CESifo WORKING PAPERS
7708
2019
June 2019

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CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
www.cesifo-group.org/wp

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CESifo *Working Paper No. 7708*
JEL-Classification J: Labor and Demographic Economics

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Abstract

Thanks to algorithmic management, the digital platform sector does not require sophisticated governance structures and labour intensity tends to be higher than in traditional sectors. So, why aren't usually digital labour platforms worker cooperatives? We develop a simple model to study the comparative viability of a worker-managed (WM) via-app labour platform firm vis-à-vis a capital-managed (CM) counterpart. Firms compete over workers by choosing the optimal size and (CM firms only) the pay policy. Given the size of the market, we show that WM platforms maximize per-capita incomes over a middle range interval of firm size. At the equilibrium size, viability of WM firms may be impeded by the costs of the external capital, no matter how low, which enable CM firms to pay a wage premium. The worker payoff in CM firms is higher in the presence of higher unit revenues and network effects (which improve the ability to pay of WM firms, thereby stimulating pay competition between platforms) and lower when WM platforms need to charge new members a fee to overcome free-riding problems faced by those who fund the initial investment. The model also shows that the conditions for worker buyouts are weaker than those required for WM platform creation from scratch, and that group incentive mechanisms allow WM platforms to better pursue quality improvements than CM firms, when digital techniques make the cost of effort relatively low.

JEL-Codes: J540, L220, P130.

Keywords: labour platforms, via-app work, worker-managed firms.

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I wish to thank seminar and conference participants at the 2019 CESifo Workshop on the Economics of the Gig Economy, USI, Lubjiana and Bologna for useful suggestions. Any remaining errors are my own.

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 via-apps. 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 (Smith and Leberstein, 2015; Harris and Krueger, 2015; Katz and Krueger, 2019; Abraham *et al.*, 2017). Sectors of activity cover (and are not limited to) delivery, home services and transportation. Well-known companies operating through labour platforms are *Uber*, *Lyft*, *TaskRabbit*, *Care.com*, *Amazon Mechanical Turk*, *Crowdflower*, *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 and Krueger, 2016). As a result, unlike conventional firms, labour 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).

An unexplored issue in the literature on this new type of firm organization is the relationship between the typical cost structure of digital platform-based activities and the ownership of the firm. According to a large literature (starting from Jensen and Meckling (1976)), the capital structure of the firm is essential to the distribution of ownership rights. In particular, when financing requirements are large and the capital market is imperfect, workers may encounter problems when seeking loans to finance firms (Stiglitz and Weiss, 1981), and this contributes to explain why outside (shareholder) ownership is likely to emerge in capital-intensive industries (Podivinsky and Stewart, 2007; Conte and Jones, 2015). In the platform economy, start-up financing of non-human assets bites relatively less and capital costs do not increase significantly with the number of workers. Thus, the comparative disadvantage of worker-ownership is reduced with respect to traditional services and manufacturing sectors. Moreover, the nature of platform-based services typically requires homogeneous workforce, what reflects one of the main regularities of worker-managed firms pointed out by ownership theory (Hansmann, 1996).

With this paper, we investigate theoretically the issue of the ownership of a digital labour platform organization. We trace a broad distinction among various types of ownership according to whether ownership is shared among workers who equally divide residual profits (worker-managed (WM) structure) or all control rights and rights to residual profits are allocated to capital suppliers (capital-managed (CM) structure). We then study the comparative viability 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 via-app platform as a digital infrastructure through which a homogenous service is provided to customers on-demand. Due to the technological characteristics of labour 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. Digital algorithmic monitoring also reduces possible advantages or disadvantages of WM versus CM forms of economic organization, and monitoring costs can be assumed to be the same across diverse ownership structures. 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 platform is shown to be the same, in the presence of a competitive market for membership. In particular, 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. In extensions of the basic model, we consider both user-side and worker-side network effects and introduce some additional essential differences between WM and CM platforms, including employment concerns in WM firms and coalition costs that make the establishment of a WM platform relatively more costly.

Against this background, we study under which conditions WM labour platforms may emerge, concentrating on the short-run implications of the model. We model the relative payoff of the workers across WM and CM platforms ownership structures as depending, all else being equal, on the overhead commission that the workers must pay to the platform owner if they work as employees in a CM firm. At the equilibrium size, the extra-costs of the external capital for WM platforms 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 workers of CM firms. This pay premium makes CM platforms more attractive and impedes viability of WM firms.

When workers show employment concerns, CM firms keep their optimal size fixed and reduce the overhead fee to compensate for the fact that workers place value on higher employment levels. We also find that the maximum level of the overhead compatible with attractiveness of CM firms increases with the initial cost of the platform and decreases when unit revenues are higher and 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 employees, an increase in the revenues, due to network externalities (or to any other productivity improvement), accrues to employees 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. Some reported anecdotal evidence on platform cooperativism in the on-line market of ethical goods and artistic products (where demand aggregation effects are particuarly important) appears consistent with this conclusion.

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 labour 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 revealed to be 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 and 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 initital fixed costs of the platform may bite significantly. Without WM platforms showing any type of cost advantage *vis-à-vis* CM counterparts, financial constraints are found to matter crucially, by creating a cost wedge, no matter how small, which allows CM firms to provide workers with a higher monetary payoff. At the same time, in the presence of an extra-cost for workers raising external capital, in our model, worker buyouts are shown to require weaker conditions for viability with respect to WM platforms creation from scratch. These results point to the importance of designing alternative (innovative) fund raising methods, if one is interested in finding ways to support worker-owned digital platforms. 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 and 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 and 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 employee 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 survey), which has never addressed the issue of via-app forms of worker-managed labour 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* employees 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 WM platforms maximize per-capita earnings. In Section 3, we introduce additional differences between CM and WM platforms, namely employment level concerns and coalition costs. In Section 4, we analyze how network externalities influence the viability of WM platforms. In Section 5, we relax the initial (implicit) assumption that WM firms can be created only from scratch, and consider the possibility of workers buyouts. In Section 6, we provide 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 7. In the Appendix A, we study the implications of price setting power in the final (product) market.

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. Via-app platforms may have two possible ownership structures, organized, respectively, as capital-managed (CM) and worker-managed (WM).[1] The platform can be thought of as a digital infrastructure that allows organizing via-app the division of labour 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. 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.[2]

Organizing the workers and monitoring the quality of service provision through the platform cost m, which, due to algorithmic techniques, is constant across different numbers of workers employed in the firm and across ownership types. This is one of the main assumptions that differentiate our model of a self-managed labour platform from extant stylisations of worker cooperatives. The issue of whether cooperatives face higher costs for monitoring their workers with respect to capital-owned firms is controversial. While Alchian and Demsetz (1972) maintain that monitoring in cooperative organizations is less efficient because the benefits of monitoring are diluted among workers-members (similarly, Hueth and Marcoul (2015) assume that monitoring by producers is costly relative to monitoring by specialists), the literature on worker cooperatives show that workers-members may have incentives to monitor their peers in a more efficient way than in traditional firms (Putterman, 1984; Kandel and Lazear, 1992) and that this may be one of the efficiency advantages of WM firms (Bai and Xu, 2001; Bowles and Gintis, 2008). Differently from traditional industries, in the digital platform sector there are no physical or organizational reasons why monitoring costs should differ across ownership structures. Moreover, due to algorithmic monitoring and digital workload management, it is

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

[2] 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.

also reasonable to assume that monitoring costs are fixed (i.e. 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).

Assuming that a given via-app labour platform is suited for providing a given homogenous service through a given organization of work, the platform can be stylised as a combination of I, m and r, with $r > 0$ denoting the revenues per unit of service.[3] 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 labour 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.[4] Alternatively, the firm offers a new service for which there are $\bar{c}$ potential 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 workers' performance can be perfectly monitored through the via-app platform and that the workers have similar abilities. The possibility that heterogeneous workers sort endogenously among types of firm is thus excluded in this model. All agents are risk neutral.

Finally, we denote with n the number of workers and with $(1-\alpha)r$ the amount that, in a CM firm, employers pay to an employee for each unit of service provided (with $\alpha \in [0,1]$ being an overhead commission parameter and αr the total commission that the employee must pay to the platform owner; this reflects the practice of most companies operating in the platform economy).[5]

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 effort to 0, so as to measure with $(1-\alpha)r$ the

[3] Clearly, the model allows for different product quality across platforms. Assuming that product quality increases monotonically with the initial fixed investment and with monitoring costs, platforms that invest more 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 $\{I, m, r\}$ set, but cross-platform differentiations over these variables, including product quality, are compatible with the model.

