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# Platform Precommitment via Decentralization

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**Platform Precommitment via Decentralization**
**Prepared by Marco Reuter***

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**ABSTRACT:** I study an entrepreneur's incentives to build a decentralized platform using a blockchain. The entrepreneur can either build the platform using a regular company and retain control of the platform, or build the platform using a blockchain and surrender control of the platform. In either case, the platform's users experience a locked-in effect. I show that a decentralized implementation of the platform is both (i) more profitable for the entrepreneur and (ii) a Pareto improvement, if and only if the size of the locked-in effect exceeds some threshold. Further, progressive decentralization through airdrops can be optimal.


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|---|---|
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WORKING PAPERS

# Platform Precommitment via Decentralization

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# I Introduction

More and more entrepreneurs are building decentralized platforms using blockchains. Over the last years, venture capital investments into Web3 startups have totaled over $87 billion and an average of 20,000 to 30,000 developers have been building in the space.[1] What is driving entrepreneurs to build decentralized platforms? In this paper, I argue that platform startups face the problem of being unable to credibly commit to not change the terms of the platform in the future to the detriment of the platform's users, which causes a hold-up problem. For example, many platforms such as Google, Facebook or YouTube started with no advertisement and have steadily increased advertisement over time. Additionally, many large platforms have been the target of antitrust investigations and under scrutiny for their (mis)use of user data. If users are forward-looking, the anticipation of worsening conditions causes a reluctance to join the platform for a fear of future exploitation. In this paper, I show that decentralization can effectively remedy the hold-up problem and be beneficial, for both the entrepreneur and the platform's users. That said, hold-up problems have been extensively studied in economics, and decentralization using a blockchain is not the only approach to solve them. For example, hold-up problems can be remedied through the use of contracts, however contracts can suffer from incompleteness (Hart and Moore (1988), Hart and Moore (1999)). Further, decentralization can take place without a blockchain. For example, a platform could be organized as a cooperative, ensuring cooperation towards a mutual goal. However, members of a cooperative typically share a common locality and legal system. For internet based platforms with user bases that span the globe, blockchain based decentralization may be a technologically suitable option.[2] That said, most of the points in the paper can be understood while considering decentralization per se, and blockchain as a technological device that enables decentralization.[3]

In this paper, I develop a theoretical model that determines when an entrepreneur prefers to implement a platform in a centralized manner and when it is optimal to decentralize through the use of a blockchain. With that, I contribute to the literature considering blockchain and token based platforms (i.e. Sockin and Xiong (2023), Goldstein, Gupta and Sverchkov (2019), Chod and Lyandres (2023), Cong, Li and Wang (2022)), by examining the optimal choice between centralization and decentralization in a dynamic model that incorporates network effects, growth and locked-in effects. Locked-in effects are the core friction at play. I assume that users of the platform are subject to a locked-in

[1] Crunchbase Web 3 Tracker and a16z State of Crypto Index

[2] Examples of platforms that have decentralized their governance through blockchains include Uniswap, MakerDAO and many others.

[3] The verifiability, trust and immutability that blockchains provide may be critical technological aspects to allow large amounts of users to effectively cooperate with each other.

effect, for example due to switching costs.[4] If the frictions that arise due to the potential of exploiting this locked-in effect by the entrepreneur are sufficiently large, I show that an entrepreneur prefers decentralizing her platform. As a result, she effectively gives up control of the platform and thus generates commitment to not abuse the locked-in effect of the users.

Achieving such commitment can lead to a Pareto improvement compared to a centralized implementation of a platform through a regular company. That is, both the entrepreneur who creates the platform, and the users may be better off if the platform is decentralized. However, decentralization also comes at a cost for the entrepreneur: she surrenders the control of the platform to the users and, to align incentives, engages in revenue sharing. Therefore, there is a trade-off between the costs of centralization and decentralization. I show that if the locked-in effect is small, an entrepreneur should implement her platform in a centralized manner. On the other hand, if the locked-in effect is sufficiently large, an entrepreneur should implement her platform in a decentralized manner.

In the model, an entrepreneur (she) creates a platform for her (potential) users (he). The users need the platform to interact or achieve a goal. However, they lack the ability to develop a technological solution that suits their needs. The entrepreneur, on the other hand, possesses the necessary skills to build a platform that fits the users' needs. At the start of the game, the entrepreneur decides between a centralized implementation of the platform through a regular company and a decentralized implementation using a blockchain.[5] In both implementations, the platform can be monetized (for example through advertisement, sale of user data, or other means), and any revenues that are raised can be shared between the entrepreneur and the users. The entrepreneur and the users interact with each other through the platform over an infinite time horizon. If the entrepreneur chooses centralized governance, she can change monetization and revenue sharing in every period. If the entrepreneur chooses decentralized governance, revenue sharing is decided by the entrepreneur through the tokenomics at the start of the game.[6] Then, the users decide on monetization in every period through decentralized governance.[7] Regardless of governance, each period, the existing users of the platform can

[4]For example, Shapiro and Varian (1998) remark that "switching costs are the norm, not the exception, in the information economy". For empirical measurements of switching costs, see for example Chen and Hitt (2002), Li and Agarwal (2017)

[5]In an extension in section III.A, I allow the entrepreneur to delay decentralization. That is, she can decentralize at a later time using an *airdrop*.

[6]Tokenomics is a mix of the two words token and economics. *Token* refers to a digital asset. Tokenomics describes the underlying economics of the particular token, such as supply, distribution, vesting and other parameters. In practice, tokenomics are seen as a critical part of the successful design of a decentralized platform.

[7]In practice, there are many mechanisms for on-chain governance. In the model, I use majority

stay in the platform or leave the platform. Further, new users arrive every period and can choose to join or not join the platform.

There is complete information and the full history of the game is observed by both the entrepreneur and the users. The entrepreneur is purely interested in generating revenue through monetization, while the users' utility consists of three parts: First, they derive utility from using the platform. Second, they dislike monetization such as advertisements, and third, they benefit from any revenue that is shared with them. I use sub-game perfect equilibria to analyze the game. Therefore, an entrepreneur using a centralized implementation of the platform is unable to credibly commit to future levels of monetization and revenue sharing. Instead, her choice of monetization and revenue sharing has to be sequentially optimal for every history of the game given the strategy of the users.

I divide the analysis of the model into three subsections. First, the sub-game of centralized governance. Second, the sub-game of decentralized governance and third, determining the optimal governance structure for the platform.

In the analysis of centralized governance, I show that the equilibrium of the game features two distinct phases. First, a growth phase in which the entrepreneur provides incentives for new users to join the platform. Second, an exploitation phase in which the entrepreneur exploits the locked-in effect of the existing users through increased monetization and decreased revenue sharing, and no new users join the platform. The threshold for the transition between the two phases crucially depends on the network effects and the platform's future growth. It is characterized by the point at which the entrepreneur is indifferent between attracting new users, and foregoing growth to exploit the locked-in effect of the existing users. In equilibrium, the users anticipate being locked-in to the platform and have to be compensated up front to be incentivized to join the platform.[8] The compensation equals the discounted value of the switching costs that lead to the locked-in effect. Thus, as the severity of the locked-in effect increases, it becomes increasingly harder for the entrepreneur to attract users in the first place. I show that for a sufficiently large locked-in effect, no users join the platform in equilibrium, resulting in zero revenues for the entrepreneur. This highlights the commitment problem, that an entrepreneur may try to solve with decentralization through a blockchain.

If the entrepreneur chooses decentralized governance, the degree of monetization is decided by the users. Unlike the entrepreneur, the users internalize the negative effects of

voting, where 1 unit of the token equals 1 vote, and an even split of tokens among the users.

[8] This property of the equilibrium is nicely summarized in Shapiro and Varian (1998)'s advice to buyers that anticipate becoming locked-in: "Bargain hard at the outset of the lock-in cycle for a sweetener or some form of long-term protection before you become locked in"

monetization on their utility. As a result, a platform in which monetization is controlled by its users, does not exploit the locked-in effect. To align incentives, the entrepreneur engages in revenue sharing with the users. If she decided not to share any revenues, the users would vote for zero monetization of the platform. Further, the platform grows every period, unlike in centralized governance. However, decentralized governance has two drawbacks. First, the entrepreneur surrenders control of the platform, such that she cannot choose her preferred degree of monetization. Second, because users choose the degree of monetization, the entrepreneur has to engage in revenue sharing to align incentives.

Finally, I determine the optimal governance of the platform by comparing centralized governance to decentralized governance. I show that for minimal locked-in effects, an entrepreneur is better off choosing centralized governance, as her commitment problem is negligible. In contrast, for a sufficiently large locked-in effect, decentralized governance is preferred, as the entrepreneur is unable to attract any users when choosing centralized governance. To determine the optimal mode of governance for an arbitrarily sized locked-in effect, I show that, perhaps surprisingly, the revenue that the entrepreneur can achieve with centralized governance is a *decreasing* function of the size of the locked-in effect. There are two effects that drive this result. First, in equilibrium, it is more expensive to compensate users ex-ante compared to what can be expropriated from them through future exploitation. Second, larger locked-in effects lead to smaller platforms in equilibrium, which are less profitable. In contrast, the revenue that the entrepreneur can raise with decentralized governance is independent of the size of the locked-in effect. When the users are in charge of monetization, they do not exploit the own locked-in effect. Thus, there exists a threshold size, such that the entrepreneur prefers to decentralize her platform if and only if the locked-in effect is sufficiently severe.

*Literature:* This paper contributes to the literature on the economics of blockchains. It most closely relates to papers that have discussed blockchains with a focus on commitment and competition. Similar to Sockin and Xiong (2023), I consider an entrepreneur who can exploit the platform's users and show that creating commitment through a blockchain may be beneficial for the entrepreneur. My paper contributes relative to theirs as follows: First, they consider a one shot interaction between the entrepreneur and the users on the platform. As such, in centralized governance, exploitation occurs for sure since there is no ongoing relationship between the entrepreneur and the users. I contribute by considering a repeated interaction between the entrepreneur and the users, and show that the problem of exploitation persists even in repeated interactions. Further, I consider the potential for user growth in the platform, and show that user growth can be a substitute for commitment when future growth is strong, but fails to generate commitment when future growth is sufficiently low. Finally, the longer time horizon allows me to consider locked-in effects and show that the entrepreneur decentralizes her platform if and only if the locked-in effect is sufficiently large.

