and capital owners again prefer production than lending. Finally, at the equilibrium capitalist entrepreneurs may be able to get profits higher than π^*_{CM} (and so a higher compensation for their capital), if the monopolistic position in the product market prevents entry by WM competitors and allows CM firms to set the commission fee above α_E. We do not discuss these possibilities formally and, to keep the model simple, refer to an environment where the entrepreneurs-owners of CM firms cannot act as lenders to WM firms.

To study the relative cost efficiency of WM and CM platforms, it is useful to look at their average variable costs, that are $AVC_{CM} = (1/n)[n(1 - \alpha)r] = (1 - \alpha)r$ and $AVC_{WM} = (1/n)(Ii)\ \forall n \leq \bar{c}$. Note that AVC_{WM} decreases with n, whilst AVC_{CM} remains constant. At $n = 1$, $AVC_{CM}(n = 1) = (1 - \alpha)r$ and $AVC_{WM}(n = 1) = Ii$. When α is set at the optimal level according to Equation (7), manipulating, we obtain that $AVC_{WM}(n = 1) < AVC_{CM}(n = 1)$ if:

$$i < \frac{r\bar{c}}{I(1 + \bar{c})} \tag{9}$$

From this, we can state the following proposition.

Proposition 2. *If CM platforms are viable (i.e.* $i > 0$), they may be less efficient than WM platforms at the equilibrium. If WM platforms are viable (i.e. $i = 0$), they are more efficient than CM platforms at the equilibrium.

Proof See the Appendix. ■

In words, the mechanisms behind Proposition 2 are as follows:

- When $i = 0$, WM platforms are viable and more efficient in terms of average variable costs, because $AVC_{WM} = 0$ while AVC_{CM} is positive for any level of firm size;
- When $0 < i < \frac{r\bar{c}}{I(1+\bar{c})}$, WM platforms are not viable but they would have been more efficient in terms of average variable costs for any level of firm size, because the AVC_{WM} curve lies below the AVC_{CM} curve for any $n > 0$ below $\bar{c}$;
- When $i > \frac{r\bar{c}}{I(1+\bar{c})}$, WM platforms are not viable but they would have been more efficient in terms of average costs at the equilibrium when $\bar{c}$ is relatively large $\left(\text{precisely, when } \bar{c} > \frac{Ii}{(1-\alpha)r}\right)$, because the AVC_{WM} curve lies below the AVC_{CM} curve for any level of firm size above such threshold.

From a qualitative point of view, these results are suggestive because they point to the importance of addressing the issue of access to capital for WM firms, particularly when the cost of capital prevents the viability of WM platforms but WM platforms would be more desirable in terms of market efficiency. Indeed, WM firms creation may be impeded by the cost of capital, but this does not necessarily imply that WM are less efficient than CM counterparts. Interestingly enough, since it is impossible that $i = 0$ whilst Equation (9) does not hold, it is also impossible that WM platforms are viable but also less efficient than CM firms for any level of size.

Beside the issue of efficiency, the analysis of the pattern of economies of scale allows emphasizing that, in equilibrium, digital platforms may tend to achieve a monopoly position in the market, due to non-increasing average variable costs. This equals to say that, when a firm (whether it is WM or CM) is established in a platform market and has reached the equilibrium size, barriers to entry of the type typical in a natural monopoly may emerge, as the incumbent may enjoy average costs lower (or not higher) than potential competitors outside the market. The monopoly position in the product market may also reflect into a monopsony position in the labor market (related to this, Dube et al. (2020) show that many platform firms behave in fact as massive employers with monopsony power). The empirical regularity that platform firms enjoy a monopsony position, which is also a possible implication of our model as shown here, does not contradict the basic mechanism of our framework of workers choosing between alternative firms based on payoff maximization. Under perfect information, workers may choose the type of firm (i.e. WM or CM) that offers a higher wage by backward induction, before firms are created. Hence, it is not necessary to have more than one firm simultaneously active in the market, for the mechanism of firms competition over workers to work. Clearly, when a firm has a monopoly position both in the product and in the labor market, it can adjust the pay policy to extract additional rents from the labor relationship under the protection of barriers to entry that impede pay competition from inside the market. In the case of a CM platform enjoying such position, this would translate into the ability of the firm to push the commission fee above the α_E threshold. We do not integrate this possibility formally into the model; nevertheless, we admit that the actual pay policy of CM platforms with monopsony power may generate lower worker payoffs than those determined in our model. Finally, monopsony may also be associated with underemployment, if the supply of labor is larger than the demand (Bell & Blanchflower, 2021). This may create an additional channel for CM platforms to further reduce workers pay.

3 | OTHER SOURCES OF WM PLATFORMS DIFFERENTIATION

3.1 | Employment concerns

The hypothesis that WM firms maximize only net income per-unit of labor dates back to the first formal model of workers cooperative provided by Ward (1958). Although the per-capita income maximization assumption has been extensively used in the self-management literature, it has been also showed not entirely plausible in theory (Dow, 2003) and its empirical support has been proved to be modest (Craig & Pencavel, 1992, 1993). Thus, we next relax this assumption and extend our baseline framework to possible employment concerns in WM platforms.