[4] 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.

[5] In most of the existing CM labour 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). To reduce distractions in the text, we will refer to CM platform workers as employees. 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.*, 2019) and contract incompleteness issues (partly mitigated by online reputation mechanisms (Benson *et al.*, 2015)).

net payoff of employees in a CM firm, 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 (rc) are larger than the total costs of both the WM and CM firm (i.e., respectively, $I(1+i)+m$ and $I+m+n(1-\alpha)r$). For simplicity, we consider these variables as normalized at a one-period production level, so that the costs I and m denote the fraction of the total fixed costs (for, respectively, buying the platform and monitoring workers) relative to each period and c and n the number of customers and workers who are, respectively, served and employed in each period. Both CM and WM firms treat I, m, 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 via-app 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 labour platform, we assume to have only one owner.[6] His profits are:

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

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 $r_0 = 0$.

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

$$\pi_{WM} = \begin{cases} \frac{rc}{n} - \frac{I(1+i)+m}{n} & \text{if} \quad n \leq \bar{c}, \quad \text{with} \quad c = n \\ \frac{r\bar{c}}{n} - \frac{I(1+i)+m}{n} & \text{if} \quad n > \bar{c} \end{cases} \tag{2}$$

From Equation (1), it is straightforward to observe that $\pi_{CM} < 0$ when $rc < I+m+n(1-\alpha)r$ and $\pi_{CM} \geq 0$ when $rc \geq I+m+n(1-\alpha)r$. In particular, $\partial\pi_{CM}/\partial n > 0$ if $n < \bar{c}$, while

[6] 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.

$\partial\pi_{CM}/\partial n = 0$ if $n > \bar{c}$. From Equation (2), we observe that $\pi_{WM} < 0$ when $rc < I(1+i) + m$ and $\pi_{WM} \geq 0$ when $rc \geq I(1+i)+m$, and that, again, $\partial\pi_{WM}/\partial n > 0$ if $n < \bar{c}$, while $\partial\pi_{WM}/\partial n < 0$ if $n > \bar{c}$ (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, i.e. 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 paid a wage, which is a function of the unit revenues. 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 needs to choose α in such a way that $\pi_{CM} \geq 0$, i.e., from Equation (1),

$$\alpha \geq \frac{I+m}{rn} + 1 - \frac{c}{n} \equiv \alpha_{min} \tag{3}$$

With this very simplified framework, we can study the possible emergence of via-app WM labour platforms, under the assumption that the workers choose whether to work as employees in a CM structure or to organize themselves in a WM structure only depending on the relative monetary 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 employment outside options are always available to workers; i.e., 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.

2.2 Optimal size of WM and CM platforms

Before obtaining the optimal size of both WM and CM platforms, it is useful to present descriptively the main intuition why the size of the firm is crucial for viability, under both ownership structures. Let us do so, at this stage, by assuming that α is given (i.e., the CM firm does not maximize profits with respect to α), in order to make basic intuitions clearer. Under this special assumption, as n increases for both WM and CM platforms, workers' payoffs change as follows.

- If $n < \frac{I+m}{\alpha r}$, then $\pi_{WM} < 0$ and $\pi_{CM} < 0$, and both WM and CM labour platform structures are not profitable.

- If $\frac{I+m}{\alpha r} < n < \frac{I(1+i)+m}{r}$, then $\pi_{WM} < 0$ and $\pi_{CM} > 0$. Only the CM labour platform is viable.[7]

- If $\frac{I(1+i)+m}{r} < n < \frac{I(1+i)+m}{\alpha r}$, then $\pi_{WM} > 0$ and $\pi_{CM} > 0$. While both the CM and WM labour platforms are viable, the payoff $(1-\alpha)r$ that workers can get from being employees in a CM platform is higher than what they can get from organizing themselves through a WM platform, i.e. $0 < \pi_{WM} < (1-\alpha)r$. Thus, workers will prefer to offer their work as employees rather than as members of a WM organization.

- If $\frac{I(1+i)+m}{\alpha r} < n < \frac{1}{1-\alpha}(\bar{c} - \frac{I(1+i)+m}{r})$, then $\pi_{CM} > 0$ and $\pi_{WM} > (1-\alpha)r > 0$. For the workers, to run a WM platform, rather than being employees in a CM organization, is more convenient.

- Finally, if $n > \frac{1}{1-\alpha}(\bar{c} - \frac{I(1+i)+m}{r})$, $\pi_{CM} > 0$ and $0 < \pi_{WM} < (1-\alpha)r$. In this case, the workers are better off, again, as employees in a CM organization.

Summing up (see also Figure (1) for convenience), α being given, the key determinant of whether the preferred ownership structure for workers will be WM or CM is the firm's size relative to that of the market. In particular, WM firms would be preferred for a middle range of size. The intuition is that, if n is too low, fixed costs effects bite relatively more, thereby making WM dividends lower than a capitalist salary, whilst, if n is too large, fixed costs are diluted among many members, but also dividends will be reduced.

[insert Figure (1) about here]

With α being given, we can now define the survival size of a WM platform, denoted with s_{WM}.

Definition 1. *Define s_{WM} as $n : \pi_{WM} = (1-\alpha)r$, with $(1-\alpha)r > 0$, i.e. the size at which a WM platform becomes attractive for workers, by making non-negative profits and paying average earnings equal to a capitalist salary.*

For an income maximizing WM platform, the survival size is:

$$s_{WM} = \frac{I(1+i)+m}{\alpha r} \tag{4}$$

CM and WM platforms choose the optimal size by maximizing, respectively, Equation (1)

[7] $\frac{I+m}{\alpha r} < \frac{I(1+i)+m}{r}$ will hold when $\alpha > \frac{I+m}{I(1+i)+m}$. Hence, when $\alpha < \frac{I+m}{I(1+i)+m}$ we may have that $\frac{I(1+i)+m}{r} < n < \frac{I+m}{\alpha r}$: in this case, $\pi_{WM} > 0$ and $\pi_{CM} < 0$, i.e. only WM platforms are viable, but self-managed workers obtain a payoff that is lower than what they would get as employees in a CM firm, which however is not viable.

and Equation (2) with respect to n, i.e.:

$$n^*_{CM} \equiv \underset{n}{\text{argmax}}\ \pi_{CM} \quad \text{and} \quad n^*_{WM} \equiv \underset{n}{\text{argmax}}\ \pi_{WM} \tag{5}$$

From (5), 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:[8]

$$n^*_{WM} = n^*_{CM} = \bar{c} \tag{6}$$

For CM platforms, profits are maximized at any size $n \geq \bar{c}$ (as variable labour 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 (6) holds.

Equation (6) 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). This follows from the cost structure of platform firms, with variable operating costs being negligible (as modeled by Rey and Tirole (2007)),[9] and reflects the actual dynamics of many platform firms (e.g., *Uber* and *Amazon*), which behave as massive employers with monopsony power (Dube *et al.*, 2019). Equation (6) 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 (Dow, 2018, Chapter 2). To keep things simple, throughout the paper we will refer to a stylised WM firm in the platform economy as an income maximizing firm, even if its employment behaviour 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 (6) that the optimal size of a CM platform does not depend on the pay policy (α).

[8]This crucially depends on our assumption of an horizontal demand curve. In Appendix A, we consider a downward sloping demand curve and show that the optimal size of the platform, in this case, differs across CM and WM firms. Whilst being less realistic in the platform economy sector, a downward sloping demand curve is standard in textbook-style monopolistic competition contexts.

[9]Rey and Tirole (2007) model 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.

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.[10]

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. 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:

$$\underbrace{\left[\frac{r\bar{c}}{\bar{c}+\Delta c} - \frac{I(1+i)+m}{\bar{c}+\Delta c} - (1-\alpha)r\right]\Delta c}_{\text{Willingness to pay of outsiders}} \geq \underbrace{\left[\left(\frac{r\bar{c}}{\bar{c}} - \frac{I(1+i)+m}{\bar{c}}\right) - \left(\frac{r\bar{c}}{\bar{c}+\Delta c} - \frac{I(1+i)+m}{\bar{c}+\Delta c}\right)\right]\bar{c}}_{\text{Loss of insiders}} \tag{7}$$

Some algebra shows that Equation (7) holds if:

$$\alpha \geq 1, \tag{8}$$

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

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 employees, 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 (7) to hold.