Goldstein, Gupta and Sverchkov (2019) argue that using an initial coin offering (ICO) and committing to the free resale of tokens can enable a monopolistic entrepreneur to commit to competitive pricing. However, Goldstein, Gupta and Sverchkov (2019) show that committing to the free resale of tokens yields lower profits for an entrepreneur compared to operating the platform in a traditional, centralized manner. In contrast, I show that an entrepreneur can increase her revenue by implementing her platform through a blockchain, if the costs of centralization are too large. Further, I contribute by focussing on the importance of locked-in effects, and by adding platform growth and showing that growth can be a substitute for commitment at first, but fails to be a substitute for commitment when growth slows down over time.

Chod and Lyandres (2023) consider duopolistic competition among platforms that can issue tokens, and show that tokens can be useful in platform competition. Huberman, Leshno and Moallemi (2021) focus on bitcoin as a payment system (BPS), and show that user surplus in the BPS is larger compared to a centralized monopolist payment provider. However, the incentives for a monopolist to set up a decentralized platform such as bitcoin remain unclear. Brzustowski, Georgiadis-Harris and Szentes (2023) show that the Coase conjecture fails if a seller can generate commitment through smart contracts.

Catalini and Gans (2018) focus on entrepreneurs that are capital constrained and need to raise capital through an ICO to fund their platform. Cong, Li and Wang (2022) consider dynamic platform financing through tokens. Bakos and Halaburda (2018), Li and Mann (2018) and Cong, Li and Wang (2021), show how ICOs can mitigate coordination failures in the users' decision to join or not join a particular platform. In empirical assessments of ICOs, Howell, Niessner and Yermack (2020) find that success in ICOs is associated with disclosure, credible commitment to the platform, and quality signals, while Adhami, Giudici and Martinazzi (2018) find that, among other things, revenue sharing makes ICOs more successful.

Arruñada and Garicano (2018) and Chen, Pereira and Patel (2021) investigate the details of decentralized governance more closely. Further, this paper also relates to the literature of blockchain consensus, as it shares some intersections with blockchain governance. Contributions include Abadi and Brunnermeier (2018), Biais et al. (2019), Catalini, Jagadeesan and Kominers (2020) and Saleh (2021). Decentralization through a blockchain gives users decision power in the platform. Thus, my paper also shares some commonalities with the literature on common ownership in traditional corporations, for example Magill, Quinzii and Rochet (2015), Cres and Tvede (2023) and Azar and Vives

(2021), but with a drastically different focus.

Another strand of the literature that connects to my model is the IO literature on (two-sided) platforms and network effects, with seminal contributions by Katz and Shapiro (1985), Farrell and Saloner (1986), Rochet and Tirole (2003) and Armstrong (2006). Cabral (2011) develops a dynamic model of platform competition.[9] This literature focuses on equilibrium pricing and competition between platforms. As such, my paper is complementary, as my model features neither competition between platforms nor focuses on prices for either side of the market. I focus on the value of commitment for the entrepreneur as a function of the size of the locked-in effect of the platform. I also connect to papers that - from a regulatory perspective - investigate platform governance, for example Jullien and Pavan (2019), Choi and Jeon (2022) and Teh (2022). For a general overview of the literature, see for example Farrell and Klemperer (2007) and Belleflamme and Peitz (2021).

The rest of the paper is structured as follows: Section II consists of the model and the results that determine when decentralization is preferable to centralization. Section III discusses extensions of the model. Section IV provides further discussion and concludes.

# II Model

The model is a sequential game with infinitely many periods $t = 0, 1, 2, ...$ between an entrepreneur (she) and a continuum of users (he), indexed by $i$. The entrepreneur creates a platform for the users in $t = 0$ and the mass of users in the platform at time $t$ is denoted by $\mu_t$. In $t = 1, 2, 3, ...$ the platform can be monetized (for example through advertisement, sale of user data, or other means). The revenue from monetization can be decomposed into two parts. First, there is a level of monetization of the platform $\pi_t \in \mathbb{R}_+$. This variable represents the intensity with which the platform is monetized, such as how often or how many advertisements are displayed, or how much of the user data is sold. Second, given a measure of users $\mu_t$ and a level of monetization $\pi_t$, the revenue generated by the platform equals $\pi_t \phi(\mu_t)$ where $\phi$ is an increasing, continuously differentiable function with $\phi(0) = 0$. $\phi(\mu_t)$ represents the rate an advertiser is willing to pay for advertisements or for user data. Throughout the paper, I assume that $\frac{\phi(\mu_t)}{\mu_t}$ is non-decreasing in $\mu_t$.[10] Any revenues that are raised can be shared between the entrepreneur and the users. The fraction of revenue that the entrepreneur keeps is denoted

[9] Peitz, Rady and Trepper (2017) study price setting dynamics on platforms experimentally.

[10] For example, this holds true in cost-per-view and cost-per-click advertisement that is commonly used in online advertisement. If $c$ is the cost per click/view and a fraction $\gamma \in [0, 1]$ of the users interacts with advertisement, it holds that $\frac{\phi(\mu_t)}{\mu_t} = c\gamma$, which is constant in $\mu_t$.

by $\alpha_t$, while the leftover fraction of revenue $(1-\alpha_t)$ is shared with the users.

How monetization and revenue sharing are chosen depends on the mode of governance of the platform. At the beginning of the game, in $t=0$, the entrepreneur chooses the mode of governance (centralized or decentralized). If the entrepreneur chooses centralized governance, she can change monetization $\pi_t$ and revenue sharing $\alpha_t$ in every period $t=1,2,....$ If the entrepreneur chooses decentralized governance, she commits, without loss of generality, to a fixed percentage $\alpha$ of revenue sharing in $t=0$ through the tokenomics of the platform.[11] She achieves this through the appropriate distribution of the platform's token between herself and the users.[12] In every period $t=1,2,...$ the users of the platform determine the amount of monetization $\pi_t$ through *on-chain governance*. Regardless of the mode of governance, each period, users have a binary choice. Newly arriving users can join or not join the platform. Existing users can stay in the platform or leave the platform. Users that decide to leave the platform or newly arriving users who decide not to join the platform exit the game and realize the value of their outside option.

**Growth.** Every period, new potential users become aware of the platform. Let $\mu_{t-1}$ be the mass of users in the platform in period $t-1$. Then, in period $t$ there will be a mass of $g(\mu_{t-1})-\mu_{t-1}\geq 0$ new users who become aware of the platform. Each potential new user can join or not join the platform. For example, if all new users join, the new measure of users in the platform is equal to $g(\mu_{t-1})$. If no new user joins, the platform remains at $\mu_{t-1}$ users. If only some users join, the platform will have a size in between these two. The growth function $g$ is continuously differentiable and the mass of users in period 0 is set to $\mu_0=0$. I assume that if the platform loses all its users within a period, no new users will arrive at any point in the future. This assumption rules out cyclical equilibria in which the entrepreneur continuously "starts over". There is complete information and both the entrepreneur and the users observe the full history of the game.

**Preferences.** The entrepreneur is strictly interested in revenue, as the costs for operating the platform have been normalized to 0. Her utility in a particular period $t$ is equal to her revenue share $\alpha_t$ multiplied by the revenue raised by monetization $\pi_t\phi(\mu_t)$: $u_t^E=\alpha_t\pi_t\phi(\mu_t)$. The utility a user receives from participating in the platform has three components: First, a user derives utility $V(\mu_t)$ from using the platform. I assume that $V$ is increasing, i.e. there are network effects, it is continuously differentiable and that $V(0)=0$. Second, as a result of the monetization of the platform, $\pi_t$, the user's utility

[11] In an extension in appendix A.K, I allow the entrepreneur to pre-commit to a path for revenue sharing and show that she chooses a constant percentage of revenue sharing. Thus, considering a fixed percentage throughout the main body of the paper is without loss of generality.

[12] For the example of Uniswap, 60% of the token supply has been allocated to users, while the other 40% is split between the Uniswap team, investors, and advisors. For details, see https://uniswap.org/blog/uni.

decreases by $k\pi_t^2$, where $k > 0$ describes the user's aversion to monetization. This represents the decrease in utility a user suffers when being forced to watch advertisements, through the sale of his data, or other detrimental effects of monetization. As a third component, a user may potentially receive a share of the revenues that the platform generates. I assume that this share is equally split between all users, such that each user receives a fraction $\frac{1-\alpha_t}{\mu_t}$ of the revenue. The utility function of a user equals the sum of these three components: $u_t = V(\mu_t) - k\pi_t^2 + \frac{(1-\alpha_t)}{\mu_t}\pi_t\phi(\mu_t)$.

**Locked-in effects.** A user who newly arrives in the platform can decide to join the platform and realize the utility as described above. If the user decides not to join the platform, he realizes an outside option that is normalized to 0. A user who has already taken part in the platform for at least one period can decide to stay in the platform, realizing the utility of participating, or leave the platform. However, the outside option for these users is equal to $-u < 0$.[13] Thus, users that already take part in the platform suffer from a *locked-in effect*. This assumption represents the idea that users have spent time interacting with the platform, such that its algorithm has adapted to their needs.[14] An equivalent interpretation is that the value of the outside option has remained constant, but users encounter a switching cost equal to $u$ when leaving the platform in favor of the outside option.[15]

Both the entrepreneur and the users maximize the sum of their discounted utilities. Future utilities are discounted by a common discount factor $\delta \in (0, 1)$. I divide the analysis into subsections dedicated to the sub-games of centralized and decentralized governance. Within those sections, I provide a detailed description of the structure of the sub-games of centralized and decentralized governance. Then I derive the sub-game perfect Nash equilibria and discuss their properties. Finally, I determine the optimal decision of the entrepreneur at the start of the game: to implement her platform with centralized or decentralized governance.

[13] In section IV, I argue that a more general approach of modeling $u = u(\mu_t)$ with $u(\mu_t)$ being increasing in the number of users, leaves the model results qualitatively unchanged.

[14] For example, Google's search algorithm learns from a user's past searches and improves its search results. Spotify's algorithm learns a user's taste in music, improving the likelihood of playing music that the user likes.

[15] An essentially equivalent modeling approach would be to assume that the value of the outside option stays constant, and users gain extra utility $u$ one period after joining. The reason this approach is equivalent, is that the entrepreneur can exploit her existing users more (as they enjoy the benefit $u$) than newly arriving users. Therefore, the entrepreneur faces the same trade-off between growth and exploitation that is discussed in detail in the section on centralized governance. This argument should become clearer after reading the section on centralized governance that follows shortly. I would like to thank an anonymous referee for raising the question of equivalence of this approach.