If WM organizations are concerned also with employment levels, they will maximize a more general welfare function than Equation (2), which can be written as follows:

$$W_{WM} = \begin{cases} \beta\left(\dfrac{rc - Ii}{n}\right) + (1-\beta)n & \text{if} \quad n \leq \bar{c}, \quad \text{with} \quad c = n \\ \beta\left(\dfrac{r\bar{c} - Ii}{n}\right) + (1-\beta)n & \text{if} \quad n > \bar{c} \end{cases} \tag{10}$$

where both earnings per-member and total employment enter as inputs and where β (with $0 < \beta < 1$) is the weight that a WM organization places on earnings per-member. When $\beta = 1$, then Equation (10) reduces to Equation (2), that is, $W_{WM} = \pi_{WM}$.

Maximizing Equation (10) with respect to n and recalling from Equation (4) that the income maximizing number of customers is $\bar{c}$, we obtain the following FOC:

$$\beta\frac{Ii - r\bar{c}}{n^2} + (1-\beta) = 0 \tag{11}$$

from which we can obtain the optimal size of a WM organization concerned with both income per-worker and employment, that is,:

$$n_{WM}^{**} = \sqrt{\frac{\beta}{1-\beta}[r\bar{c} - Ii]} \tag{12}$$

If $n_{WM}^{**} > \bar{c}$, then Equation (1) is maximized with $\pi_{WM} < (1-\alpha)r$, that is, workers-members maximize their welfare by running a WM platform that is larger than in the case where they do not have employment concerns, even at the price of collecting per-capita earnings lower than the monetary payoff they would get as workers in a CM organization. Manipulating Equation (12), we can obtain the threshold level of β causing $n_{WM}^{**} > \bar{c}$, that is:

$$\bar{\beta} = \frac{r\bar{c} - Ii}{r\bar{c} - Ii + (1-\alpha)^2 r^2} \tag{13}$$

In this case, the optimal pay policy of CM platforms is required to change with respect to the one determined where employment concerns are absent, due to the need of CM firms to compensate for the fact that now workers also place some value on employment levels. With $i > 0$, the threshold level of α making WM platforms never convenient for workers will be the one where the following condition holds:

$$\beta(1-\alpha_E)r + (1-\beta)\bar{c} = \beta\left(\frac{r\bar{c}}{n_{WM}^{**}} - \frac{Ii}{n_{WM}^{**}}\right) + (1-\beta)n_{WM}^{**} \tag{14}$$

that is

$$\alpha_E = 1 - \frac{\bar{c}}{n_{WM}^{**}} + \frac{Ii}{n_{WM}^{**}r} + \frac{(1-\beta)\left(\bar{c} - n_{WM}^{**}\right)}{\beta r} \tag{15}$$

Equation (15) tells us that, since $\bar{c} - n_{WM}^{**} < 0$, a decrease in the weight that WM organizations place on per-capita incomes results into a lower α_E. That is, as the employment concerns of WM platforms increase, CM firms will need to reduce their commission fees to continue being attractive to workers. Clearly, when WM platforms do not show employment concerns (i.e. $\beta = 1$), then $n_{WM}^{**} = \bar{c}$ and Equation (15) simplifies to $\alpha_E = \frac{Ii}{\bar{c}r}$.

Moreover, from Equation (12), we can see that, for a WM organization concerned also with employment levels, an exogenous negative shock in the demand for the service translates into lower reductions of employment levels comparatively to income maximizing WM firms, at the price of accepting also some reduction of per-capita incomes. In particular, in our model, one-unit reduction of $\bar{c}$ induces a reduction of n by $(\beta r)/\left[2(1-\beta)\sqrt{\frac{\beta(r\bar{c}-Ii)}{1-\beta}}\right]$. Clearly, that WM platforms reduce per-capita incomes when facing a negative demand shock, whilst CM platforms can freely adjust labor, might be seen as a disadvantage of WM platforms, which lose economic attractiveness with respect to their CM competitors.

Employment concerns in WM platforms may also be of a different nature, with workers-members being concerned about their own employment position and not about employment of prospective new members (i.e., concerns for employment are asymmetrical, as insider workers oppose adjustments downwards but are neutral with respect to those upwards). In this case, WM platforms expand up to $\bar{c}$ according to the problem in Equation (3), but at the same time tend to be conservative when $\bar{c}$ reduces according to the weight they place on existing employment. Formally, one-unit reduction of $\bar{c}$ in this case induces a reduction of n by $1-\beta$.

It is easy to observe that the elasticity of size with respect to $\bar{c}$, when employment concerns are asymmetrical, depends only on β. When concerns are about overall employment, instead, the elasticity of size with respect to $\bar{c}$ depends on β, r and on $\bar{c}$ itself. Moreover, when β goes down (i.e. the weight placed on employment goes up), WM firms concerned with overall employment adjust labor quantity less than when concerns are asymmetrical; this difference is larger when the market is smaller and when the unit price is higher.

While previous empirical evidence (Craig & Pencavel, 1992) has already showed that self-managed firms are more inclined to adjust pay than employment in response to market changes, a novelty of our model here is in providing a measure of the magnitude of employment adjustments both in the case when insiders members have concerns on overall employment and in the case when these concerns are asymmetrical.

An additional reason making employment concerns interesting in this setting is that introducing the dual target of employment and revenue for workers in the WM firm's welfare function gives WM platforms an additional degree of freedom that to some extent compensates what CM firms have in the "wedge" discussed in Section 2.3. From this point of view, our model could be seen as a model of the political economy of competition between capital-owners and worker-owners. Abstracting away from other considerations which may make workers preferring to join WM platforms, in very simple terms our model builds a story of CM and WM firms competing for workers, regardless where they are initially employed, by playing with two key attractors, that is, wage (or per-capita income) levels and employment levels and stability. This feature of the model relates to the line of literature attempting to explain capitalist firms and worker cooperatives emerge in particular market niches (see, e.g., Mikami (2011)).