[10] 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 of CM platforms and viability of WM platforms

It is now intuitive to observe that, given I, m, r and $\bar{c}$, and taking i as exogenous, for each possible size of the firm (i.e., n), the relative payoff of the workers across the two platform ownership structures depends on the overhead parameter α. As α increases, the size interval for which a WM organization is more convenient for the workers, i.e. $\left[\frac{I(1+i)+m}{\alpha r}, \frac{1}{1-\alpha}(\bar{c} - \frac{I(1+i)+m}{r})\right]$, becomes larger, on both the right- and the left-hand sides. As α decreases, this interval becomes smaller.

It follows that profit maximizing CM platforms will choose the optimal level α^* so as to maximize Equation (1) at $n^*_{CM} = \bar{c}$, i.e., 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 $\alpha \geq \alpha_{min}$ (because they need to make non-negative profits). We assume that, when $(1-\alpha)r = \pi_{WM}$, WM platforms are preferred by workers.

Definition 2. *Define*

$$\alpha_E \equiv \underset{\alpha}{\operatorname{argmin}} \, [(1-\alpha)r] \tag{9}$$

$$\text{s.t. } (1-\alpha)r \geq \pi_{WM}, \quad \text{at } n = n^*_{WM}, \tag{10}$$

i.e. 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 2, we obtain that the level of α under which the workers are always better off as employees in a CM platform is:

$$\alpha_E = \frac{I(1+i)+m}{\bar{c}r} \tag{11}$$

where $\frac{I(1+i)+m}{\bar{c}r} < 1$, due to the participation constraint (i.e., $I(1+i)+m < \bar{c}r$). When $\alpha < \alpha_E$, workers will join only CM firms.[11]

Clearly, 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. If this is the case, then only CM will emerge in the market. When $\alpha_E < \alpha_{min}$, CM platforms need to set

[11] 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 $[1-(\alpha'-b)]r = \frac{r\bar{c}}{n} - \frac{I(1+i)+m}{n}$, from which we obtain $\alpha' - b = \frac{I(1+i)+m}{\bar{c}r}$. Then, α_E can be defined as $\alpha_E \equiv \alpha' - b$.

$\alpha^* = \alpha_{min}$ level, in order to make non-negative profits. If it so, however, they will not be attractive to workers, who will all move into WM firms. Hence, in this case, WM platforms are viable.

At the optimal size n^*_{CM}, $c = \bar{c}$ and, consequently, $\alpha_{min} = \frac{I+m}{\bar{c}r}$. Thus we will have that $\alpha_E > \alpha_{min}$ when:

$$\frac{I(1+i)+m}{\bar{c}r} > \frac{I+m}{\bar{c}r} \tag{12}$$

which can be reduced to:

$$i > 0 \tag{13}$$

Equation (13) says that, in equilibrium, when the cost of the capital for WM firms (or, more generally, the extra-cost of the capital for WM firms *vis-à-vis* CM firms) is positive, only CM platforms will emerge in the market. WM firms are viable only when $i = 0$.

The intuition behind this very simple result is straightforward. In the platform sector, when the extra-cost i of the external capital for WM platforms is positive (the cost structure being otherwise identical between WM and CM firms), there is always a wedge, no matter how small, allowing CM firms to pay some premium to workers (whilst making non-negative profits), thereby impeding viability of WM firms. However, if the premium is too high, CM firms make negative profits, while, if the premium is zero, workers are better off in a WM firm (by assumption). Hence, for CM firms will be optimal to pay a premium which is positive and infinitely small.

When Equation (13) holds, α_E is an informative parameter, it being 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. Therefore, we will largely focus on α_E throughout our model extensions (presented next), by showing how it changes when the environment varies. To begin with, from Equation (11) it is easy to observe that the optimal commission fee of a profit maximizing CM platform needs to decrease both when the size of the market and the unit revenues increase. As a result, when r increases, the worker payoff in a profit-maximizing CM firm (i.e. $(1 - \alpha^*)r$) will increase more than proportionally.

To provide a better chance to read the actual behaviour of firms in platform-based markets through the lens of our model, in the rest of the paper we will also continue making s_{WM} levels explicit, as s_{WM} matters, in particular, out of the equilibrium. In the short-run, on the one side, WM firms may be unable to reach $n^*_{WM} = \bar{c}$ (due to exogenous labour supply constraints), while, on the other, CM firms may fail to set $\alpha = \alpha^*$ (due to some competitive pressure in the product market) and may take α as given; so, existing WM platforms may be observed having a lower size than n^*_{WM}, with s_{WM} being the lower size limit for viability.

3 Additional differences between CM and WM platforms

3.1 Employment level concerns

The hypothesis that WM firms maximize only net income per-unit of labour 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 and 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:

$$W_{WM} = \begin{cases} \beta \left[\frac{rc}{n} - \frac{I(1+i)+m}{n} \right] + (1-\beta)n & \text{if} \quad n \leq \bar{c}, \quad \text{with} \quad c = n \\ \beta \left[\frac{r\bar{c}}{n} - \frac{I(1+i)+m}{n} \right] + (1-\beta)n & \text{if} \quad n > \bar{c} \end{cases} \tag{14}$$

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 (14) reduces to Equation (2), i.e. $W_{WM} = \pi_{WM}$.

Maximizing Equation (14) with respect to n and recalling from Equation (6) that the income maximizing number of customers is $\bar{c}$, we obtain the following FOC:

$$\beta \frac{[I(1+i)+m] - r\bar{c}}{n^2} + (1-\beta) = 0 \tag{15}$$

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

$$n^{**}_{WM} = \sqrt{\frac{\beta}{1-\beta}[r\bar{c} - (I(1+i)+m)]} \tag{16}$$

Recall that $\frac{1}{1-\alpha}\left[\left(\bar{c} - \frac{I(1+i)+m}{r}\right)\right]$ is the size of a WM platform for which $\pi_{WM} = (1-\alpha)r$.

Thus, if the optimal size is such that

$$n_{WM}^{**} > \frac{1}{1-\alpha}\left[\bar{c} - \frac{I(1+i)+m}{r}\right] \tag{17}$$

then Equation (14) is maximized with $\pi_{WM} < (1-\alpha)r$. Manipulating Equation (17), we can obtain the threshold level of β, below which the workers maximize their welfare by running a (relatively large) WM platform even at the price of collecting per-capita earnings lower than the monetary payoff they would get as employees in a CM organization, i.e.:

$$\overline{\beta} = \frac{r\bar{c} - [I(1+i)+m]}{r\bar{c} - [I(1+i)+m] + (1-\alpha)^2 r^2} \tag{18}$$

The survival size of an employment-concerned WM platform is the one where the following condition holds:

$$\beta(1-\alpha)r + (1-\beta)n = \beta\left[\frac{rc}{n} - \frac{I(1+i)+m}{n}\right] + (1-\beta)n \tag{19}$$

Equation (19) simplifies to $n = s_{WM} = \frac{I(1+i)+m}{\alpha r}$ (i.e., the survival size of an employment-concerned WM platform is the same as for an income maximizing WM platform). Indeed, while the ownership of the platform influences the monetary payoff of the workers, a given employment level has the same value ($(1-\beta)n$) across WM and CM organizations. Thus, the size at which being members of a WM platform is more convenient than being employees in a CM firm depends only on the income per-worker.

When WM platforms show employment concerns, the optimal pay policy of CM platforms is required to change due to the need of CM firms to compensate for the fact that workers also place some value on employment levels. Recalling that the optimal size of CM firms is $n_{CM}^{*} = \bar{c}$ and that WM platforms concerned with employment choose an optimal size n_{WM}^{**} that is no lower than $\bar{c}$, the threshold level of α making WM platforms never convenient for workers will now be the one where the following condition holds:

$$\beta(1-\alpha_E)r + (1-\beta)\bar{c} = \beta\left[\frac{r\bar{c}}{n_{WM}^{**}} - \frac{I(1+i)+m}{n_{WM}^{**}}\right] + (1-\beta)n_{WM}^{**} \tag{20}$$

that is

$$\alpha_E = 1 - \frac{\bar{c}}{n_{WM}^{**}} + \frac{I(1+i)+m}{n_{WM}^{**} r} + \frac{(1-\beta)(\bar{c} - n_{WM}^{**})}{\beta r} \tag{21}$$

Equation (21) 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 (21) simplifies to $\alpha_E = \frac{I(1+i)+m}{\bar{c}r}$.

Moreover, from Equation (16), 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. That self-managed firms are more inclined to adjust pay than employment in response to market changes is consistent with previous empirical evidence (Craig and Pencavel, 1992). In particular, in our model, one-unit reduction of $\bar{c}$ induces a reduction of n^{**}_{WM} by $\frac{1}{2\sqrt{\bar{c}}}\sqrt{\frac{\beta}{1-\beta}r}$.