## II.A Centralized Governance

If the entrepreneur chooses centralized governance, every period $t = 1, 2, ...$ has the following timing:

1. The entrepreneur chooses a level of monetization $\pi_t$ and a fraction of revenue sharing $\alpha_t$
2. Users make a simultaneous choice:
   (a) Users that arrived in period $t$ choose to join or not to join
   (b) Users who are already present in the platform choose to stay or leave
3. Utilities realize

A centralized entrepreneur retains full control of the monetization and revenue sharing of the platform. However, she lacks the ability to commit to the levels of monetization and revenue sharing for future periods because her strategy has to be sequentially optimal. Next, I define strategies for the entrepreneur and the users. For that, define by $h_t$ a history of the game up to period $t$. Then a strategy is defined as a mapping from the set of possible histories into the possible actions. Specifically, for the entrepreneur, a strategy maps any possible history into some degree of monetization $\pi_t$ and revenue sharing $\alpha_t$. For the users, a strategy maps into the binary decisions to join or to not join at their time of arrival in the platform, or, if already present in the platform, into a binary decision of staying or leaving. I impose the following tie-breaking rules: Newly arriving users that are indifferent between two strategies, such that one prescribes joining the platform and one prescribes not joining the platform will join the platform. Users that are indifferent between two strategies, such that one strategy prescribes leaving the platform and another strategy prescribes not leaving in the platform, will choose to remain in the platform.

**Myopic revenue maximization.** As a preliminary step in the analysis, it is useful to think about how to myopically maximize revenue within a given period. That is, what is the maximum revenue that the entrepreneur can generate, given that the users should receive some arbitrary level of utility $\hat{u}$. Mathematically, the entrepreneur solves the following problem:

$$\begin{aligned}
&\max_{\alpha_t,\pi_t} \alpha_t \pi_t \phi(\mu_t) \\
&\text{s.t. } V(\mu_t) - k\pi_t^2 + \frac{1-\alpha_t}{\mu_t}\pi_t\phi(\mu_t) = \hat{u} \\
&\qquad 1 \geq \alpha_t \geq 0
\end{aligned}$$

From now on, I will denote the entrepreneur's revenue that results from the solution of this problem for a given platform size $\mu_t$ and user utility level $\hat{u}$ by $\psi(\mu_t, \hat{u})$. In terms of the model primitives, it is given by:

$$\psi(\mu_t, \hat{u}) = \begin{cases} \mu_t V(\mu_t) + \frac{\phi(\mu_t)^2}{4k\mu_t} - \mu_t \hat{u} & \text{if } \left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 \geq \frac{V(\mu_t)-\hat{u}}{k} \\ \sqrt{\frac{V(\mu_t)-\hat{u}}{k}}\phi(\mu_t) & \text{if } \left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 < \frac{V(\mu_t)-\hat{u}}{k} \end{cases}$$

Note that the first case corresponds to the case where the entrepreneur shares some revenue with the platform's users, i.e. $\alpha_t \in (0, 1)$, while she keeps all revenue in the second case, i.e., $\alpha_t = 1$. The exact expressions for the optimal levels of monetization, revenue sharing and other details are relegated to appendix A.A. This function $\psi(\mu_t, \hat{u})$ will be crucial for the analysis of centralized governance. In the main body of the paper, I focus on describing the characteristics of $\psi(\mu_t, \hat{u})$ and providing some intuitions. First, the entrepreneur's revenue is increasing in the amount of users $\mu_t$ and decreasing in the level of utility $\hat{u}$ that the users receive. Second, the profitability of the platform determines a limit for how large the user utility level $\hat{u}$ can be for a given platform size $\mu_t$. It is not feasible to provide a user utility level that exceeds what a user would receive if the entrepreneur distributed the entire revenue to the users. Last, depending on the users' aversion to monetization $k$, the centralized platform may or may not feature revenue sharing. That is, for small values of $k$, the entrepreneur will increase the monetization of the platform and compensate the users by sharing some of the revenue. In contrast, when $k$ is large, the entrepreneur will monetize less and not share any revenue with the users.

**Growth vs. exploitation.** To derive the equilibrium of the centralized governance sub-game, it is instructive to consider the entrepreneur's incentives to grow her platform. Every period, new users arrive to potentially join the platform. For the platform to grow, joining the platform has to be weakly beneficial for a newly arriving user. That is, joining the platform has to yield at least utility equal to 0. Instead of growing the platform, the entrepreneur can exploit the existing users. Given that existing users are locked into the platform and have an outside option that is valued at $-u < 0$, the entrepreneur can potentially achieve a higher level of revenue when focusing on extracting additional revenue from existing users. To quantify the revenue that an entrepreneur generates when she decides to exploit the users in her platform, consider some period $t$. The amount of existing users at the start of the period is equal to $\mu_{t-1}$. If she exploits the existing users forever, the present value of the stream of her discounted future revenue equals

$$\frac{1}{1-\delta}\psi(\mu_{t-1}, -(1-\delta)u) \tag{II.1}$$

Note that the entrepreneur provides a per-period utility of $-(1-\delta)u$ to the users, such that their discounted utility is equal to $-u$, keeping the users indifferent between staying and leaving. To grow the platform, the entrepreneur has to provide enough utility to the users, such that they are better off joining the platform in the first place. If the entrepreneur grows the platform one last time in some period $t$ before exploiting the existing users, she has to provide utility $\delta u$ to the last users who are to join the platform. The entrepreneur's revenue from growing the platform one more time and then exploiting the platform's users from that point onward equals

$$\psi(g(\mu_{t-1}),\delta u)+\frac{\delta}{1-\delta}\psi(g(\mu_{t-1}),-(1-\delta)u) \tag{II.2}$$

The point at which the entrepreneur is indifferent between growing the platform one last time and exploiting the existing users in her platform will be crucial for the analysis of the equilibrium. I denote this point of indifference by $\bar{\mu}$. It is defined as the solution to the following equation:

$$\frac{1}{1-\delta}\psi(\bar{\mu},-(1-\delta)u)=\psi(g(\bar{\mu}),\delta u)+\frac{\delta}{1-\delta}\psi(g(\bar{\mu}),-(1-\delta)u) \tag{II.3}$$

It is exactly at the platform size $\bar{\mu}$ where the entrepreneur is indifferent between growing the platform one last time and then exploiting the users in the future, and exploiting the users right away. It highlights the trade-off between exploiting the locked-in effect of a smaller mass $\mu_{t-1}$ of users starting today, or, growing the platform at the cost of providing utility $\delta u$ to the users to then exploit a larger platform with $g(\mu_{t-1})$ users starting tomorrow. For the purpose of this paper, I focus on the case where such a value $\bar{\mu}$ exists. Indeed, this captures the economically interesting case of the model. If no such $\bar{\mu}$ exists, the entrepreneur never wants to exploit her users, regardless of how many users there are to exploit and how few users will arrive in the future. In appendix A.B I provide an extensive discussion of sufficient conditions to assure that $\bar{\mu}$ is well-defined. For the main body of the paper, I focus on providing an intuitive characterization of these settings. The key feature is the idea, that user growth will slow down over time. For example, if the overall pool of potential users is limited and a large amount of users has already joined the platform, user growth necessarily slows down mechanically over time. However, there is some nuance in that a slowdown in user growth can be partially offset through an increase in revenues due to network effects. If these network effects are particularly strong relative to the growth rate of the platform, growing the platform remains preferable for the entrepreneur. What is important for $\bar{\mu}$ to exist, is that eventually growth slows down sufficiently to offset increased network effects, or that the network effect of attracting an additional eventually diminishes when the platform is large enough. As a last point, I want to provide one particularly tractable example: $V(\mu_t)$ is constant (i.e. there are no network effects), $\phi(\mu_t)$ is linear in $\mu_t$ and $g(\mu_t) = \mu_t + \gamma(\mu_t)$ where $\gamma(\mu_t)$ is a strictly decreasing, strictly positive function that approaches 0 as $\mu_t \to \infty$. It is rather intuitive that this specification permits such general growth functions, as there is no network effect to be offset by the growth function.

**Strategies.** For now, suppose that the platform is sufficiently profitable at size $\bar{\mu}$ to be able to provide utility level $\delta u$ to its users.[16] That is, the following inequality holds:

$$\frac{\phi(\bar{\mu})^2}{4k\bar{\mu}^2} + V(\bar{\mu}) \geq \delta u \tag{II.4}$$

For a better understanding of the equilibrium characterization that will follow shortly, I will describe a particular set of strategies in some detail. First off, I describe a strategy that I am naming *grow-then-exploit* for the entrepreneur. To avoid confusion when reading the strategy, I want to emphasize that the level of user utility $\hat{u}_t$ that is implied by a degree of monetization $\pi_t$ and revenue sharing $\alpha_t$ is a function of the amount of users $\mu_t$ that are present in the platform at the end of period $t$. For example, a particular tuple $(\pi_t, \alpha_t)$ implies different user utility levels $\hat{u}_t$ when $\mu_t = 0$ compared to when $\mu_t > 0$.

**Definition 1 (Grow-then-exploit strategy)** *The grow-then-exploit strategy of the entrepreneur is defined as follows:*

- *If $g(\mu_{t-1}) < \bar{\mu}$, set $\pi_t$ and $\alpha_t$ to maximize revenue as given by $\psi(\mu_t, \hat{u}_t)$ for user utility level $\hat{u}_t = 0$ and platform size $\mu_t = g(\mu_{t-1})$*
- *If $\mu_{t-1} < \bar{\mu}$ and $\bar{\mu} \leq g(\mu_{t-1})$, set $\pi_t$ and $\alpha_t$ to maximize revenue as given by $\psi(\mu_t, \hat{u}_t)$ for user utility level $\hat{u}_t = \delta u$ and platform size $\mu_t = g(\mu_{t-1})$*
- *If $\bar{\mu} \leq \mu_{t-1}$ set $\pi_t$ and $\alpha_t$ to maximize revenue as given by $\psi(\mu_t, \hat{u}_t)$ for user utility level $\hat{u}_t = -(1-\delta)u$ and platform size $\mu_t = \mu_{t-1}$*

The entrepreneur's strategy has three distinct parts. If $g(\mu_{t-1}) < \bar{\mu}$, the entrepreneur will grow the platform again in the next period, as $g(\mu_{t-1}) = \mu_t < \bar{\mu}$. Thus, the entrepreneur sets user utility equal to $\hat{u}_t = 0$ and the users are willing to join the platform. Note that in these growth periods, the entrepreneur has basically regained commitment to not abuse the locked-in effect of the users. The entrepreneur refrains from exploiting the locked-in effect of the existing users in the platform with the aim to grow the platform larger. At the point when $\mu_{t-1} < \mu$ and $\bar{\mu} \leq g(\mu_{t-1})$, the entrepreneur reaches the limits of how far she is willing to grow the platform. If the entrepreneur grows the platform it holds that $g(\mu_{t-1}) = \mu_t \geq \bar{\mu}$, such that in the future, the entrepreneur will be better off

[16] As I will discuss later, the entrepreneur will be unable to attract any users to the platform if this condition fails to hold.

with exploiting the locked-in effect of the users compared to growing the platform any further. However, to attract users to the platform, the entrepreneur has to offer a utility level equal to $\hat{u}_t = \delta u$. In the last part, when $\bar{\mu} \leq \mu_{t-1}$, the entrepreneur is better off exploiting the locked-in effect of the platform's existing users by providing utility level $\hat{u}_t = -(1-\delta)u$.