In the rest of the paper, we will generally keep referring to an income maximizing stylized WM firm. This is to avoid unnecessary notation and to keep mathematics simple, not to exclude that WM firms may also maximize a convex combination of employment and dividends.

3.2 | Ability to gain from network effects

3.2.1 | User-side network effects

For platform services, it is commonly the case that the more users participate to the platform, the more useful it becomes for all users. This may be due to direct effects linking the number of customers to the value of the service itself for each individual user (e.g. when a service implies digital social interactions, more users belonging to the network imply a greater value of being connected to the platform) or to indirect effects that push platform owners to improve the platform, and therefore the quality service, in order to deal with more customers (these indirect effects may be associated with the development of additional features of the platform and with the supply of complementary services). These effects translate into an increasing willingness to pay of customers, as the number of customers increases. Here, we take into account this possibility, by assuming that, for both WM and CM platforms, total revenues grow in the number of customers according to

$$rc^{\delta}, \tag{16}$$

with $\delta > 1$ (and reasonably close to 1) being a user-side network effect parameter.[15] Unit revenues will be rc^{δ}/c. Hence, the payoff of a worker in a CM platform will be:

$$(1-\alpha)rc^{\delta-1} \tag{17}$$

while the payoff in a WM income maximizing platform will be:

$$\pi_{WM} = \begin{cases} \dfrac{rc^{\delta} - Ii}{n} & \text{if} \quad n \leq \bar{c}, \quad \text{with} \quad c = n \\[2ex] \dfrac{r\bar{c}^{\delta} - Ii}{n} & \text{if} \quad n > \bar{c} \end{cases} \tag{18}$$

It is straightforward to obtain that the threshold level of α making WM platforms never convenient is:

$$\alpha_E = \frac{Ii}{\bar{c}^{\delta} r} \tag{19}$$

The main intuition behind Equation (19) is as follows. When a CM firm does not pay fix wages but retains an overhead on the revenues raised by the workers, an increase in total revenues —e.g. as due to network effects—accrues to workers only partly. On the other side, in a WM platform, an increase in revenues is entirely captured by the workers. Therefore, for CM firms to be attractive to workers, as total revenues increase, the overhead must decrease. More in general, the overhead applied by capitalist owners being equal, WM platforms should be more convenient for workers when network externalities are stronger.

Finally, with network externalities, the optimal (income maximizing) size is again:

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[15] Under the assumption that $n = c$, Equation (16) may also reflect cross-side network effects, where an increased number of workers pushes up the willingness to pay of customers. This may be the case when the quality of the service mechanically improves as the number of workers increases (i.e. without additional costs for the workers). An example is the quality of geo-referenced platforms, which provide much more granularity and better precision of information when more workers are logged-in to the platform. It is possible that the network externality is exhausted above some critical threshold level c_T. Here, we assume that $\bar{c} < c_T$.

$$n^{***}_{WM} = \bar{c}. \tag{20}$$

and, again, WM firms viability is impeded if $i > 0$.

3.2.2 | Worker-side network effects

Suppose that, at some cost, the worker can exert cooperative effort η that increases the general quality of the service (i.e. joint reputation), thereby improving the ability of the entire workforce to raise higher unit revenues (in doing so, we are implicitly relaxing our assumption of service homogeneity).[16] Denote the cost of the cooperative effort with $\phi(\eta)$ (where $\phi'(\eta) > 0$ and $\phi''(\eta) > 0$). Cooperative effort is not contractible. Assume also that unit revenues are a function of η, according to $r(\eta)$, with $r'(\eta) > 0$ and $r''(\eta) < 0$.[17]

In equilibrium, the payoff of a worker in a CM platform is:

$$U = (1 - \alpha^*)r(\eta) - \phi(\eta) \tag{21}$$

and the corresponding FOC with respect to η is:

$$(1 - \alpha^*)r'(\eta) = \phi'(\eta) \tag{22}$$

Denote the optimal level of cooperative effort, for Condition (22) to hold, in a CM platform with η^*_{CM}. The per-capita earnings of a worker in a WM platform, under the belief that the others workers exert zero cooperative effort, are:

$$\pi_{WM} = \frac{r(\eta)\bar{c}}{n} - \frac{Ii}{n} - \phi(\eta) \tag{23}$$

and (since $\bar{c} = n$) the corresponding FOC is:

$$r'(\eta) = \phi'(\eta) \tag{24}$$

Denote the optimal level of cooperative effort, for Condition (24) to hold, in a WM platform with η^*_{WM}. It is straightforward to observe that, in equilibrium, $\eta^*_{WM} > \eta^*_{CM}$.

This result may also hold in a more particular case where cooperative effort exerted by one worker causes only the unit revenues of the rest of the workforce to increase, by Δ_r (e.g. due to information sharing), so that she will continue to raise r while each of the other workers obtains $r + \Delta_r$. To keep things simple, assume that $\eta = \{0, 1\}$ and that the unit cost of $\eta = 1$ also equals 1. Clearly, in a CM firm, where the wage is determined as $(1 - \alpha)r$, the worker has now no

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[16] In many digital services, sharing economy platforms use reputation systems to ensure a high level of service quality. A worker who improves his/her performance generates positive externalities accruing to all the team members, thereby contributing to the ability of co-workers to make higher prices.