In the rest of the paper, we will generally keep focusing on s_{WM} and α_E, referring to an income maximizing stylised 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 Coalition costs

The main results of our framework do not change substantially if we remove an implicit assumption that we have made so far. We have considered self-managed workers and capital owners as having the same capability to develop an initial entrepreneurial idea. Hence, both workers-members and capitalist entrepreneurs would only need to bear the initial investment I (i.e., the cost of the platform) for starting the business. Related to this, the tacit assumption was that there are no other costs involved in rolling-out the activity.

This is actually very rare for cooperative organizations. In fact, while the assumption of zero roll-out costs may be reasonable for CM firms, where the capital owner only needs buying the platform and posting job vacancies to hire workers, the same is less true for WM organizations, where the workers need to assemble a team and to make initial collective decision-making (including that related to the interaction with programmers and creditors) before buying the platform. These coalition costs can be considered as increasing in the number of workers-members involved. Let us denote total coalition costs with $K(n)$ and define them as:

$$K(n) = kn \tag{22}$$

In the presence of positive coalition costs, standard economic intuition would predict that a free-riding problem affects the initial stage of organizing a WM firm. The benefits from forming a WM platform may be seen as a public good: the investment borne by an individual for building a via-app platform organization and for finding the workforce generates benefits that accrue to all the workers-members. Hence, none of the potential members will be willing to take over the initial stage of a platform development. In particular, a coalition failure will be more likely to arise when many workers have to coordinate simultaneously for the roll-out of a self-managed activity, as in the platform economy. This is a straightforward consequence of standard models of public goods production, which finds support both in the traditional cooperative economics literature (Staatz, 1983) and in the related experimental research (e.g., Andreoni *et al.*, 2003) and that does not need to be formally discussed.

This problem may be addressed by a WM platform by requiring founding members to pay an initial price p for membership as for a standard club good. If K is divided equally across members, the price for initial membership is $p = k$. As a result, per-capita earnings in an income maximizing WM organization will change with respect to our initial formulation (2) only slightly:

$$\pi_{WM} = \begin{cases} \frac{rc}{n} - \frac{I(1+i)+m}{n} - p & \text{if} \quad n \leq \bar{c}, \quad \text{with} \quad c = n \\ \frac{r\bar{c}}{n} - \frac{I(1+i)+m}{n} - p & \text{if} \quad n > \bar{c} \end{cases} \tag{23}$$

Given per-capita earnings as specified in (2), we can obtain that the survival size of a WM platform becomes:

$$s_{WM} = \frac{I(1+i)+m}{p - r\alpha} \tag{24}$$

which is obviously higher than that obtained without coalition costs, and that the threshold level of α making WM platforms never convenient is now:

$$\alpha_E = \frac{1}{r}\left(\frac{I(1+i)+m}{\bar{c}} + p\right) \tag{25}$$

In the presence of coalition costs, α_{min} does not change with respect to Equation (3), while α_E is as in Equation (25). Thus, it can be obtained that $\alpha_E > \alpha_{min}$ when:

$$i > -\frac{p\bar{c}}{I} \tag{26}$$

i.e., CM platforms are able to attract workers by means of a pay premium (whilst making non-negative profits) even if the extra-cost of capital for WM firms *vis-à-vis* CM firms is negative.

4 Network effects

4.1 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 translates 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

$$rc^{\delta}, \tag{27}$$

with $\delta > 1$ (and reasonably close to 1) being a user-side network effect parameter.[12] Unit revenues will be rc^{δ}/c. Hence, the payoff of a worker in a CM platform will be:

$$(1-\alpha)rc^{\delta-1} \tag{28}$$

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

$$\pi_{WM} = \begin{cases} \frac{rc^{\delta}}{n} - \frac{I(1+i)+m}{n} & \text{if} \quad n \leq \overline{c}, \quad \text{with} \quad c = n \\ \frac{r\overline{c}^{\delta}}{n} - \frac{I(1+i)+m}{n} & \text{if} \quad n > \overline{c} \end{cases} \tag{29}$$

It is straightforward to obtain that the survival size of a WM platform, in the presence of network effects, is:

$$s_{WM} = \sqrt[\delta]{\frac{I(1+i)+m}{\alpha r}} \tag{30}$$

while the threshold level of α making WM platforms never convenient is:

$$\alpha_E = \frac{I(1+i)+m}{\overline{c}^{\delta} r} \tag{31}$$

The optimal (income maximizing) size is again:

$$n^{***}_{WM} = \overline{c} \tag{32}$$

[12] Under the assumption that $n = c$, Equation (27) may also reflect cross-side network effects, where an increased number of workers pushes up the willingness to pay of customers (e.g. when fiercer competition between workers induces quality improvements). It is possible that the network externality is exhausted above some critical threshold level c_T. Here, we assume that $\overline{c} < c_T$.

In equilibrium, finally, (in this case, α_{min} being equal to $\frac{I+m}{\bar{c}^{\delta}r}$) the condition for WM firms viability still continues to be $i = 0$.

4.2 Worker-side network effects (endogenous effort)

Suppose that, at some cost, the worker can exert effort e that increases the general quality of the service or that improves the ability of the entire workforce to raise higher unit revenues (in doing so, we are implicitly relaxing our assumption of service homogeneity).[13] Assume that algorithmic monitoring reduces to zero the possibility of shirking. Let us normalize normal effort to zero and denote the cost of the additional (cooperative) effort with $\psi(e)$ (where $\psi'(e) > 0$ and $\psi''(e) > 0$). Assume also that unit revenues are a function of e, according to $r(e)$, with $r'(e) > 0$ and $r''(e) < 0$.[14] While normal effort is contractible, i.e. we have no shirking (due to algorithmic monitoring), the additional effort is not contractible and the worker may or may not exert effort above 0.

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

$$U = (1 - \alpha^*)r(e) - \psi(e) \tag{33}$$

and the corresponding FOC with respect to e is:

$$(1 - \alpha^*)r'(e) = \psi'(e) \tag{34}$$

Denote the optimal level of effort, for condition (34) to hold, in a CM platform with e^*_{CM}. The per-capita earnings of a worker in a WM platform, under the belief that the others workers exert zero effort, are:

$$\pi_{WM} = \frac{r(e)\bar{c}}{n} - \frac{I(1+i)+m}{n} - \psi(e) \tag{35}$$

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

$$r'(e) = \psi'(e) \tag{36}$$

Denote the optimal level of effort, for condition (36) to hold, in a WM platform with e^*_{WM}. It is straightforward to observe that, in equilibrium, $e^*_{WM} > e^*_{CM}$.

[13]As for the peer-to-peer transportation sector, an example is the possibility for a driver to share her position with the other drivers through a zone-based traffic assignment algorithm for congestion reduction, thereby allowing a better match between the travel demand of transport clients with the supply by vehicles.

[14]Precisely, r is a function of the effort exerted by any worker, i.e. $r(e_j, ..., e_h, ..., e_q)$ with q being the n-th worker. We omit subscripts in the text to simplfy notation.

This result may also hold in a more particular case where the additional 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 $e = \{0, 1\}$ and that the unit cost of $e = 1$ also equals 1. Clearly, in a CM firm, where the wage is determined as $(1-\alpha)r$, the worker has now no incentive to exert cooperative effort, since she is paid a fraction of individually raised revenues and the cost of $e = 1$ translates only into higher wages for the rest of the workforce (i.e. the utility of worker i in a CM firm is here $U_i = (1-\alpha^*)r_i - \psi(e_j)$, 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 $e = 1$ must be higher than that with $e = 0$, even if she is the only worker choosing the cooperative strategy. Formally, the payoff of a representative worker concerned with the possibility of exerting additional cooperative effort, under the belief that the other workers are not, is:

$$\pi_{WM} = \left[r - \frac{I(1+i)+m}{n}\right](1-e) + \left[\frac{r + (r+\Delta_r)(n-1)}{n} - \frac{I(1+i)+m}{n}\right] e \tag{37}$$

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

$$\frac{\Delta_r(n-1)}{n} > e \tag{38}$$

If condition (38) holds for the representative worker (and assuming that workers are identical), all the workers will opt for $e = 1$. Hence, the final per-capita income will be:

$$\pi_{WM} = \frac{n(r + \Delta_r(n-1))}{n} - \frac{I(1+i)+m}{n} \tag{39}$$

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

$$\pi_{WM} = rn^{\rho-1} - \frac{I(1+i)+m}{n} \tag{40}$$

with $\rho = \frac{\ln(n(r+\Delta_r(n-1)))}{\ln(n)+\ln(r)}$ (in the more general case we began with, where 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 lower s_{WM} and 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.