Next, I describe a strategy that I am naming *join-if-compensated* for the users:

**Definition 2 (Join-if-compensated strategy)** *The join-if-compensated strategy of the users if defined as follows:*

- *In the period of arrival, join the platform*
  1. *If $g(\mu_{t-1}) < \bar{\mu}$ and $\pi_t$, $\alpha_t$ are such that user utility level $\hat{u}_t \geq 0$ for a platform size $\mu_t = g(\mu_{t-1})$*
  2. *If $\mu_{t-1} < \bar{\mu}$ and $\bar{\mu} \leq g(\mu_{t-1})$ and $\pi_t$, $\alpha_t$ are such that user utility level $\hat{u}_t \geq \delta u$ for a platform size $\mu_t = g(\mu_{t-1})$*
- *If already locked in to the platform, stay in the platform if $\pi_t$, $\alpha_t$ are such that user utility level $\hat{u}_t \geq -(1-\delta)u$ for a platform size $\mu_t \geq \mu_{t-1}$*

The users' strategies obey the following rationale: when they newly arrive at the platform, they do not suffer from a locked-in effect. They observe the platform size and if $g(\mu_{t-1}) < \bar{\mu}$, anticipate that the entrepreneur will grow the platform further in the future, such that it is optimal for them to join the platform if $\hat{u}_t \geq 0$. If $\mu_{t-1} < \bar{\mu}$ and $\bar{\mu} \leq g(\mu_{t-1})$, they know that the entrepreneur will grow the platform just one last time. As such, they require a level of utility $\hat{u}_t \geq \delta u$ to join the platform. If they are already locked into the platform, they will remain in the platform if $\hat{u}_t \geq -(1-\delta)u$, as this implies that the discounted value of their future utility is at least equal to the value of their outside option $-u$.

Naturally, as a next step, I formally establish that these strategies constitute a sub-game perfect Nash equilibrium:

**Proposition 1** *Suppose that the platform is sufficiently profitable at size $\bar{\mu}$ to ensure utility level $\delta u$ to its users, i.e. inequality II.4 is satisfied. Then, there is a sub-game perfect Nash equilibrium in which the entrepreneur plays according to the grow-then-exploit strategy and the users play the join-if-compensated strategy.*

**Proof.** See appendix A.C ■
While the detailed proof of the proposition is relegated to the appendix, I want to provide some brief intuition why those strategies constitute an equilibrium. I argue that

no profitable deviations exist for neither the entrepreneur nor the users. In equilibrium, newly arriving users are indifferent between joining and not joining the platform, while users that are already locked into the platform strictly prefer staying in the platform before the entrepreneur starts exploiting the users and are indifferent between staying and leaving when the entrepreneur starts exploiting the platform. For the entrepreneur, deviations that increase the users' utility level are not profitable, since it does not change the users actions on the equilibrium path and her revenues are decreasing in the users' utility levels. Decreasing the utility level offered to the users during the growth phase of the equilibrium causes user not to join the platform. But by definition of $\bar{\mu}$ this deviation is not profitable. Decreasing the utility level of the users during the exploitation phase of the equilibrium causes the users to leave the platform, thus not being a profitable deviation.

Now reconsider what happens if the platform is not sufficiently profitable to guarantee utility level $\delta u$ at size $\bar{\mu}$, i.e. when

$$\frac{\phi(\bar{\mu})^2}{4k\bar{\mu}^2} + V(\bar{\mu}) < \delta u \tag{II.5}$$

Then, the entrepreneur cannot pay the compensation utility $\delta u$ in the last period where she grows the platform. But if the entrepreneur sets a utility level of less than $\delta u$, no new users will join, as the value of joining is below the outside option of 0. However, if the entrepreneur is unable to attract any new users, she should maximize revenues from the existing users of the platform. That is, setting user utility equal to $-(1-\delta)u$ instead. Denote this last period of potential growth in which this issue occurs as $t^*$. Then, users should anticipate that the entrepreneur will exploit the locked-in effects not starting from period $t^*+1$ onward, but from period $t^*$. Then, the users who arrive at period $t^*-1$ need to be provided utility level $\delta u$, for them to be incentivized to join the platform. However, note that at period $t^*-1$ the size of the platform is necessarily smaller than at $t^*$. Since the platform's revenues are increasing in its amount of users $\mu_t$, it is also not feasible for the entrepreneur to provide utility level $\delta u$ to the users in period $t^*-1$. This logic carries forward until the first period, such that no users should join the platform at all. To further examine when this issue occurs, define by $\underline{\mu}$ the solution to the equation

$$\frac{\phi(\underline{\mu})^2}{4k\underline{\mu}^2} + V(\underline{\mu}) = \delta u \tag{II.6}$$

Intuitively speaking, $\underline{\mu}$ is the minimum platform size required, such that it is feasible for the entrepreneur to provide utility $\delta u$ to the users. Now, if $\bar{\mu} \geq \underline{\mu}$, the case discussed above does not occur and the entrepreneur can attract users to her platform. However, if $\bar{\mu} < \underline{\mu}$, the entrepreneur is unable to attract any users to her platform. The entrepreneur's main issue in the platform with centralized governance is her lack of commitment to not abusing the locked-in effect of the users. Thus, I focus on the effects of the severity of the locked-in effect $u$ on $\underline{\mu}$ and $\bar{\mu}$.

**Lemma 1** $\underline{\mu}$ *strictly increases in* $u$*. As* $u \to \infty$ *it holds that* $\underline{\mu} \to \infty$*.*

To see why the lemma holds true, consider equation II.6. When $u$ increases, the RHS of the equation increases. Then the lemma clearly holds true, as the LHS of the equation is increasing in $\underline{\mu}$ since $\frac{\phi(\underline{\mu})^2}{4k\underline{\mu}^2}$ is increasing in $\underline{\mu}$ $\Big($recall that $\frac{\phi(\underline{\mu})}{\underline{\mu}}$ is increasing in $\underline{\mu}$ by assumption$\Big)$ and $V(\underline{\mu})$ is also increasing in $\underline{\mu}$ by assumption.
Next, consider $\bar{\mu}$. Note that $\bar{\mu}$ is only implicitly defined in equation II.3. It is the size of the platform that makes the entrepreneur indifferent between growing the platform once more today and exploiting the users in the future vs. exploiting the users starting today. As such, I employ the implicit function theorem to show the following lemma:

**Lemma 2** $\bar{\mu}$ *strictly decreases in* $u$*. As* $u \to 0$ *it holds that* $\bar{\mu} \to \infty$*.*

**Proof.** See appendix A.D. ∎
As the size of the locked-in effect grows, the entrepreneur stops growing the platform and start exploiting the existing users earlier. Intuitively this holds, as with a larger locked-in effect, the temptation to exploit the existing users increases.

Combining both lemmata, I have shown that $\underline{\mu}$ is strictly increasing in $u$ and that $\bar{\mu}$ is strictly decreasing in $u$. Therefore, the following corollary formalizes that when $u$ grows too large, the entrepreneur is unable to attract any users to her platform:

**Corollary 1** *There exists some value* $u^*$ *such that the entrepreneur is unable to attract any users to the platform if* $u > u^*$*. Consequently, in this case, the equilibrium revenue of the platform with centralized governance is 0.*

The corollary follows by defining $u^*$ as the value of $u$ for which $\underline{\mu} = \bar{\mu}$. Then for all $u > u^*$ it holds that $\bar{\mu} < \underline{\mu}$. As the size of the locked-in effect grows too large, the entrepreneur will more readily exploit users who are already in the platform, rather than growing the platform by attracting new users. However, in equilibrium, this is anticipated by any users that arrive at the platform, such that no users join the platform at all. This highlights the commitment problem of the entrepreneur. If she was able to commit to not abusing the locked-in effect of the users, she would be able to attract users to her platform and generate revenues. Note that this corollary establishes a sufficiency result for when decentralized governance is preferred. When the size of the locked-in effect is sufficiently large, it is better to decentralize the platform, if the entrepreneur can attract at least some users in decentralized governance.

## II.B Decentralized Governance

If the entrepreneur chooses decentralized governance, every period $t = 1, 2, ...$ has the following timing:

1. Users make a simultaneous choice:
   (a) Users who are not present in the platform choose to join or not to join
   (b) Users who are already present in the platform choose to stay or leave
2. Users collectively choose $\pi_t$
3. Utilities realize

This section focuses on the sub-game of decentralized governance. In $t = 0$ the entrepreneur chooses, without loss of generality, a permanent revenue split $\alpha$. Then, in $t = 1, 2, ...$ newly arriving users join or not join the platform. Existing users stay or leave the platform. Afterward, users vote on the degree of monetization $\pi_t$ for the period and utilities realize. When analyzing the voting equilibria, I restrict the equilibrium analysis to weakly undominated strategies. In voting games, the strategy of voters has to be optimal, conditional on being pivotal. As no single voter is ever pivotal when there is a continuum of users, basically any strategy can be played in an equilibrium. Therefore, restricting the users' strategies to be weakly undominated, implies that they truthfully vote for their preferred degree of monetization $\pi_t$ *as if* they were pivotal. This leads to the following equilibrium:

**Proposition 2** *There is a sub-game perfect equilibrium such that every period the users of the platform will vote for a degree of monetization*

$$\pi_t^* = \frac{1-\alpha}{2k}\frac{\phi(\mu_t)}{\mu_t} \tag{II.7}$$

*The platform will grow every period. The entrepreneur shares half of the revenue with the users.*

**Proof.** See appendix A.E. ■

The equilibrium highlights that decentralized governance is an effective commitment tool for the entrepreneur. In contrast to centralized governance, the users can be certain that their locked-in effect will not be exploited by the entrepreneur. Thus, new users will continue to join the platform every period. However, for the entrepreneur, this commitment comes at a substantial cost: she shares half the revenues of the platform with her users. Nonetheless, it is necessary for her to share revenue with her users. If she would not share any revenue, the users would subsequently vote to stop the monetization of the platform. As a result, the entrepreneur would not receive any revenue. Therefore, sharing revenue in a decentralized implementation of the platform is necessary, as it aligns the incentives of the entrepreneur and the incentives of the platform's users.