[17] Precisely, r is a function of the effort exerted by any worker, that is, $r(\eta_j, ..., \eta_h, ..., \eta_q)$ with q being the nth worker. We omit subscripts in the text to simplify notation.

incentive to exert cooperative effort, since she is paid a fraction of individually raised revenues and the cost of $\eta = 1$ translates only into higher wages for the rest of the workforce (i.e. the utility of worker i in a CM firm is here $U_i = (1 - \alpha^*)r_i - \phi(\eta_j)$, with $j \neq i$). In a WM firm, where total revenues are divided equally, the worker may instead have incentive to improve partners' performance.

Consider again the case of an income maximizing WM platform, where $n = n^*_{WM} = \bar{c}$. For a worker being cooperative, her payoff after exerting $\eta = 1$ must be higher than that with $\eta = 0$, even if she is the only worker choosing the cooperative strategy. Formally, the payoff of a representative worker concerned with the possibility of exerting cooperative effort, under the belief that the other workers are not, is:

$$\pi_{WM} = \left[r - \frac{Ii}{n}\right](1-\eta) + \left[\frac{r + (r+\Delta_r)(n-1)}{n} - \frac{Ii}{n}\right]\eta \tag{25}$$

Some simple algebra shows that a worker will thus choose exerting cooperative effort $\eta = 1$ if:

$$\frac{\Delta_r(n-1)}{n} > \eta \tag{26}$$

If Condition (26) holds for the representative worker (and assuming that workers are identical), all the workers will opt for $\eta = 1$. Hence, the final per-capita income will be:

$$\pi_{WM} = \frac{n(r + \Delta_r(n-1))}{n} - \frac{Ii}{n} \tag{27}$$

which can be rewritten in a more compact form, as:

$$\pi_{WM} = rn^{\rho-1} - \frac{Ii}{n} \tag{28}$$

with $\rho = \frac{\ln(n(r+\Delta_r(n-1)))}{\ln(n)+\ln(r)}$ (in the more general case we began with, where cooperative effort increases the unit revenues for the entire workforce, $\rho = \frac{\ln(n(r+n\Delta_r))}{\ln(n)+\ln(r)}$). As it can be easily noticed, per-capita incomes raised by workers in a WM platform with worker-side externalities of the type modeled here have the same form as in the case of user-side network effects (except for the fact that the user-side network parameter δ may be different from the worker-side one, ρ). On the other hand, under worker-side externalities, the workers' payoff in a CM firm remains unchanged with respect to the baseline case and, precisely, equal to $(1 - \alpha^*)r$. Hence, to make some simple comparative statics without further calculation, assuming that $\delta = \rho$, we will have a lower α_E in the case of worker-side than in the case of user-side network effects. This reinforces the conclusion that, when network effects are present (whether they be on the user- or worker-side), the share of revenues retained by (and the attractiveness of) CM platforms is relatively lower than when network externalities are absent.

This result also suggests that workers' cooperative effort in WM platforms will be higher than in CM firms (in the case of collaborative effort generating only positive externalities, this is true if Condition (26) holds), thereby inducing quality improvements in WM firms which may be impeded by the CM platforms' pay policy. In this respect, the incentive effect of the pay policy of WM firms reflects a group incentive pay mechanism. Group incentive pay mechanisms, as reviewed by Bloom and Van Reenen (2011), are typically deemed to suffer from the free-rider problem, with each worker trying to enjoy the rewards from the others' effort without bearing any cost. According to the standard view, workers will shirk when the value they place on shirking is higher than the costs they expect to pay. In digital markets, where the pay policy of CM firms is based on deducting some commission fee from the unit revenues raised by the individual worker, WM platforms dividing profits evenly may show higher comparative cooperative effort levels. This may be true also when the cooperative effort of the worker does not reflect into higher unit revenues for the worker but only induces positive externalities to the advantage of the rest of the workforce, to the extent that Condition (26) holds (i.e. when the cost of cooperation is relatively low). Thanks to algorithmic technologies, this may be the case of automatic information sharing applications (such as positioning systems, in the peer-to-peer transportation sector, for avoiding supply-demand mismatch; or softwares for ranking clients and input providers), which may be costless (or very close to it) for a single worker, with the benefits accruing to all the team members being significant.

Finally, notice that, with negligible changes of the model, the results concerning cooperative effort can be generalized to other types of quality improving effort, including effort directed to developing firm-specific human capital that helps the workers at raising higher revenues by improving the quality of the specific service they provide. As the cooperative effort analyzed in this Section, worker investments in firm-specific human capital are typically non-contractible and have no value outside the firm. Hence, they are subject to the same incentive problem as cooperative effort and their optimal level for the worker depends on the worker pay policy. Since the extra-surplus from effort accrues to workers only partly in CM firms, while workers-members in a WM platform as a group enjoy the results of their effort entirely, firm-specific investments in human capital should be larger in WM firms than in CM firms. At the same time, non-contractible firm-specific effort by workers in WM firms may be reduced by free-riding when the team gets larger (this is the so-called “$1/n$ problem” (Prendergast, 1999)). As we have shown here, however, if the cost of effort is sufficiently low, the extra-revenues due to improved effort may induce each worker to undertake the investment even when n is large.