Interestingly enough, this result shows that workers' 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 (38) 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 effort levels. This may be true also when the 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 (38) holds (i.e. when the cost of performance improving effort 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 non-negligible.

5 Worker buyouts

In the baseline model, we assumed that WM firms can be created only from scratch. We next consider also the possibility of workers buyouts. Suppose that a CM platform is already established and that it is profit-maximizing. Under the assumption that a WM platform would maximize per-capita earnings, a buyout is welfare improving for the workers if the following conditions hold:

I. the prospective workers-members expect to get overall profits greater than the compensation asked by the capital owners for selling their platform, plus the cost of rising the external finance needed for the buyout, i.e.

$$rn_{WM} - m > [rn_{CM} - (I + m + n_{CM}(1 - \alpha^*)r)](1 + i) \tag{41}$$

II. the per-capita earnings of the self-managed workers are expected to be higher than the monetary payoff they would get as employees in a CM firm, i.e.

$$\frac{rn_{WM} - m}{n_{WM}} - \frac{[rn_{WM} - (I + m + n_{WM}(1 - \alpha^*)r)](1 + i)}{n_{WM}} > (1 - \alpha^*)r \tag{42}$$

In equilibrium (with $n_{WM} = n_{CM} = \bar{c}$), if both conditions (41) and (42) hold, they can be reduced to:[15]

$$i < \frac{I}{r\bar{c}\alpha^* - (I + m)} \tag{43}$$

Recalling that $\alpha^* = \alpha_E - \varepsilon$ and that, under the assumption that WM firms are income maximizing, $\alpha_E = \frac{I(1+i)+m}{\bar{c}r}$ (see Equation (11)), omitting ε for simplicity and substituting Equation (11) into Equation (43), we obtain that the condition for which a buyout is convenient for the workers is:

$$i < 1 \tag{44}$$

It is interesting observing that the threshold in Equation (44) is independent of the initial investment costs and of the size of the market. Moreover, Equation (44) is less strict than the condition for WM firms viability seen in our basic model setting (i.e., $i = 0$); thus, when cost of the external capital for workers is positive (but lower than 1), workers may be more likely to create WM platforms from buyouts rather than from scratch. It is worth emphasizing, however, that the external capital needed for covering the initial investment in the platform and that needed to buyout an existing (and profit maximizing) platform may have a different nature. At the initial stage of platform development, asymmetric information problems (and risk exposure of creditors) may bite relatively more, while risk exposure of creditors of a buyout is arguably

[15] We are not considering coalition costs here. One may argue that also the coalition costs for setting a buyout up are positive (Dow, 2018, Chapter 13). While this might be true, however, it is reasonable to normalize these costs to zero, as the workers of a CM platform already have relevant information on the platform's characteristics and on their potential partners, who are those involved as employees in the CM firm.

lower. This may further differentiate the sources of external finance (and credit constraints) across the two cases.

6 Comparative statics and anecdotal evidence

In this Section, we perform some comparative statics to highlight how the conditions that may make WM platforms viable change in response to variations of the model's parameters. Then, we compare the qualitative results from the comparative statics with some anecdotal evidence.

An intuitive way to investigate the comparative viability of WM platforms is the analysis of the pattern of α_E, i.e. the maximum level of the overhead parameter of a CM firm making WM platforms never convenient and s_{WM}, i.e. the minimum size at which WM platforms may become attractive for workers (α being given, i.e. out of equilibrium). Before deriving the qualitative comparative statics for a one-time permanent change of the model's parameters, we need to calibrate the model. 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 a via-app 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 to \$115,000. Thus, considering a one-year breakeven plan, we choose $I = \$15,000$ per quarter before breakeven. The same survey reports that maintenance after one year costs less than \$10,000 for 60% of the respondents. By including performance, ratings and reviews management under this item, we therefore set $m = \$2,500$ per quarter. We select $i = 1\%$, taking as a reference that the U.S. annual lending interest rates have been around 4% over the last five years (IMF, 2018) and considering a 25% increase of it, roughly, for loans of up to \$250,000 (ECB, 2017). Unit product prices may vary largely. We refer to an average ride of 10 kilometers with a standard transportation via-app company (such as *Uber*), which costs around \$20 in cities like Munich, New York and Sydney (Uber, 2018). As a price per-worker to cover initial coalition costs, we consider $p = \$20$. As network effects (for simplicity, here, we consider only user-side externalities), to set $\delta = 1.005$ (i.e., the willingness to pay increases by 0.5% for each additional user) seems a reasonable compromise between having some non-negligible difference across models with and without network effects and keeping network externalities realistically low. Finally, following standard practice of via-app platforms, in the analysis of s_{WM} we choose $\alpha = 0.2$ (which is broadly consistent with the average commission rate of *Uber*, *Lyft* and *Amazon Mechanical Turk*, among others), while, when studying α_E, we set $\bar{c} = 2,000$ as a number of customers per quarter that may be consistent with typical small-medium via-app activities.

We now analyze how different parameters influence the endogenous variables. In Figure (2), we show the qualitative comparative statics results, focusing on the survival size s_{WM} of WM platforms. In particular, the model versions with network effects, with coalition costs and without both of them are disentangled (the latter is our basic model version). As discussed in the previous Section, s_{WM} does not change depending on whether the WM platform is income-maximizing or also concerned with employment, all else being equal.

[insert Figure (2) about here]

The survival size is shown to increase with I, m and i, particularly for WM firms bearing some coalition costs. In the presence of coalition costs, s_{WM} increases also with r and, to a larger extent, with α, while, when coalition costs are absent, s_{WM} is strongly reduced by higher levels of r and α. With positive network effects, moreover, the survival size of WM platforms is lower than when network effects are zero.

How α_E thresholds change across different levels of our main variables is shown in Figure (3). Again, the model versions with network effects, with coalition costs and without both of them are disentangled.

[insert Figure (3) about here]

As one can notice, the maximum level of the overhead granting CM firms survival increases with I, m and i, i.e. CM firms are better able at providing improved workers' conditions when the initial investment, monitoring and organizational costs and the cost of the external capital for WM firms are high. It is worth specifying that the higher convenience of being employees at higher levels of m does not depend on a higher monitoring efficiency of CM platforms, but it is due to the fact that, in a WM firm, monitoring and organizational costs influence directly workers-members' incomes, while, in a CM firm, they rest on the employer. Interestingly enough, α_E decreases in the unit revenues (r), the equilibrium level of customers ($\overline{c}$) and the network effects parameter (δ). These results are intuitive and specific of the platform economy. When a CM firm does not pay fix wages but retains an overhead on the revenues raised by the employees, an increase in the revenues - being it due to higher unit prices and higher demand, or to network externalities - accrues to workers only partly. On the other side, in a WM platform, a unit increase in the revenues is entirely captured by the workers. Therefore, for CM firms to be attractive to workers, as the revenues increase, the overhead must decrease.

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, is compatible with standard theory (Brewer and Browing, 1982; Miyazaki and Neary, 1983). More in general, the overhead applied by capitalist owners being equal, WM platforms should be more convenient for workers in higher value added activities and larger markets and when network externalities are stronger.

In addition, we also observe that, in all the panels represented in Figure (3), α_E is lower in the presence of network effects with respect to when network externalities are absent, for any value of all the other variables.

Finally, we also obtain the kernel density distributions of α_E and s_{WM} generated from random values of our models' variables, after 1,000 iterations. Table (1) summarizes the range of the parameters used for the simulation exercise.

[insert Table (1) about here]

We plot the results in Figure (4). Although the two sets of distributions, so obtained, present a rather low kurtosis, they are also useful to give a sense of scale of a realistic range of α_E and s_{WM}. According to our simulations, both α_E and s_{WM} might touch quite extreme values, however the probability mass of α_E is concentrated mostly between 0.2 and 0.5 (with a modal value around 0.35 for our basic model specification, around 0.25 in the presence of network externalities and around 0.5 in the presence of coalition costs), while a typical survival size may be between 2,000 and 4,000 workers-members (with a modal value around 2,000 in the presence of network effects and around 3,500 when both coalition costs and network effects are absent).