One potential point of contention in decentralized governance could be conflicts of interest between existing and newly arriving users. The users' utility function equals $V(\mu_t) - k\pi_t^2 + \frac{1-\alpha}{\mu_t}\pi_t\phi(\mu_t)$. The share of revenue that each user gets in the platform is $\frac{1-\alpha}{\mu_t}$. As such, newly arriving users dilute the revenue shares of existing users in the platform. However, note that the users' per period utility in the equilibrium equals $V(\mu_t) + \frac{\phi(\mu_t)^2}{8k\mu_t^2}$. Since $\frac{\phi(\mu_t)}{\mu_t}$ is non-decreasing by assumption, the equilibrium utility is increasing in $\mu_t$. Intuitively speaking, the network effects that accompany the entry of new users sufficiently compensate the dilution of the revenue share of existing users. Thus, there is no incentive for existing users to try to prevent entry from newly arriving users to avoid dilution of their revenue shares.[17]

## II.C Optimal Governance

The two preceding sections have solved the sub-games of centralized and decentralized governance. But the main question remains: which form of governance the entrepreneur should choose when she creates her platform? As has been shown in proposition 1, centralized governance will result in the entrepreneur eventually stopping to grow the platform and starting to exploit the locked-in effect of the users. This change from platform growth to exploiting the users is inherent in centralized governance, as the entrepreneur is unable to commit to future monetization and revenue sharing. Subsequently, corollary 1 showed that, when the locked-in effect is sufficiently large, the entrepreneur is unable to attract any users to the platform, yielding her 0 revenue in equilibrium. This threshold of the locked-in effect serves as a sufficient condition for when it is optimal to decentralize. However, a complete comparison between the entrepreneur's revenue in centralized and decentralized governance remains. That is, what is the optimal mode of governance for any arbitrary size of the locked-in effect? To answer this question, I start by considering the opposite extreme, namely when the locked-in effect is very small. Then, I move to locked-in effects of arbitrary size.

For small locked-in effects, the commitment problem of the entrepreneur becomes less and less severe, and in the limit of $u = 0$, disappears entirely. Comparing centralized and decentralized governance for $u = 0$ is rather straightforward. When $u = 0$, there is no locked-in effect that can be abused by the entrepreneur in the future. Thus, users will join the platform every period, resulting in growth in any period in the centralized

[17] In section IV, I discuss the implications of alternative modeling approaches of decentralized governance for the paper.

platform. In comparison, note that the decentralized platform also featured growth in every period. As such, the potential revenues that can be generated in both modes of governance are the same. However, in centralized governance, the entrepreneur stays in control and can generate maximum amounts of revenue for herself, while she surrenders control of the platform in decentralized governance and has to engage in revenue sharing to align the users' preferences with hers. Thus, centralized governance is superior when the locked-in effect is small. This intuition is condensed in the following lemma:

**Lemma 3** *As the size of the locked-in effect decreases, that is as $u \to 0$, centralized governance is always preferred over decentralized governance.*

**Proof.** See appendix A.F ■

This establishes comparisons of centralized and decentralized governance for both extremely small and large locked-in effects. For minimal locked-in effects, centralized governance is optimal for the entrepreneur, while for sufficiently large locked-in effects, decentralized governance is optimal for the entrepreneur. For intermediate values, the optimal mode of governance is hard to compute explicitly, as the revenue of the entrepreneur in the centralized platform is only given implicitly, through the implicit definition of the maximum platform size $\bar{\mu}$. However, I will enable the comparison of revenues for any locked-in effect using a monotonicity result. That is, I show that as the size of the locked-in effect increases, the entrepreneur's revenue in centralized governance decreases. As a result, there is a clear cutoff in the size of the locked-in effect, such that decentralized governance is preferred if and only if the size of the locked-in effect is larger than this cutoff. This idea is condensed into the following proposition:

**Proposition 3** *There exists a well-defined size of the locked-in effect, $u^{**}$, such that decentralized governance is preferred by the entrepreneur if and only if $u > u^{**}$.*

**Proof.** See appendix A.G. ■

The idea of the proof is as follows. First, recall that I have shown that at the two extremes of minimal and very large locked-in effects, the entrepreneur prefers centralized and decentralized governance respectively. Next, note that the entrepreneur's revenue with decentralized governance is independent of the size of the locked-in effect $u$. This holds as the users decide the level of monetization in the platform with decentralized governance, and their optimal decision does not depend on $u$. The final step of the proof shows, that the entrepreneur's revenue with centralized governance is decreasing in the size of the locked-in effect $u$. Together, these observations imply the result, as they imply that the functions of the revenue under centralized and decentralized governance cross exactly once.

To realize why the entrepreneur's revenue with centralized governance is decreasing in $u$, consider the effect of a change in the size of the locked-in effect. In the centralized platform, revenue is generated in three different phases. First, the growth phase in which the entrepreneur provides 0 period utility to the users. Second, the last period of growth in which the entrepreneur provides utility equal to $\delta u$ to the users, and last, the periods of exploiting where the entrepreneur provides utility equal to $-(1-\delta)u$ to the users. Consider the immediate effect of an increase in $u$. The revenue of the first phase of the platform is independent of $u$ and remains unchanged. Second, the required period utility of the users in the last phase of growth, $\delta u$ increases, resulting in decreased revenue for the entrepreneur. Finally, the user utility level in the exploitation phase, $-(1-\delta)u$ decreases and leads to increased revenues for the entrepreneur. However, the entrepreneur's revenue is a function that is concave in the utility level $\Big($c.f. $\psi(\mu_t, \hat{u}) = \mu_t V(\mu_t) + \frac{\phi(\mu_t)^2}{4k\mu_t} - \mu_t \hat{u}$ or $\psi(\mu_t, \hat{u}) = \sqrt{\frac{V(\mu_t)-\hat{u}}{k}}\phi(\mu_t)\Big)$ that is extracted from the users. As a result, the additional cost of providing additional utility in the last period of growth does not outweigh the additional benefit from the extra revenue the entrepreneur generates in the exploitation phase. Thus, the immediate effect on the entrepreneur's revenue of an increase in the size of the locked-in effect is negative.

As a secondary effect, an increase in the size of the locked-in effect $u$, decreases the maximum size of the platform $\bar{\mu}$, as was shown in Lemma 2. Since the entrepreneur's revenue is increasing in the size of the platform, such that a decrease in the platform size decreases the entrepreneur's revenue. As both the immediate and secondary effects on the entrepreneur's revenue from an increase in the size of the locked-in effect are negative, the total effect is negative. Thus, the entrepreneur's revenue with centralized governance is decreasing in $u$.

## II.D Welfare

Finally, I want to address the welfare implications of the governance decision. In particular: When does decentralization improve welfare?

**Pareto efficiency.** It turns out that the analysis that has been conducted so far is sufficient to compare the modes of governance in terms of Pareto efficiency. First, note that users in the centralized implementation of the platform are always indifferent between joining the platform and their outside option ex-ante. Thus, their equilibrium utility is 0. In contrast, users receive strictly positive utility in the decentralized implementation of the platform. Ergo, users always prefer decentralized governance. For the entrepreneur, proposition 3 has established that she prefers decentralization if and only if the size of the locked in effect $u$ is larger than the threshold $u^{**}$. Therefore, the following corollary can be established:

**Corollary 2** *Decentralized governance of the platform is a Pareto improvement over* *centralized governance if and only if the size of the locked-in effect $u$ is larger than $u^{**}$*

**Utilitarian welfare.** As an alternative, one might consider utilitarian welfare. Naturally, utilitarian welfare is also higher with decentralized governance if decentralization constitutes a Pareto improvement, i.e. if the size of the locked-in effect $u$ is larger than $u^{**}$. However, the statement for utilitarian welfare is not an if and only if statement. In general, it is not obvious whether it would improve welfare to force an entrepreneur to decentralize her platform when locked-in effects are smaller than $u^{**}$. Doing so creates two welfare effects with opposing signs: the decrease in revenue for the entrepreneur, and increase in utility for the users. The sign of the aggregate of these two effects will generally depend on the parametrization of the model.

# III Discussion

## III.A Airdrops: Decentralizing at a Later Time

One thing that commonly occurs in practice when an entrepreneur decentralizes her platform are so-called *airdrops*. That is, instead of decentralizing her platform at the very beginning, the entrepreneur delays decentralizing her platform until a later time. At the time of decentralization, she sends tokens to the wallets of existing users (the tokens are "airdropped") and moving forward, the platform is subject to decentralized governance.[18] This practice of airdrops can be rationalized within my model by allowing the entrepreneur to delay decentralizing her platform until a later period. The main concern is whether an entrepreneur who announces the intention to decentralize at a later time will actually decentralize the platform at a later time, given that she lacks the power to commit to it. That is, once the time comes to follow through on the announcement and decentralize, the entrepreneur may be tempted to revise her plans and stay centralized to exploit the users that have already joined the platform. Thus, for delayed decentralization to be credible, it has to be sequentially optimal for her to decentralize the platform at that later point in time. Intuitively, the temptation to revise her plans for decentralization is larger when the platform has already grown to a large amount of users. This intuition is distilled into the following lemma:

**Lemma 4** *Suppose growth slows down over time, that is $g(\mu_t) - \mu_t \to 0$ as $\mu_t \to \infty$. Then, there exists a sufficiently large platform size $\mu_t$ such that it is sequentially optimal to keep the platform centralized.*

**Proof.** See appendix A.H ■

This lemma highlights that an entrepreneur who delays decentralization for too long, will

[18] For example, Uniswap was founded in November 2018 and decentralized its governance after an airdrop in September 2020.

in fact not follow through with a promise for future decentralization. Instead, she will keep the platform centralized to exploit the locked-in effect of the users. Next, I show that the option to delay decentralization is nonetheless useful for the entrepreneur. That is, she can increase her revenues by delaying decentralization of her platform for some time. The intuition is, that at the start, when the amount of users in the platform is small, a centralized entrepreneur gains implicit commitment to not exploit the locked-in effect of the users by the prospects of future growth. Using that commitment, she can avoid the costs of decentralization for some time to increase her overall profits.