4 | ANECDOTAL EVIDENCE AND EXTERNAL VALIDITY OF THE MODEL

While the results of our model are generally coherent with available theoretical studies on the possible merits of WM firms, they also contribute emphasizing that the cost of external capital may be one of the main obstacles to the creation of WM platforms. Moreover, our simple model shows intuitively that the commission fee charged by CM platforms should be lower, in equilibrium, when the fixed cost of the platform is lower and when the final market is characterized by larger size, higher unit revenues and higher network effects. These ingredients may help explaining why WM and CM platforms co-exist in some sectors and why WM firms are not even created in others.

The peer-to-peer transportation sector is an interesting context of analysis. The last decade has seen the impressive development of app-based platforms for on-demand transportation services, including both CM firms (such as *Uber* and *Lyft*) and WM companies (e.g., *Union Taxi* and *Green Taxi Cooperative* in Denver–Colorado, *Union Cab* in Madison–Wisconsin, *People's*

Ride in Grand Rapids–Michigan, *Coop Taxi* in Montreal–Canada, and *COOP Taxi* in Seoul–South Korea). An intuitive way to investigate the comparative viability of WM platforms in this sector and therefore to understand why CM platforms, like *Uber*, have been able to cannibalize the market (despite the co-existence of WM taxi cooperatives in many cities) is to look at the pay policy of CM platforms in comparison with the "theoretical" maximum fee of a CM firm making WM platforms inconvenient for the workers, that is, —according to the notation of our model— α_E. Let us focus on the case of *Uber* as a representative case.

In this comparative statics exercise, we proceed as follows. We first calibrate the model, with reference to the ideal context of an app-based platform in the peer-to-peer transportation sector of a medium-size city. Second, we set reasonably wide ranges for our model's parameters around calibrated values and make multiple random extractions over these ranges for each model variable, assuming an underlying normal distribution. Third, we calculate α_E for each extraction round and obtain the distribution of the "empirical" (or experimental) α_E that is so generated. Fourth, finally, we look at the modal value of α_E over this distribution, and compare it with the actual commission fee generally applied by Uber. By looking at the commission fees chosen by CM platforms in other sectors, we will support our conclusion with a simple external validity exercise.

We think of a unit of time as representing one quarter. We choose the initial sunk cost I, based on a 2015 survey of app development for platform-based businesses (Clutch, 2017). The cost of building an app-based platform varies according to the app's features and complexity and depending on the number of hours of work required at the different stages (discovery, design, development, testing and deployment). At \$100/hour, the median cost of an app ranges from around \$25,000–\$115,000. The same survey reports that maintenance after one year costs less than \$10,000 for 60% of the respondents. We select $i = 1\%$, taking as a reference that the U.S. annual lending interest rates have been around 4% over the last 5 years (IMF, 2018) and considering a 25% increase of it for loans of up to \$250,000 (ECB, 2017). Unit product prices may vary largely. We refer to an average ride of 10 km with a standard transportation app-based company, which costs around \$20 in cities like Munich, New York and Sydney (Uber, 2018). Finally, we set $\bar{c} = 2,000$ as a number of customers in a short-run period that may be consistent with typical small-medium app-based activities.

Based on this calibration, we create reasonably wide ranges of possible values of our model's variables, as reported in Table 1, and run 10,000 iterations for generating and extracting random values over these ranges.

We then calculate as many simulated α_E and obtain the kernel density distributions of the "empirical" α_E, plotted in Figure 1.

The distribution of simulated α_E is asymmetric and shows a longer and thinner tail on the right. This suggests that, over the range of parameters' values used in this exercise, the frequency of α_E is more likely to be concentrated around 0.25 or below rather than above. A direct implication would be that an α_E above 0.25 or more is unlikely to be sustainable for CM platforms.

This simulation is also useful to give a sense of scale of a realistic range of α_E in the app-based transportation sector. Indeed, a value of 0.25 is in line with the commission policy of *Uber*. *Uber* passes the payment of each ride on to drivers after deducting an overhead commission generally ranging between 20% and 30% (Rosenblat & Stark, 2016). Hence, the actual commission fee charged by *Uber* may be just a bit lower than the α_E threshold simulated by our model. This is coherent with recent evidence documented by Hall and Krueger (2018) and Berger et al. (2018), showing that *Uber*'s drivers in the U.S. are shown to receive earnings per

TABLE 1 Selection of parameters for simulation analysis.

Parameter	Generating process
Initial sunk investment for platform provision per quarter before breakeven, in \$ (I)	Random [10,000, 250,000]
Interest rate (i)	Random [0.01, 0.5]
Revenues per unit of service, in \$ (r)	Random [5, 50]
Equilibrium number of customers per quarter ($\bar{c}$)	Random [50, 5000]
Commission fee to be paid to capitalist employers (α)	Random [0.05, 0.5]