[insert Figure (4) about here]

Our results, specific to the platform economy, differ from previous theoretical research on worker cooperatives 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 set employment at the level where the marginal product of labour equals the given wage, while worker cooperatives set employment at a lower level, where the marginal product of labour 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 that in WM ones. In our framework, both WM income maximizing and CM profit maximizing platforms choose to employ $n = \overline{c}$ workers, because at $n = \overline{c}$ they maximize per-capita earnings and profits, respectively. In particular, this theoretical result and our simulations taken togheter, it seems unlikely that a typical WM platform may employ less than 2,000 workers-members.

Second, the relationship between the optimal level of employment $n^*_{WM} = \overline{c}$ of an income maximizing WM platform and r is different from usual theory of worker cooperatives. In our model, an increase in r may be associated with an increase in $\overline{c}$ (if due, for instance, to a positive demand shock) and thereby in n^*_{WM}. We also find that n^*_{WM} is not affected by variations in I and m. Instead, standard theory would predict that employment is higher when fixed costs are greater and that, if labour 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)).[16] Related to this, we do find, however, that increases in unit revenues and fixed costs, respectively, reduce and increase the survival size s_{WM}, with the effect of r being strong in magnitude, according to our static simulations.

While the qualitative results from the comparative statics analysis follow straight from the model previously presented and hold under the assumptions made there, they seem to be also consistent with 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.

[insert Table (2) about here]

As shown in our static simulations, 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 those sectors where unit prices are higher and network effects are stronger.

As a representative example, consider *Uber*, which is the best known CM labour platform

[16] 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 and 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).

in the private peer-to-peer transportation sector. *Uber* passes the payment of each ride on to drivers after deducting an overhead commission generally ranging between 20% and 30% (Rosenblat and Stark, 2016). Given that, in the transportation sector, network externalities are relatively low and confined to the benefits of multiple rating (apart from this, the value of a ride for the final user does not increase significantly with the number of riders), an overhead parameter between 25% and 30% is presumably lower than the α_E threshold (ranging around 35%-40%, according to our static simulations) corresponding to the fixed and operating costs, market size and average unit prices specific to the sector. This is coherent with recent evidence documented by Hall and Krueger (2018) and Berger *et al.* (2018), showing that *Uber*'s drivers in the US are shown to receive higher earnings per hour than their driver counterparts working in traditional taxi companies.[17] 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 average more than \$6 per-hour, the net hourly earnings of *Uber*'s drivers exceed the hourly wage of taxi drivers, on average, and that *Uber*'s overhead commissions are set just below the critical threshold α_E that our model would predict.

In Table (3), we consider a small sample of well established WM platforms. These experiences may be taken as an example of real WM platforms out of equilibrium, with respect to our model. In this case, it is interesting to observe how the size of such cooperatives is very similar to or slightly higher than the minimum size granting viability that our model would predict, given the characteristics of the sector of activity. Related to this, it is also worth noting that the real size of actual WM platforms is 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 and Pencavel, 1992) and reduces below 100 workers for Uruguay (Burdín and Dean, 2009) and France (Pérotin, 2016). This peculiarity of real WM platforms is captured by the static simulations of S_{WM} based on our model and reported in Table (3).

[insert Table (3) about here]

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

7 Conclusions

Our simple model shows that, in equilibrium, the cost of accessing external capital is crucial for WM platforms viability. When capital costs are positive, CM firms may be able to pay a wage premium, thereby attracting workers and pushing WM firms out of the market. When WM firms do not show a cost disadvantage *vis-à-vis* CM firms, WM platforms may be viable; if it is so, WM firms may also adjust their size depending on workers' employment level concerns.

In general, workers benefit from a positive pay gap as employees in CM firms, which is lower when the initial cost of the platform and the cost of external capital are lower and in environments characterized by high unit revenues. The difference between the equilibrium worker payoffs under a CM and a WM ownership structure is reduced also when network effects are larger. This latter 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 benfits 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-via-app counterparts. To different extents, this result can be generalized to other sources of productivity improvements.

Whilst being intuitive, these findings are also suggestive, as they fit available anecdotal evidence showing that the most successful WM platforms are confined to activities related to on-line trade of ethical goods and artistic products, where demand bunching effects matter. Moreover, our result of the capital cost constraint being crucial to WM platforms development, from a policy perspective, 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).

While providing a contribution to both the stylization of via-app labour 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 via-app activities. A broad distinction may be traced among the various forms of commercial digital labour 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 (this is the case of *Uber*, for instance). When it is so, the total number of potential customers (i.e. the potential demand) at a geographical level is finite and may be entirely served by a single sufficiently large firm. This introduces the issues of market power and market structure, that influence the way prices and workers' earnings are determined. Moreover, we didn't consider many additional aspects, which may play some significant role in our framework, including crowdfunding (as a way to raise finance at a relatively low costs for financially constrained workers), effort and productivity levels (which may differ across diverse ownership structures, also depending on an endogenous sorting of workers; see Burdín (2016)), cross-side network effects, and the fact that workers in a WM firm may maximize a more complex welfare function where democratic participation is inherently valued, in addition to per-capita earnings and employment level, and where also income stability and job stability are included (Burdín, 2014; Arando *et al.*, 2015).

Appendix

A Optimal size with downward sloping demand curve

In the paper, we have assumed an horizontal demand curve in the product market, 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. One of the consequence of this, in our benchmark model version, is that both CM and WM firms expand their business up to the level where all the available demand is met, at $\bar{c}$. As a straightforward result, the income maximizing size of the organization is the same in a CM and in a WM platform, i.e. $n^*_{WM} = n^*_{CM} = \bar{c}$. Here, we consider a downward sloping demand curve and show that the optimal size of the platform, in this case, differs across CM and WM firms. Whilst being less realistic in the platform economy sector, a downward sloping demand curve is standard in textbook-style monopolistic competition contexts.

Suppose that the firm faces the following inverse demand curve:

$$r = \bar{r} - bc \tag{45}$$

with b being the shape parameter and $\bar{r}$ a constant term.

For a CM platform, profits will be:

$$\pi_{CM} = \bar{r}c - bc^2 - \mathcal{K}_{CM} - (1-\alpha)(\bar{r} - bc)n \tag{46}$$

with $\mathcal{K}_{CM} = I + m$. By maximizing Equation (46) with respect to n, under the assumption that $c = n$, we obtain the following FOC:

$$\frac{\partial \pi_{CM}}{\partial n} = \alpha\bar{r} - 2\alpha bn = 0 \tag{47}$$

Hence, the optimal size of a CM platform is

$$n^*_{CM} = \frac{\bar{r}}{2b} \tag{48}$$

Moreover, substituting Equation (48) into Equation (45), we also obtain that the optimal price is

$$r^*_{CM} = \frac{\bar{r}}{2} \tag{49}$$

As for a WM firm, per-capita earnings will be

$$\pi_{WM} = \frac{\overline{r}c - bc^2 - \mathcal{K}_{WM}}{n} \tag{50}$$

with $\mathcal{K}_{WM} = I(1+i)+m$. By maximizing Equation (50) with respect to n (again, with $n = c$), we obtain the following FOC:

$$\frac{\partial \pi_{WM}}{\partial n} = \frac{\mathcal{K}_{WM}}{n^2} - b = 0 \tag{51}$$

The optimal size of a WM platform is

$$n^*_{WM} = \sqrt{\frac{\mathcal{K}_{WM}}{b}} \tag{52}$$

Substituting Equation (52) into Equation (45), we obtain that the optimal price for a WM platform is

$$r^*_{WM} = \overline{r} - \sqrt{\frac{\mathcal{K}_{WM}}{b}} \tag{53}$$

It is worth noting that, with respect to our basic model version, also s_{WM} and α_E change when the demand curve is downward sloping. In particular, the survival size of a WM platform being the level of n where $r^*_{CM}(1-\alpha) = r^*_{WM} - \frac{\mathcal{K}_{WM}}{n_{WM}}$, and using Equations (49) and (53), after some algebra we obtain that

$$s_{WM} = \frac{\mathcal{K}_{WM}}{\left[\frac{\overline{r}}{2}(\alpha - 1) + \overline{r} - \sqrt{\frac{\mathcal{K}_{WM}}{b}}\right]} \tag{54}$$

and

$$\alpha_E = \frac{2}{\overline{r}}\left(\sqrt{\frac{\mathcal{K}_{WM}}{b}} + \frac{\mathcal{K}_{WM}}{n}\right) - 1 \tag{55}$$

In equilibrium, with downward sloping demand curve, $\alpha_{min} = \frac{\mathcal{K}_{CM}}{\overline{c}(\overline{r} - b\overline{c})}$, hence $\alpha_E > \alpha_{min}$ when:

$$\frac{2}{\overline{r}}\left(\sqrt{\frac{\mathcal{K}_{WM}}{b}} + \frac{\mathcal{K}_{WM}}{n}\right) - 1 > \frac{\mathcal{K}_{CM}}{\overline{c}(\overline{r} - b\overline{c})} \tag{56}$$

It can be showed that Equation (56) holds when:

$$i > -\frac{4(I\bar{c}^2 + 2I^2b + 2Imb) + \sqrt{16(I\bar{c}^2 + 2I^2b + 2Imb)^2 - 16I^2b\left[4b\mathcal{K}_{CM}^2 + 4\bar{c}^2\mathcal{K}_{CM} - \bar{r}^2b\bar{c}^2 - \frac{\mathcal{K}_{CM}^2\bar{r}^2b}{(\bar{r}-b\bar{c})^2}\right]}}{8I^2b} \tag{57}$$

From Equation (57), it is straightforward to observe that WM platforms will be viable only when the extra-cost of the external capital for WM firms *vis-à-vis* CM firms is negative (i.e., in the unlikely situation in which WM platforms have some sort of cost advantage in accessing external capital).