**Proposition 4** *Suppose it is optimal for the entrepreneur to decentralize in $t = 0$. Then it is optimal for the entrepreneur to delay decentralizing the platform. Further, the option to decentralize the platform at a later time lowers the threshold value $u^{**}$ of locked-in effects for which decentralization is optimal.*

**Proof.** See appendix A.I ■

As a secondary result, the proposition shows that giving the entrepreneur more flexibility for when she decentralizes, naturally makes decentralization more appealing. Further, combining lemma 4 and proposition 4 provides a prediction about the timeline of successful decentralization using an airdrop. That is, the entrepreneur initially launches a centralized platform and then decentralizes the platform at a later date. However, the later date has to be sufficiently early. There has to be sufficient growth potential left for the platform, such that the benefits of a growing, decentralized platform outweigh the temptation of exploiting the users of a stagnant, centralized platform. As a last point, I note that in my model decentralization is delayed purely to increase revenue. In practice, an important reason to delay decentralization may also be to give the entrepreneur control over the platform, while she builds the necessary platform infrastructure and features.

## III.B Equilibrium Selection

Section 2 has discussed the implications of centralized governance for an equilibrium in which the entrepreneur grows the platform up to a particular size and then stops growing the platform to exploit the locked-in effect of its users. However, there exist other subgame perfect equilibria.[19] In particular, one might be interested if it would be possible for users to coordinate on another equilibrium that disciplines the entrepreneur to refrain from exploiting the users. Here, I argue such equilibria exist, but require a high degree of coordination among the users. Thus, I perceive them as less convincing. To illustrate the point, consider the following folk-theorem type of equilibrium that exists when the

[19] A multitude of equilibria is common in dynamic games and has been establishes through various folk theorems (e.g., Abreu (1983), Abreu, Pearce and Stacchetti (1986), Fudenberg and Maskin (1990)).

discount factor $\delta$ is sufficiently large:

**Users' strategy.** Existing users stay in the platform and newly arriving users join the platform if the level of utility implied by revenue sharing $\alpha_t$ and monetization $\pi_t$ for a platform of size $\mu_t = g(\mu_{t-1})$ in the history of the game at any time $t$ is at least $\hat{u}_t = V(g(\mu_{t-1})) - (1-\delta)u$. If not, the entrepreneur is "punished", i.e. existing users leave the platform and newly arriving users do not join the platform.[20]

**Entrepreneur's strategy.** In every period $t$, set revenue sharing $\alpha_t$ and monetization $\pi_t$ such that the level of utility for the users is equal to $\hat{u}_t$ for a platform of size $\mu_t = g(\mu_{t-1})$. If the entrepreneur is being "punished" by the users, set utility equal to $-(1-\delta)u$ conditional on 0 (measure) users being in the platform.

A proof that these strategies constitute a sub-game perfect Nash equilibrium can be found in appendix A.J. This type of equilibrium could be employed by the users to discipline the entrepreneur and to avoid exploitation. In practice, there may be a concern that it is particular demanding in terms of coordination. That is, how can a large amount of users ensure that they coordinate on the exact same level of utility as a trigger for punishing the entrepreneur? To illustrate this point, I will show that small uncertainties about the utility level which the users coordinate upon can be problematic for equilibrium stability. Suppose that the entrepreneur (one-shot) deviates and instead offers utility level $\hat{u}_t - \epsilon$ for some arbitrarily small $\epsilon$. Since the utility level of the deviation is close to $\hat{u}_t$, suppose that a user $i$ is not entirely certain whether all other users will follow the equilibrium strategy and punish the entrepreneur by leaving the platform/not joining the platform. User $i$ assigns probability $p$ to the event that all other users unexpectedly stay in the platform, for example because the trigger strategy they follow is slightly more lenient than expected. With probability $1-p$ user $i$ expects all other users to leave the platform as prescribed by the equilibrium. I consider an equilibrium to be unstable, for a degree of uncertainty of punishment $p$, if there is a small deviation $\epsilon$ in the utility offered by the entrepreneur such that any user $i$ is better off staying in the platform and not punishing the entrepreneur.

**Proposition 5** *The alternative equilibrium discussed in this section is unstable for any degree of uncertainty $p > 0$. In contrast, the equilibrium of the main body of the paper, i.e., in proposition 1, is stable for all degrees of uncertainty.*

**Proof.** See appendix A.J ■

Intuitively speaking, the folk-theorem style equilibrium has the feature that a particular user $i$ will want to follow through with punishing the entrepreneur for deviating *only if*

[20] The utility level $\hat{u}_t = V(g(\mu_{t-1})) - (1-\delta)u$ is the largest utility level that users can coordinate upon, such that it is optimal to leave if the entrepreneur provides slightly less utility to the users.

all other users also follow through. He wants to avoid punishing the entrepreneur, if the other users do not follow suit. Thus, this kind of equilibrium requires a non-negligible degree of coordination, that may be especially hard to obtain in large platforms. In contrast, the equilibrium presented in the main paper takes a conservative stance on coordination, such that a user $i$ will want to leave the platform (punish the entrepreneur) *regardless* of whether the other users also leave. Thus, no degree of coordination is necessary.[21]

# IV Discussion and Conclusion

Before concluding, I want to briefly discuss some further points of interest.

First, one might wonder if this model implies that an established platform such as Google or Facebook should decentralize their business through a blockchain. Such a conclusion cannot be drawn from this model, as these platforms have already established a large amount of users (e.g. Facebook already has around 3 billion users[22]). As such, the value of extracting additional revenues from existing users that are already locked-in may outweigh the value of commitment that is offered by a decentralized implementation. In contrast, the model provides insights on the optimal governance of newly founded platforms.

Second, it may be plausible that locked-in effects become larger when there are more users. The model shows that when the platform size is small, growth can be a substitute for commitment. Smaller locked-in effects for small platforms would leave this result unchanged. But when the platform size, and thus the locked-in effect, would be large, the entrepreneur will find it even more beneficial to stop growing the platform and exploit the existing users. Therefore, such an extension will leave the model qualitatively unchanged.

Third, consider the possibility that the entrepreneur may treat newly arriving and already existing users differently. For example, she could try to treat newly arriving users or early adopters favorably. However, if this also implies that she can treat existing users less favorably, this change would exacerbate the commitment problem of the entrepreneur when choosing centralized governance even further. That is, it would be sequentially optimal to exploit the locked-in effect of all users as soon as possible. Therefore, commitment should become even more valuable for the entrepreneur.

Last, one may wonder how different approaches to modelling decentralized governance affect the results. For example, the entrepreneur could be given more or less control over the rules she can set forth for decentralized governance. Alternatively, one may wonder how different frictions within decentralized governance affect the results. I argue

[21] There are other equilibria where users coordinate on utility levels that are less than $\hat{u}_t = V(g(\mu_{t-1})) - (1-\delta)u$. They trade off robustness against larger degrees of uncertainty for lower equilibrium utility levels. In this context, the equilibrium presented in the main body of the paper can be seen as a conservative equilibrium that is robust to *any* degree of uncertainty.

[22] Meta Earnings Presentation Q2, 2022, p.14

that introducing such changes will leave the main theorem of the paper qualitatively unchanged. That is, there will still be a value of the locked-in effect above which decentralization is optimal. However, they may lead to a quantitative change. That is, when decentralized governance becomes better for the entrepreneur (for example, through more control), the threshold at which decentralization is preferred decreases. Conversely, when decentralized governance becomes worse (for example, through frictions), the threshold for decentralization increases. For this paper, I focus on highlighting the general trade-off between centralization and decentralization. Introducing changes to decentralization that change results quantitatively but not qualitatively are interesting questions left for future research.

To summarize, this paper provides a rationale for entrepreneurs to build decentralized platforms on blockchains. As the main result, I showed that (i) an entrepreneur prefers to decentralize her platform and (ii) decentralization is a Pareto improvement, if and only if the locked-in effect is sufficiently large. To broaden our understanding of further implications of decentralization, I believe that further research is needed, especially regarding the economics of decentralized governance and competition between centralized and decentralized platforms.

# A Appendix

## A.A Myopic Revenue Maximization

**Lemma 5** *Consider the entrepreneur's problem to maximize revenue myopically in a single period $t$ while ensuring utility $\hat{u}$ for users when the platform size is $\mu_t$.*

1. *If $\frac{\phi(\mu_t)^2}{4k\mu_t^2} + V(\mu_t) < \hat{u}$ the entrepreneur is unable to ensure utility $\hat{u}$ for the users.*

2. *If $\frac{\phi(\mu_t)^2}{4k\mu_t^2} + V(\mu_t) \geq \hat{u}$ and*

   (a) $\left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 \geq \frac{V(\mu_t)-\hat{u}}{k}$, *the optimal $\pi_t, \alpha_t$ are given by*

$$\pi_t = \frac{\phi(\mu_t)}{2k\mu_t} \tag{A.1}$$

$$\alpha_t = \frac{1}{2} + \frac{2k\mu_t^2(V(\mu_t) - \hat{u})}{\phi(\mu_t)^2} \tag{A.2}$$

   *The entrepreneur's revenue is equal to*

$$\mu_t V(\mu_t) + \frac{\phi(\mu_t)^2}{4k\mu_t} - \mu_t\hat{u} \tag{A.3}$$

*(b)* $\left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 < \frac{V(\mu_t)-\hat{u}}{k}$*, the optimal* $\pi_t, \alpha_t$ *are given by*

$$\pi_t = \sqrt{\frac{V(\mu_t) - \hat{u}}{k}} \tag{A.4}$$

$$\alpha_t = 1 \tag{A.5}$$

*The entrepreneur's revenue is equal to*

$$\sqrt{\frac{V(\mu_t) - \hat{u}}{k}}\phi(\mu_t) \tag{A.6}$$

**Proof.** The lemma follows from the following maximization problem:

$$\max_{\alpha_t, \pi_t} \alpha_t \pi_t \phi(\mu_t) \tag{A.7}$$

$$\text{s.t. } V(\mu_t) - k\pi_t^2 + \frac{1-\alpha_t}{\mu_t}\pi_t\phi(\mu_t) = \hat{u} \tag{A.8}$$

$$1 \geq \alpha_t \geq 0 \tag{A.9}$$

The problem can be solved through a standard KKT approach. The FOCs associated with the resulting Lagrangian with the complementary slackness conditions then reads

$$\frac{\partial}{\partial \alpha_t} = \pi_t\phi(\mu_t) + \lambda_1\left(\frac{-\pi_t}{\mu_t}\phi(\mu_t)\right) - \lambda_2 + \lambda_3 = 0 \tag{A.10}$$

$$\frac{\partial}{\partial \pi_t} = \alpha_t\phi_t(\mu_t) + \lambda_1\left(-2k\pi_t + \frac{1-\alpha_t}{\mu_t}\phi(\mu_t)\right) = 0 \tag{A.11}$$

$$\frac{\partial}{\partial \lambda_1} = V(\mu_t) - k\pi_t^2 + \frac{1-\alpha_t}{\mu_t}\pi_t\phi(\mu_t) - \hat{u} = 0 \tag{A.12}$$

$$\frac{\partial}{\partial \lambda_2}\lambda_2 = (1-\alpha_t)\lambda_2 = 0 \tag{A.13}$$

$$\frac{\partial}{\partial \lambda_3}\lambda_3 = \alpha_t\lambda_3 = 0 \tag{A.14}$$