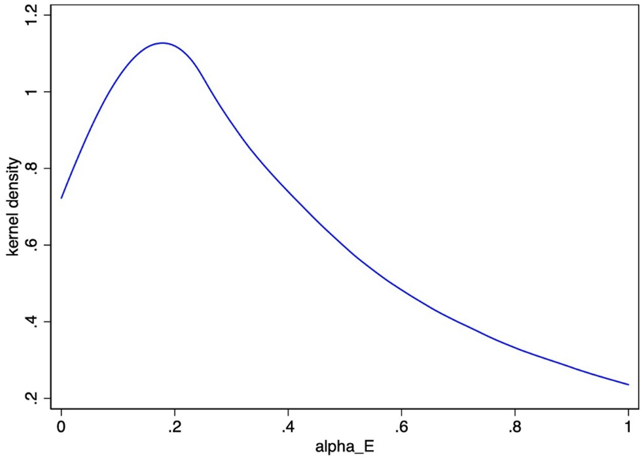

FIGURE 1 Simulated levels of α_E from random values of the model's variables (10,000 iterations). Kernel density distributions of α_E generated from random values (10,000 iterations) of the models' variables, with $r \in [5, 50]$, $i \in [0.01, 0.5]$, $\bar{c} \in [50, 5000]$, $I \in [10{,}000, 250{,}000]$. [Colour figure can be viewed at wileyonlinelibrary.com]

hour that are slightly higher than their driver counterparts working in traditional taxi companies.[18] Specifically, the average earnings per-hour of Uber's drivers range from \$16.20 in Chicago to \$30.35 in New York, while hourly wages of taxi drivers are \$11.87 and \$15.17 respectively. Uber's drivers are not reimbursed for driving expenses, such as gasoline, depreciation, or insurance (though they may be able to partially deduct work-related expenses from their income for tax), while taxi drivers may not have to cover those costs. Nonetheless, the data suggest that unless their after-tax costs on average are more than \$6 per-hour, the net hourly earnings of Uber's drivers exceed the hourly wage of taxi drivers and that Uber's overhead commissions are set just below the critical threshold α_E that our model would predict.[19] This may contribute to explaining why Uber has been able to expand, often up to market saturation, even in cities where competing platforms were available and to explaining why available WM platforms in this sector appear less attractive to prospective drivers. This is not to say that WM platforms are not viable in the peer-to-peer transportation sector. WM firms are active in several

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[18] This is partly contested by Berg and Johnston (2019).

[19] That Uber has engaged in vicious price wars where it makes fees close to sustainability in order to attract drivers is widely acknowledged (Forbes, 2019).

cities and drivers often work on CM and WM platforms simultaneously (this is the co-called "moonlighting"). Net driver payoffs in WM and CM transportation platforms may be substantially similar in actual facts (our simulation generates a predicted α_E that is indeed close enough to the actual fee of Uber), what allows co-existence of competing platforms. Clearly, asymmetric regulatory regimes and licensing costs also played a role in determining Uber's success.

As a simple external validity check, let us compare simulated values of α_E from our model, under different scenarios in terms of unit revenues and demand-side network effects, with some available anecdotal evidence. In Table 2, we list some of the best known CM firms currently operating in the digital platform economy along with their sector of activity and the commission fee that they charge. For each company and sector of activity, moreover, we indicate the upper bound of the commission fee (α_E) that our model would predict given the class of value of the unit revenues and the network effects (which mainly refer to reputation mechanisms and rating) typical in the sector.

As shown in our theoretical discussion over the previous Sections, higher unit revenues and stronger network externalities reflect into lower values of α_E. Table 2 reports that this pattern corresponds to the actual pay policy of the CM platforms here considered, which in fact charge lower fees in sectors where unit prices are higher and network effects are stronger.

Finally, we provide some empirical support for our prediction that digital platforms, including WM ones, tend to expand up to $\bar{c}$. Comparable estimates of the potential size of the market for a comprehensive range of sectors are not available; however, information on the number of workers-members of some existing WM platforms is provided on the official public websites of the platforms themself. If it is correct the prediction of app-based WM firms expanding as much as allowed by the potential demand, we should expect a number of coworkers in WM digital firms no lower than the average size of standard WM firms in traditional sectors, which experience much more significant variable operating costs. To verify this, in Table 3, we consider a small sample of well established WM digital platforms and report their actual size. It is easy to notice that the real size of WM platforms is in fact relatively large compared to the average size of worker cooperatives in more traditional sectors, which ranges from 200 to 300 workers according to available statistics for Italy (Pencavel et al., 2006) and the US (Craig & Pencavel, 1992) and reduces below 100 workers for Uruguay (Burdín & Dean, 2009) and France Pérotin, 2016).

The existence of WM platforms in other sectors besides peer-to-peer transportation is useful also to highlight what are the enabling factors that count the most for WM platforms viability. The anecdotal evidence reported in Table 3 suggests that WM platforms tend to produce non-standardized goods and services, and operate in sectors characterized by more radical asymmetric information problems, idiosyncratic investments in human capital, production of tacit knowledge and various external effects. These are the elements typical in the fair trade, in the market of artistic and ethical products and in general in the production processes where the human contribution of the worker is more significant. As showed in our model, moreover, in these non-traditional sectors, WM platforms may show some pay advantage over CM platforms due to stronger network effects, which include some of the elements mentioned just above, particularly the positive externalities generated by investments in project-specific human capital, reputation and collective image building.

TABLE 2 Anecdotal evidence: pay policy of best known CM platforms.