Compliance with Ethical Standards: The authors declare that they have no conflict of interest.

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Table 1: Selection of parameters for simulation analysis.

Parameter	Generating process
Initial sunk investment for platform provision per quarter before breakeven, in \$ (I)	Random [500, 50000]
Workers organization and monitoring costs per quarter, in \$ (m)	Random [50, 5000]
Interest rate per quarter (i)	Random [0.005, 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]
Network externalities parameter (δ)	Random [1.00001, 1.1]
Fee for overcoming free-riding costs at the coalition stage, in \$ (p)	Random [1, 30]

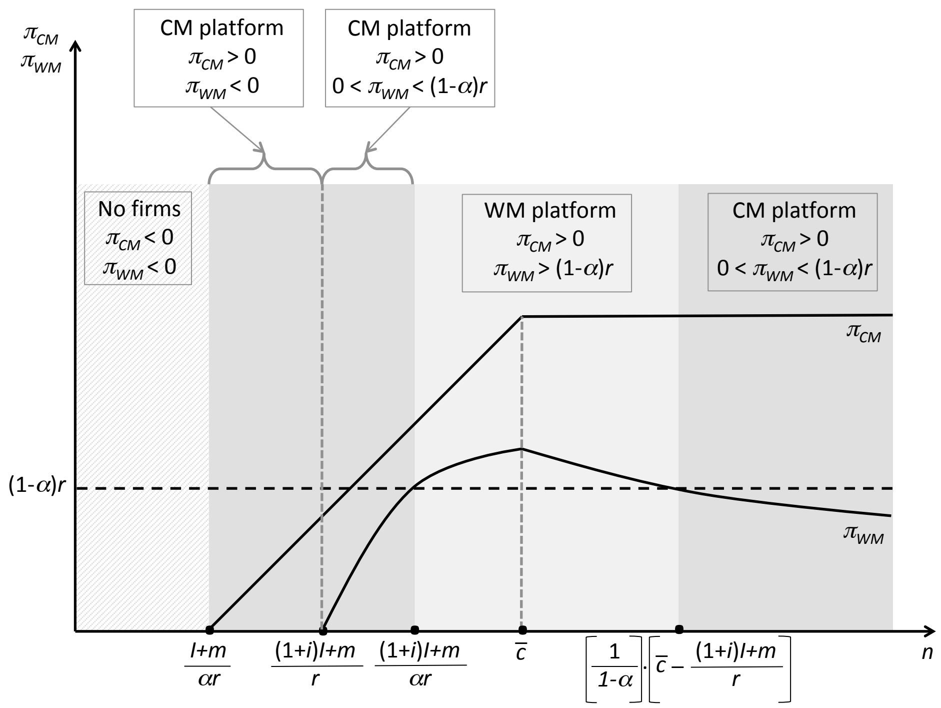
Table 2: Anecdotal evidence: pay policy of best known CM platforms.

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 and 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.	$\sim 0.25/0.3$	$\sim 0.3/0.4$
Lyft	Peer-to-peer transportation	**Low.** Similar to *Uber*, or slightly higher (Leskin, 2019).	**Low.** Same as *Uber*.	$\sim 0.25/0.3$	$\sim 0.3/0.4$
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	~ 0.3
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	~ 0.2
Handy	Home care and handyman	**Medium.** Similar to *TaskRabbit* (Lamberti, 2019).	**Medium.** Same as *TaskRabbit*.	$\sim 0.1/0.15$	~ 0.2
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 preceived quality of the products. Cross-side network effects may be significant.	$\sim 0.03/0.04$	~ 0.05

Table 3: Anecdotal evidence: size of WM platforms out of equilibrium.

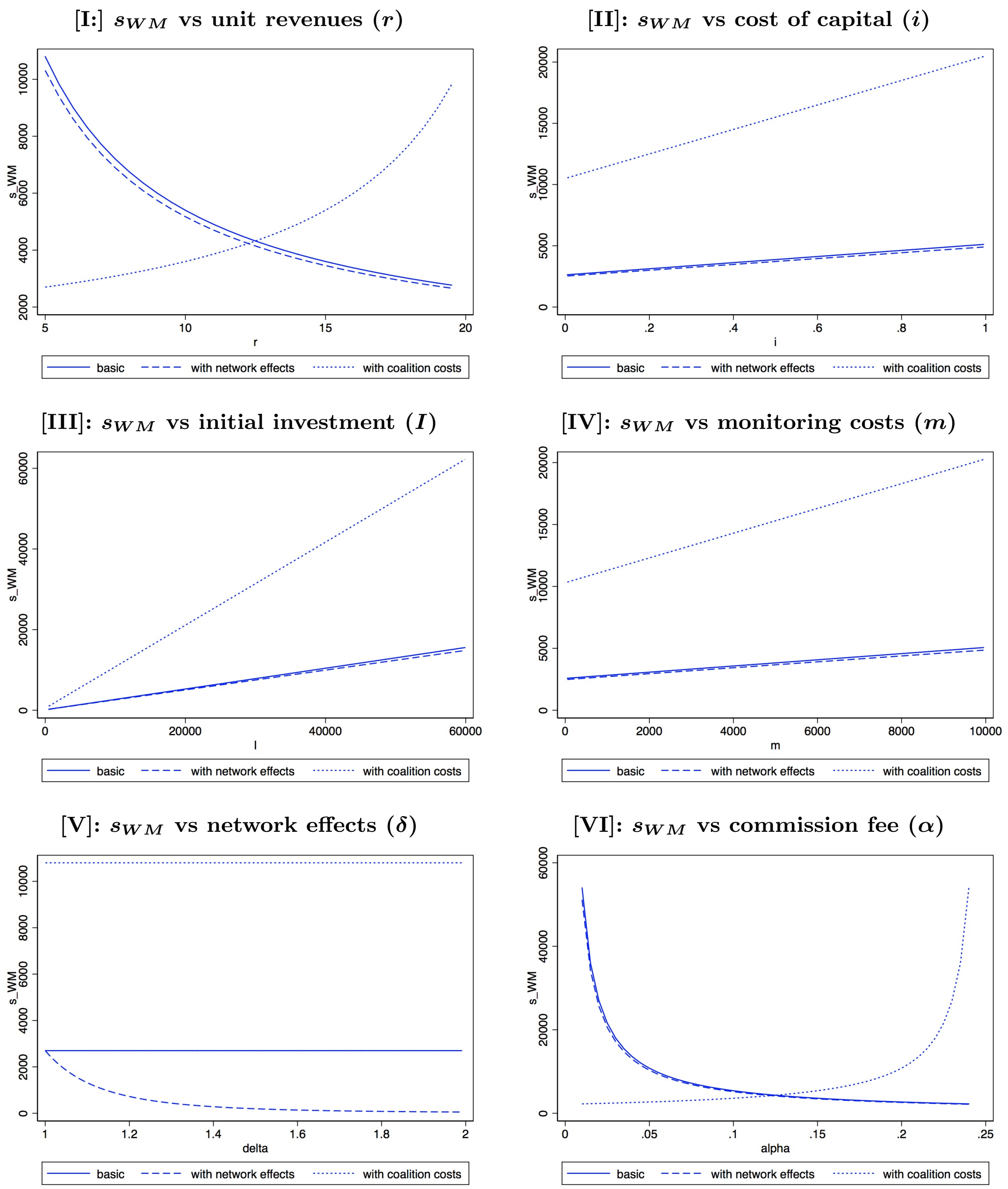
COMPANY	SECTOR OF ACTIVITY	UNIT REVENUES	NETWORK EFFECTS	n (ACTUAL VALUE)	S_{WM} (MODEL SIMULATION)
Loconomics	Home care and handyman	**Medium.** Average pay is around \$25-\$35 per-hour.	**Medium.** Rating mechanisms and feedback-based reputation of workers is important. Higher numbers of requesters of house-cleaning and related services also induce higher competition and improved service quality. Cross-side network effects may be significant.	~ 2000	~ 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	~ 1500
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	~ 1000

Figure 1: Per-capita earnings and the emergence of CM and WM via-app labour platforms.