First, focus on the case where $\alpha_t \in (0, 1)$, such that $\lambda_2, \lambda_3 = 0$. Then straightforward calculations yield that

$$\pi_t = \frac{\phi(\mu_t)}{2k\mu_t} \tag{A.15}$$

$$\alpha_t = \frac{1}{2} + \frac{2k\mu_t^2(V(\mu_t) - \hat{u})}{\phi(\mu_t)^2} \tag{A.16}$$

And the entrepreneur's revenue equals

$$\left(V(\mu_t) + \frac{\phi(\mu_t)}{4k\mu_t^2} - \hat{u}\right)\mu_t \tag{A.17}$$

Note that $\alpha_t \in (0,1)$ requires that

$$\alpha_t > 0 \tag{A.18}$$

$$\iff \frac{\phi(\mu_t)^2}{4k\mu_t^2} + V(\mu_t) > \hat{u} \tag{A.19}$$

and

$$1 > \alpha_t \tag{A.20}$$

$$\iff \left(\frac{\phi(\mu)}{2k\mu_t}\right)^2 > \frac{V(\mu_t) - \hat{u}}{k} \tag{A.21}$$

Next, consider the possible solution with $\alpha_t = 1$. Then it follows that

$$\pi_t = \sqrt{\frac{V(\mu_t) - \hat{u}}{k}} \tag{A.22}$$

The entrepreneur's revenue then equals

$$\sqrt{\frac{V(\mu_t) - \hat{u}}{k}}\phi(\mu_t) \tag{A.23}$$

Last, consider the possible solution where $\alpha_t = 0$. Of course, this case is a minimum, as the entrepreneur's revenue is equal to 0 regardless of the choice of $\pi_t$. The choice of $\pi_t$ that maximizes the users' utility is $\pi_t = \frac{\phi(\mu_t)}{2k\mu_t}$. Then it is not possible to ensure utility $\hat{u}$ for the user if

$$V(\mu_t) - k\left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 + \frac{\phi(\mu_t)}{2k\mu_t}\frac{\phi(\mu_t)}{\mu_t} < \hat{u} \tag{A.24}$$

$$\iff V(\mu_t) + \frac{\phi(\mu_t)^2}{4k\mu_t^2} < \hat{u} \tag{A.25}$$

■

## A.B Sufficient conditions for $\bar{\mu}$ to be well-defined

In this section I first provide sufficient conditions for the existence and uniqueness of $\bar{\mu}$ and then discuss how these conditions can be weakened further. Consider the following conditions:

1. As $\mu_t \to \infty$ it holds that $g(\mu_t) - \mu_t \to 0$
2. $\psi(g(\mu_t), \hat{u}) - \psi(\mu_t, \hat{u})$ is decreasing in $\mu_t$ for all $\hat{u}$
3. $\sqrt{2kV'(\mu_t)\mu_t} < \frac{\phi(\mu_t)}{\mu_t}$ for all $\mu_t > 0$

First, I provide intuitions for the conditions.

Condition 1: It represents the idea that as the size of the platform increases, fewer new users will arrive. This condition should be satisfied in many applications, where the potential amount of users of a platform is limited.

Condition 2: The condition imposes a regularity on the difference between the revenue that the entrepreneur generates. As the platform grows, the gap between the revenue created from a platform that has grown one more time and a platform that has not, shrinks.

Condition 3: The condition requires that the growth of the network effects can be bounded by the advertisement revenue per user $\frac{\phi(\mu_t)}{\mu_t}$. To illustrate the point, consider an example with $V(\mu_t)$ constant and $\phi(\mu_t) = C \cdot \mu_t$.

**Proposition 6** *The conditions presented above are sufficient to guarantee the existence and uniqueness of $\bar{\mu}$.*

### A.B.1 Proof of proposition 6

Recall the definition of $\bar{\mu}$ as the value that solves the equation

$$\frac{1}{1-\delta}\psi(\bar{\mu}, -(1-\delta)u) = \psi(g(\bar{\mu}), \delta u) + \frac{\delta}{1-\delta}\psi(g(\bar{\mu}), -(1-\delta)u) \tag{A.26}$$

Note that at $\mu = 0$ it holds that LHS of equation $<$ RHS of the equation. Evaluating at $\mu \to \infty$ implies LHS of equation $>$ RHS of the equation. Given the continuity of all functions involved, an application of the intermediate value theorem implies existence. To show the unique cutoff, consider the first derivative of the difference of the RHS and the LHS with respect to $\mu$:

$$\text{(A.27)} \qquad g'(\mu)\psi_\mu(g(\mu), \delta u) + g'(\mu)\frac{\delta}{1-\delta}\psi_\mu(g(\mu), -(1-\delta)u) - \frac{1}{1-\delta}\psi_\mu(\mu, -(1-\delta u))$$
$$= g'(\mu)\psi_\mu(g(\mu), \delta u) - \psi_\mu(\mu, -(1-\delta)u) + \frac{\delta}{1-\delta}\left(g'(\mu)\psi_\mu(g(\mu), -(1-\delta)u) - \psi_\mu(\mu, -(1-\delta)u)\right)$$

To establish the unique cutoff, I show that this first derivative is negative. To this end, I show an intermediate result: under the assumption that $\sqrt{2kV'(\mu)\mu} < \frac{\phi(\mu)}{\mu}$ for all $\mu > 0$ it holds that $\frac{\partial \psi^2}{\partial \mu \partial \hat{u}} < 0$ for all $\mu > 0$.

**Lemma 6** $\sqrt{2kV'(\mu)\mu} < \frac{\phi(\mu)}{\mu}$ *for all* $\mu > 0$ *implies* $\frac{\partial \psi^2}{\partial \mu \partial \hat{u}} < 0$ *for all* $\mu > 0$.

**Proof.** Note that

(A.28)
$$\frac{\partial \psi^2}{\partial \mu \partial \hat{u}} = \begin{cases} -1 & \text{if } \left(\frac{\phi(\mu)}{2k\mu}\right)^2 \geq \frac{V(\mu)-\hat{u}}{k} \\ -\frac{\phi'(\mu)}{2\sqrt{k}}(V(\mu)-\hat{u})^{-0.5} + \frac{V'(\mu)}{4\sqrt{k}}(V(\mu)-\hat{u})^{-1.5}\phi(\mu) & \text{if } \left(\frac{\phi(\mu)}{2k\mu}\right)^2 < \frac{V(\mu)-\hat{u}}{k} \end{cases}$$

Therefore I focus on showing that the second case is negative:

$$-\frac{\phi'(\mu)}{2\sqrt{k}}(V(\mu)-\hat{u})^{-0.5}+\frac{V'(\mu)}{4\sqrt{k}}(V(\mu)-\hat{u})^{-1.5}\phi(\mu)<0 \tag{A.29}$$

$$\iff -2\phi'(\mu)(V(\mu)-\hat{u})+V'(\mu)\phi(\mu)<0 \tag{A.30}$$

Note that to be in this second case, $\hat{u}$ is bounded above such that $\hat{u} < -\left(\frac{\phi(\mu)}{2k\mu}\right)^2 k+V(\mu)$. Therefore, it holds that

$$-2\phi'(\mu)(V(\mu)-\hat{u})+V'(\mu)\phi(\mu) < -2\phi'(\mu)\left(\frac{\phi(\mu)}{2k\mu}\right)^2 k+V'(\mu)\phi(\mu) \tag{A.31}$$

This is smaller than 0 if

$$-2\phi'(\mu)\left(\frac{\phi(\mu)}{2k\mu}\right)^2 k+V'(\mu)\phi(\mu)<0 \tag{A.32}$$

$$\iff 2k\mu^3V'(\mu)\frac{\phi(\mu)}{\phi'(\mu)\mu}<\phi(\mu)^2 \tag{A.33}$$

Note that the assumption that $\frac{\phi(\mu_t)}{\mu_t}$ is non-decreasing guarantees that $\frac{\phi(\mu)}{\phi'(\mu)\mu} \leq 1$. This implies that the inequality below is a sufficient condition for A.33

$$\sqrt{2kV'(\mu)\mu}<\frac{\phi(\mu)}{\mu} \tag{A.34}$$

Which is the uniqueness part of the conditions. ■

Now, I revisit the initial derivative

$$g'(\mu)\psi_\mu(g(\mu),\delta u)-\psi_\mu(\mu,-(1-\delta)u)+\frac{\delta}{1-\delta}\left(g'(\mu)\psi_\mu(g(\mu),-(1-\delta)u)-\psi_\mu(\mu,-(1-\delta)u)\right) \tag{A.35}$$

Using the lemma derived above, note that $\psi_\mu(\mu,\delta u)<\psi_\mu(\mu,-(1-\delta)u)$. Thus, it holds that

$$g'(\mu)\psi_\mu(g(\mu),\delta u)-\psi_\mu(\mu,-(1-\delta)u)+\frac{\delta}{1-\delta}\left(g'(\mu)\psi_\mu(g(\mu),-(1-\delta)u)-\psi_\mu(\mu,-(1-\delta)u)\right) \tag{A.36}$$

$$<g'(\mu)\psi_\mu(g(\mu),\delta u)-\psi_\mu(\mu,\delta u)+\frac{\delta}{1-\delta}\left(g'(\mu)\psi_\mu(g(\mu),-(1-\delta)u)-\psi_\mu(\mu,-(1-\delta)u)\right) \tag{A.37}$$

Further, the assumption that $\psi(g(\mu_t), \hat{u}) - \psi(\mu_t, \hat{u})$ is decreasing in $\mu_t$ for all $\hat{u}$ implies that

$$g'(\mu)\psi_\mu(g(\mu), \hat{u}) - \psi_\mu(\mu, \hat{u}) \leq 0 \tag{A.38}$$

Using this implies that expression A.37 is smaller than 0 which finishes the proof.