Company	Sector of activity	Unit revenues	Network effects	α (Actual value)	α_E (Model simulation)
Uber	Peer-to-peer transportation	**Low.** Pay varies widely, on average it ranges between \$15 and \$20 per-hour (Hall & Krueger, 2018)	**Low.** Rider-side (direct) network effects are relatively low. Rating mechanisms and feedback-based reputation of drivers play some significant effect only when the supply of drivers with respect to riders is large; when it is so, however, an excess of supply of drivers may cause returns to diminish, thereby lowering cross-side network effects	~0.25/ 0.3	~0.25/0.35
Lyft	Peer-to-peer transportation	**Low.** Similar to uber, or slightly higher (Leskin, 2019)	**Low.** Same as uber	~0.25/ 0.3	~0.25/0.35
Amazon MTurk	Crowdwork and crowdsourcing	**Low/very-low.** Average pay is \$2 per-hour (Hara et al., 2018)	**Medium.** Rating mechanisms and feedback-based reputation of workers play non-negligible role, as the expected quality of the service is otherwise difficult to be anticipated by users. Higher numbers of requesters of a same task also induce higher competition and improved service quality. Cross-side network effects may be significant	~0.2	~0.25
TaskRabbit	Home care and handyman	**Medium.** Average pay is \$35 per-hour (Campbell, 2019)	**Medium.** Rating mechanisms and feedback-based reputation of workers is important. Higher numbers of requesters of house-cleaning and related services also induce higher competition and improved service quality. Cross-side network effects may be significant	~0.15	~0.15

TABLE 2 (Continued)

Company	Sector of activity	Unit revenues	Network effects	α (Actual value)	α_E (Model simulation)
Handy	Home care and handyman	**Medium.** Similar to TaskRabbit	**Medium.** Same as TaskRabbit	~0.1/ 0.15	~0.15
Freelancer	Freelance services and online outsourcing	**Medium.** Anywhere between $5 and $50 per-hour	**Medium/high.** Similar to Amazon MTurk, but here rating mechanisms and feedback-based reputation of workers play a larger role, as the tasks typically require some higher skills than Amazon MTurk. Cross-side network effects may be significant	~0.1	~0.15
Etsy	Handmade and vintage goods	**High.** Prices vary widely and average prices are difficult to determine. The average price of vintage goods may be high or very high and the average price of handmade products may be equivalent to about $50 per-hour of work or more	**Medium/high.** Rating mechanisms and feedback play a significant role. Demand bunching dynamics may increase the perceived quality of the products. Cross-side network effects may be significant	~0.03/ 0.04	~0.04

Abbreviation: capital-managed.

5 | CONCLUSIONS

Our simple model shows that WM firms operating in digital platform sectors may show some important efficiency advantages with respect to competing CM firms. At the equilibrium, WM platforms may be more efficient in terms of average costs and may show higher productivity due to a better ability to benefit from network effects (whether they are on the demand or on the supply side). This result is peculiar of the platform economy, where WM platforms can benefit from larger network externalities by increasing the size of the business without suffering from higher costs. A typical limit to the growth of worker cooperatives in traditional sectors is given by the difficulties of raising additional capital to afford the costs of an expansion of the production capacity, so that the benefits associated with a larger network may be offset by the costs of expansion. Instead, in the digital platform sector, where marginal costs are virtually zero, WM firms are better able to capture size-related network benefits than their traditional non-app-based counterparts. To different extents, this result can be generalized to other sources

TABLE 3 Anecdotal evidence: size of WM platforms.

Company	Sector of activity	Unit revenues	Network effects	*n* (Actual value)
Green taxi cooperative	Peer-to-peer transportation (Denver, CO)	**Low.** Pay varies widely, on average it is around $20 per-hour	**Low.** Rider-side (direct) network effects are relatively low. Rating mechanisms and feedback-based reputation of drivers play some significant effect only when the supply of drivers with respect to riders is large; when it is so, however, an excess of supply of drivers may cause returns to diminish, thereby lowering cross-side network effects	~1000
Loconomics	Home care and handyman	**Medium.** Average pay is around $25–$35 per-hour	**Medium.** Rating mechanisms and feedback-based reputation of workers is important. Higher numbers of requesters of house-cleaning and related services also induce higher competition and improved service quality. Cross-side network effects may be significant	~2000
Fairmondo	Ethical goods and services	**Medium/high.** Prices vary widely and average prices are difficult to determine. The average price of products may range anywhere between $10 and $100. It is fair to say that the average price of products is equivalent to about $50 per-hour of work or more	**Medium/high.** Subjective evaluation and feedback play a role. Demand bunching dynamics may increase the willingness to pay of buyers. Cross-side network effects may be significant	~2000
Stocksy United	Artistic products and photography	**High.** Prices vary widely and average prices are difficult to determine. The average price of articstic products (photo and video) may range anywhere between $50 and $500. It is fair to say that the average price of products is equivalent to about $100 per-hour of work or more	**High.** Subjective evaluation plays a significant role. Demand bunching dynamics may increase the preceived quality of the products. Cross-side network effects may be significant	~1000

Abbreviation: WM, worker-managed.

of productivity improvements. Moreover, if established, WM platforms may also couple efficiency and productivity advantages with a higher ability to accommodate workers' preferences about employment levels.[20] At the same time, however, the extra-costs for accessing external capital may critically hamper WM firms creation. Our model provides a simple unified framework with these ingredients and leads to some intuitive results fitting available anecdotal evidence which shows that the most successful WM platforms operate in the on-line trade of ethical goods and artistic products, where demand bunching effects may matter the most.