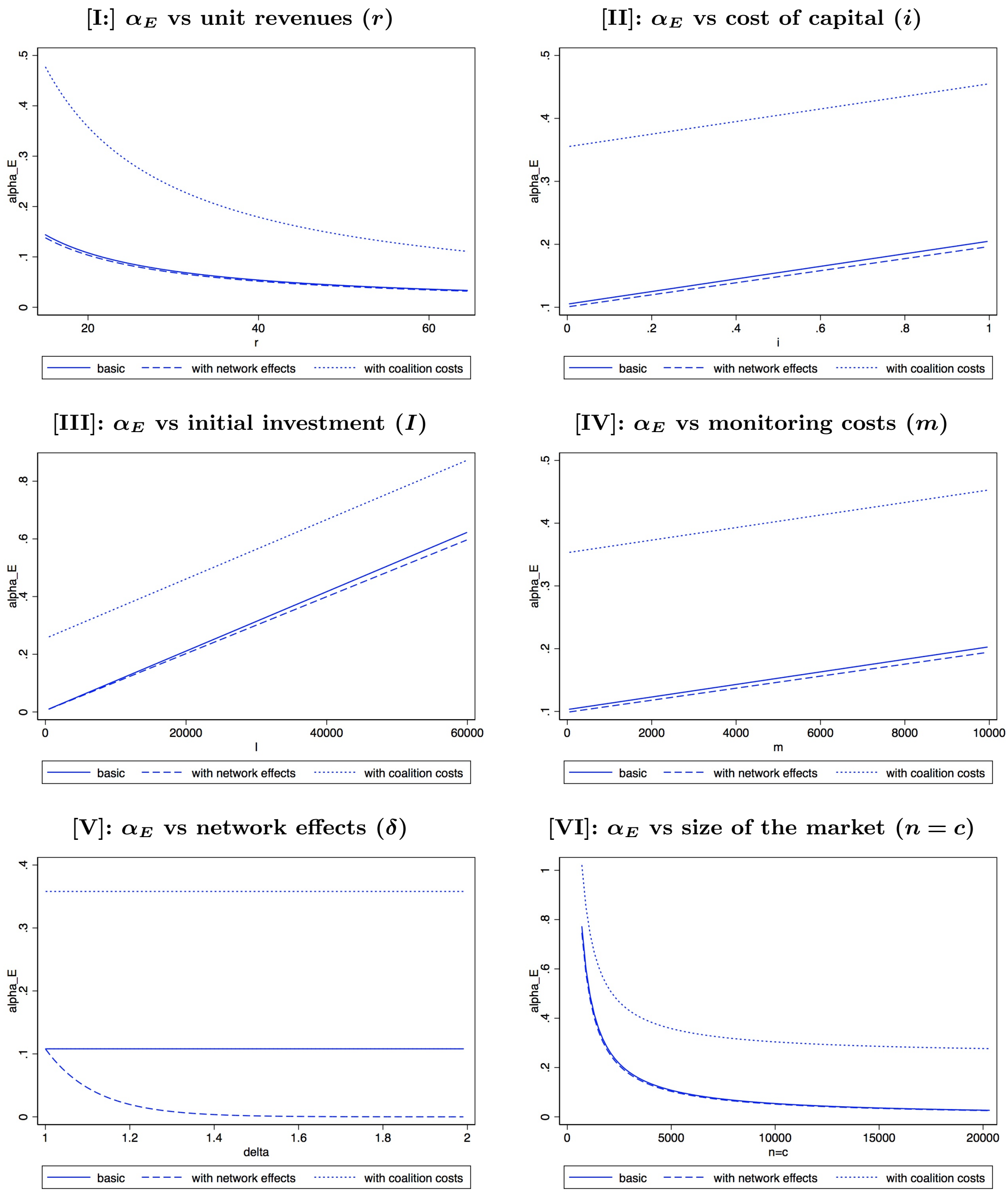
Note: I = initial sunk investment for platform provision; i = interest rate; m = workers organization and monitoring costs; $\overline{c}$ = equilibrium number of customers; r = revenues per unit of service; n = number of workers employed; α = overhead parameter to be paid to capitalist employers.

Figure 2: Minimum size at which WM platforms become attractive for workers, in disequilibrium.



Note: each panel shows s_{WM} patterns across different levels of the models' variables, considered separately. s_{WM} patterns obtained by means of different model's versions are disentangled: "basic" (without network effects and coalition costs), "with network effects" (and without coalition costs), "with coalition costs" (and without network effects). Recall that s_{WM} does not change depending on whether the WM platform is income-maximizing or also concerned with employment, all else being equal. Symbols: I = initial sunk investment for platform provision (in \$); i = interest rate; m = workers organization and monitoring costs (in \$); α = overhead parameter; r = revenues per unit of service (in \$); δ = network externalities parameter; n = number of workers-members. Baseline parameters are set as follows: $r = 20$, $i = 0.01$, $\alpha = 0.2$, $d = 1.005$, $I = 15000$, $m = 2500$, $p = 20$.

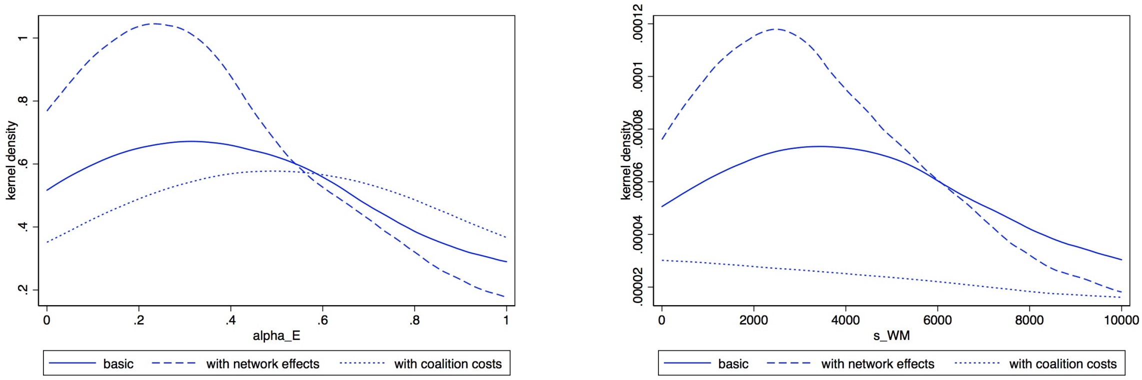
Figure 3: Maximum levels of α making WM platforms never convenient, in equilibrium.



Note: each panel shows α_E patterns across different levels of the models' variables, considered separately. α_E patterns obtained by means of different model's versions are disentangled: "basic" (without network effects and coalition costs), "with network effects" (and without coalition costs), "with coalition costs" (and without network effects). Symbols: I = initial sunk investment for platform provision (in \$); i = interest rate; m = workers organization and monitoring costs (in \$); $\bar{c}$ = equilibrium number of customers; r = revenues per unit of service (in \$); δ = network externalities parameter. Baseline parameters are set as follows: $r = 20$, $i = 0.01$, $n = \bar{c} = 2000$, $d = 1.005$, $I = 15000$, $m = 2500$, $p = 20$.

Figure 4: Simulated levels of α_E and s_{WM} from random values of the model's variables (1000 iterations).

[I]: Kernel density of α_E (simulated values) **[II]: Kernel density of s_{WM} (simulated values)**



Note: kernel density distributions of α_E and s_{WM} generated from random values (1000 iterations) of the models' variables, with $r \in [5, 50]$, $i \in [0.005, 0.5]$, $d \in [1.00001, 1.1]$, $\bar{c} \in [50, 5000]$, $I \in [500, 50000]$, $m \in [50, 5000]$, $p \in [1, 30]$, $\alpha \in [0.05, 0.5]$. Different model's versions are disentangled: "basic" (without network effects and coalition costs), "with network effects" (and without coalition costs), "with coalition costs" (and without network effects). Recall that s_{WM} does not change depending on whether the WM platform is income-maximizing or also concerned with employment, all else being equal.