Our model also provides direct and useful implications from the point of view of policy. We have showed that the paucity of WM platforms does not necessarily imply that shared-ownership is less efficient than capital-ownership.[21] Hence, policy makers concerned with market efficiency should not shy away from implementing actions aimed at supporting WM ownership in digital platform sectors. In particular, the presence of economies of scale combined with obstacles in the access to external capital for financially constraints workers points to the importance of designing alternative solutions for financing worker cooperatives in the platform sector. The creation of Internet-based WM platforms may benefit from improvements in crowdfunding mechanisms as a way allowing investors to more easily identify and support projects and enabling WM start-ups to pool financial resources at a lower cost. On this, legislative discussion is currently taking place at a European Commission level, with some recent proposals for an EU framework on crowd and peer-to-peer finance, aimed at facilitating the scaling up of crowdfunding services across the internal market (EC, 2018). More in general, declining average costs suggest that financial policies that want to help WM platform creation should focus on instruments for subsidizing the start-up of the platform rather than providing permanent tax subsidies. Related to this, indeed, our model suggests that WM firms may need external finance to afford the initial fixed investment more than to expand, due to their improved ability to enjoy a number of efficiency and productivity advantages. Finally, given the more democratic pay policy adopted by WM platforms, encouraging such ownership structures could be a viable regulatory alternative in monopsonistic markets, where CM firms have the bargaining power to keep worker remunerations at minimum.

While providing a contribution to both the stylization of app-based labor platforms and to the literature on the rarity of WM organizations, needless to say, the model also suffers from some limitations. First, we referred to a general platform firm, being it CM or WM, without disentangling possible variants of app-based activities. A broad distinction may be traced among the various forms of commercial digital labor platforms according to whether the platform deals with cloud work (web-based) or gig work (location-based). Location-based platforms provide services and tasks which are bound to a specific location and may take advantage from a lower geographical mobility of workers. When it is so, worker switching costs may alter the ability of platforms to compete over workers and compensation schemes adopted by WM and CM firms may be more complex than the ones used in our model. Moreover, we didn't consider many additional aspects, which may play some significant role in our framework, including

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[20] Democratic participation as a mechanism for inducing platform firms to accommodate workers' preferences for employment stability may be particularly important in light of the fact that workers involved in atypical work arrangements are often found to be willing to give up some of the salary in exchange for non-monetary job attributes (Dutta, 2019).

[21] The view that markets select efficient governance structures and therefore that the rarity of WM firms is sufficient to infer their comparative inefficiency can be traced back to the transaction costs economics, as brought to the fore by Williamson (1985).

crowdfunding (as a way to raise finance at a relatively low costs for financially constrained workers) and the possibility of endogenous sorting of workers across platforms based on their different predetermined abilities and digital alphabetization.

ACKNOWLEDGMENTS

I wish to thank seminar and conference participants at the 2019 CESifo Workshop on the Economics of the Gig Economy, 2018 STILE Law & Economics Workshop (Lugano), 2018 IAFEP Conference (Lubjiana), 2018 SIE Conference (Bologna) and at the Economic Seminars at the University of Parma. I also thank three anonymous referees for helpful comments. Any remaining errors are my own. Financial support from the University of Siena and the University of Chieti-Pescara is gratefully acknowledged. Address: Piazza San Francesco 7, 53100 - Siena, Italy. Email: filippo.belloc@unisi.it.

Open access publishing facilitated by Universita degli Studi di Siena, as part of the Wiley - CRUI-CARE agreement.

DATA AVAILABILITY STATEMENT

Simulated data were used in this study. Simulated data were gererated by the author. Simulated data will be provided by the author upon request.

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How to cite this article: Belloc, F. (2025). A simple comparative model of worker-managed and capital-managed digital platforms. *Metroeconomica*, *76*(1), 162–191. https://doi.org/10.1111/meca.12482

APPENDIX

Proof of Proposition 1

Proof Suppose not and that new members above n^*_{WM} are accepted by insiders upon payment. Insiders will be willing to accept new members if the reduction in their per-capita earnings is, at least, compensated by the revenues obtained by selling new membership shares. On the other side, outsiders will be willing to pay, at most, the difference between the per-capita earnings they will get as workers-members in a WM platform and the wage offered by a CM platform. Denoting with Δc the amount of new members, the following inequality holds:

$$\underbrace{\left[\frac{r\bar{c}}{\bar{c}+\Delta c}-\frac{Ii}{\bar{c}+\Delta c}-(1-\alpha)r\right]\Delta c}_{\text{Willingness to pay of outsiders}} \geq \underbrace{\left[\left(\frac{r\bar{c}}{\bar{c}}-\frac{Ii}{\bar{c}}\right)-\left(\frac{r\bar{c}}{\bar{c}+\Delta c}-\frac{Ii}{\bar{c}+\Delta c}\right)\right]\bar{c}}_{\text{Loss of insiders}} \tag{A1}$$

Some algebra shows that Equation (A1) holds if:

$$\alpha \geq 1, \tag{A2}$$

which contradicts Proposition 1. Hence, if $\alpha < 1$, $n^*_{WM} = \bar{c}$ is an equilibrium. ■

Proof of Proposition 2

Proof. As for the first part of Proposition 2, CM platforms are viable when $i > 0$. When it is so, $AVC_{CM} > AVC_{WM}\ \forall n > 0$, if $i < \frac{r\bar{c}}{I(1+\bar{c})}$, and $AVC_{CM} > AVC_{WM}\ \ \forall\ n < \frac{Ii}{(1-\alpha)r}$, if $i > \frac{r\bar{c}}{I(1+\bar{c})}$. As for the second part of Proposition 2, WM platforms are viable when $i = 0$. When it is so, it is straightforward that $AVC_{CM} > AVC_{WM}\ \forall n > 0$. ■