### A.B.2 An example with a general growth function and linear revenues:

First off, I show that the specification of $V(\mu)$ constant and $\phi(\mu) = \mu$ with $g(\mu) = \mu + \gamma(\mu)$ and $\gamma$ being strictly decreasing, strictly positive and approaching 0 as $\mu \to \infty$ satisfy the sufficient conditions above. Clearly, as $\mu \to \infty$ it holds that $g(\mu_t) - \mu_t \to 0$ as $\gamma(\mu) \to 0$ as $\mu \to \infty$. Next, consider the difference $\psi(g(\mu_t), \hat{u}) - \psi(\mu_t, \hat{u})$. Plugging in $V$ and $\phi$ yields that $\psi(\mu_t, \hat{u})$ is a linear function of $\mu_t$. Now for the assumption to hold, consider the first derivative of the difference $\psi(g(\mu_t), \hat{u}) - \psi(\mu_t, \hat{u})$:

$$\frac{\partial}{\partial \mu_t}\left(\psi(g(\mu_t), \hat{u}) - \psi(\mu_t, \hat{u})\right) = g'(\mu_t)\psi_{\mu_t}(g(\mu_t), \hat{u}) - \psi_{\mu_t}(\mu_t, \hat{u}) \tag{A.39}$$

$$= g'(\mu_t)\psi_{\mu_t}(\mu_t, \hat{u}) - \psi_{\mu_t}(\mu_t, \hat{u}) \tag{A.40}$$

$$= \gamma'(\mu_t)\psi_{\mu_t}(\mu_t, \hat{u}) < 0 \tag{A.41}$$

The condition for uniqueness can be easily confirmed.

### A.B.3 An example with a general revenue function and growth that slows abruptly:

For another example, consider the opposite end of the spectrum. That is, consider a growth function $g(\mu)$ such that

$$g(\mu) = \begin{cases} g(0) > 0 & \text{if } \mu = 0 \\ \mu & \text{if } \mu > 0 \end{cases} \tag{A.42}$$

and arbitrary functions $V(\mu)$ and $\phi(\mu)$. Then clearly we have

$$\psi(g(\mu), \hat{u}) - \psi(\mu, \hat{u}) > 0 \tag{A.43}$$

if $\mu = 0$ and the difference equals 0 otherwise. Intuitively speaking, this growth function allows the platform to grow for exactly 1 period at the start, and then in future periods no new users arrive. Restricting the growth function in this way allows for maximum freedom regarding the functions $V$ and $\phi$.[23]

[23]Note that this definition of $g$ includes a discontinuity. To use such a $g$ in the model, one would have to extend $g$ to a continuous function or use a slightly more general definition of $\bar{\mu}$, both of which can be

To recap, the sufficient conditions rely on a balance between the convexity of the revenue function $\psi$ in relation to the growth function $g$. For the minimum degree of convexity of $\psi$, i.e., when $\psi$ is linear when $V$ is constant and $\phi(\mu) = \mu$ it is possible to allow very general growth functions $g$. On the other end, it is possible to allow very general functions $V$ and $\phi$, implying very general shapes on the revenue function $\psi$, if growth slows down extremely fast, that is, decreases to 0 within 1 period. In general, appropriate functions for $V$, $\phi$ and $g$ can be found by keeping in mind the trade-off between relatively more convex revenue functions $\psi$ (as calculated by $V$ and $\phi$) for growth functions $g$ that slow down relatively faster and vice versa.

### A.B.4 More general sufficient conditions:

What is important for the proofs in the paper is that $\bar{\mu}$ exists and is unique. For this, I have presented sufficient conditions above. However, they are not necessary. Alternatively, it is possible to assume that

$$\psi(g(\mu), \delta u) + \frac{\delta}{1-\delta}\psi(g(\mu), -(1-\delta)u) - \frac{1}{1-\delta}\psi(\mu, -(1-\delta)u) \tag{A.44}$$

is

1. Increasing up to some value $\tilde{\mu}$
2. Strictly decreasing for any $\mu > \tilde{\mu}$

This case carries the intuition that the network effects through the entry of additional users outweigh a slowdown in growth up to $\tilde{\mu}$ users. Afterward, the relationship reverses. Note that mathematically this assumption also guarantees the existence of a unique $\bar{\mu}$ and that it is more general in the sense that it contains the sufficient conditions from above for the case where $\tilde{\mu} = 0$. However, it is considerably more challenging to calculate examples that satisfy this assumption.

## A.C Proof of Proposition 1

To check for profitable deviations by the entrepreneur or the users, I employ the one-shot deviation principle (see for example Theorem 4.2 in Fudenberg and Tirole (1991)). Note that the one-shot deviation principle applies, as the game is obviously continuous at infinity.[24] Therefore, it is sufficient to check that there is no single period profitable deviation.

accommodated fairly easily.

[24]c.f. Definition 4.1 and explanation in Fudenberg and Tirole (1991): A game is continuous at infinity if for each player $i$ the utility function $u_i$ satisfies $\sup_{h,\tilde{h} \text{ s.t. } h^t=\tilde{h}^t} |u_i(h) - u_i(\tilde{h})| \to 0$ as $t \to \infty$. It is

### A.C.1 Deviations by the entrepreneur:

Consider a history of the game up to some period $t$ that results in a mass of users $\mu_{t-1}$ at the start of the period. Then there are two cases:

**Case 1($\mu_{t-1} \leq \bar{\mu}$):** First, note that deviations that increase the utility of the users are not profitable, since the equilibrium path remains unchanged and the entrepreneur's revenue is decreasing in the utility level she provides to the users. Now, consider a deviation that decreases the utility level the entrepreneur provides for the users. Given the users' strategies, a large decrease in the utility level below $-(1-\delta)u$ will cause all users to leave the platform and not be profitable. A small decrease will cause existing users to remain in the platform and newly arriving users to not join the platform. Therefore, the most profitable deviation would be to a utility level of $-(1-\delta)u$. The entrepreneur's revenue for this deviation is $\psi(\mu_{t-1}, -(1-\delta)u)$ plus the discounted revenue of the continuation of the initial strategy starting in the next period. If the entrepreneur had not deviated, she would receive the value of the continuation of the initial strategy starting this period. Note that this value depends on how many more periods the entrepreneur will grow the platform according to the initial strategy. I show that the deviation is not profitable by induction on the number of periods of future growth. First, consider the case with 1 period of future growth. Then the deviation is not profitable if

$$\psi(\mu_{t-1}, -(1-\delta)u) + \delta \left( \psi(g(\mu_{t-1}), \delta u) + \frac{\delta}{1-\delta}\psi(g(\mu_{t-1}), -(1-\delta)u) \right) \tag{A.45}$$

$$\leq \psi(g(\mu_{t-1}), \delta u) + \frac{\delta}{1-\delta}\psi(g(\mu_{t-1}), -(1-\delta)u) \tag{A.46}$$

$$\iff \frac{1}{1-\delta}\psi(\mu_{t-1}, -(1-\delta)u) \leq \psi(g(\mu_{t-1}), \delta u) + \frac{\delta}{1-\delta}\psi(g(\mu_{t-1}), -(1-\delta)u) \tag{A.47}$$

Which holds true since there is one period of future growth, i.e. $\mu_{t-1} \leq \bar{\mu}$. Now for the inductive argument, suppose that it is not profitable to deviate when there are $T$ periods of future growth. Next, I show that it is not profitable to deviate with $T+1$ periods of future growth. In the following calculation, I use the notation $g^{(T)}$ to indicate chaining the $g$ function $T$ times, i.e. $g^{(2)}(\mu_t) = g(g(\mu_t))$. A deviation with $T+1$ periods of future

---

satisfied if the overall payoffs are a discounted sum of per-period payoffs and the per period payoffs are uniformly bounded.

growth is not profitable if

(A.48)

$$
\begin{aligned}
&\psi(\mu_{t-1}, -(1-\delta)u) \\
&+ \delta \left( \sum_{s=0}^{T-1} \delta^s \psi(g^{(s+1)}(\mu_{t-1}), 0) + \delta^T \psi(g^{(T+1)}(\mu_{t-1}), \delta u) + \frac{\delta^{T+1}}{1-\delta} \psi(g^{(T+1)}(\mu_{t-1}), -(1-\delta)u) \right) \\
&\leq \sum_{s=0}^{T-1} \delta^s \psi(g^{(s+1)}(\mu_{t-1}), 0) + \delta^T \psi(g^{(T+1)}(\mu_{t-1}), \delta u) + \frac{\delta^{T+1}}{1-\delta} \psi(g^{(T+1)}(\mu_{t-1}), -(1-\delta)u)
\end{aligned}
$$

(A.49)

$$
\begin{aligned}
&\iff \frac{1}{1-\delta} \psi(\mu_{t-1}, -(1-\delta)u) \\
&\leq \sum_{s=0}^{T-1} \delta^s \psi(g^{(s+1)}(\mu_{t-1}), 0) + \delta^T \psi(g^{(T+1)}(\mu_{t-1}), \delta u) + \frac{\delta^{T+1}}{1-\delta} \psi(g^{(T+1)}(\mu_{t-1}), -(1-\delta)u)
\end{aligned}
$$

Since by induction the assertion holds true for $T$ periods of future growth, it suffices to show that the RHS of the inequality above for $T$ periods of future growth is smaller than the RHS of the inequality above for $T+1$ periods of future growth, since the LHS is identical in both cases. Thus, I have to show that

$$
\sum_{s=0}^{T-2} \delta^s \psi(g^{(s+1)}(\mu_{t-1}), 0) + \delta^{T-1} \psi(g^{(T)}(\mu_{t-1}), \delta u) + \frac{\delta^T}{1-\delta} \psi(g^{(T)}(\mu_{t-1}), -(1-\delta)u) \tag{A.50}
$$

(A.51)

$$
\leq \sum_{s=0}^{T-1} \delta^s \psi(g^{(s+1)}(\mu_{t-1}), 0) + \delta^T \psi(g^{(T+1)}(\mu_{t-1}), \delta u) + \frac{\delta^{T+1}}{1-\delta} \psi(g^{(T+1)}(\mu_{t-1}), -(1-\delta)u)
$$

$$
\iff \delta^{T-1} \psi(g^{(T)}(\mu_{t-1}), \delta u) + \frac{\delta^T}{1-\delta} \psi(g^{(T)}(\mu_{t-1}), -(1-\delta)u) \tag{A.52}
$$

(A.53)

$$
\leq \delta^{T-1} \psi(g^{(T)}(\mu_{t-1}), 0) + \delta^T \psi(g^{(T+1)}(\mu_{t-1}), \delta u) + \frac{\delta^{T+1}}{1-\delta} \psi(g^{(T+1)}(\mu_{t-1}), -(1-\delta)u)
$$

Now note that $\psi(g^{(T-1)}(\mu_{t-1}), \delta u) < \psi(g^{(T-1)}(\mu_{t-1}), 0)$. Then this implication and some rearranging yields

(A.54)

$$
\frac{1}{1-\delta} \psi(g^{(T)}(\mu_{t-1}), -(1-\delta)u) \leq \psi(g^{(T+1)}(\mu_{t-1}), \delta u) + \frac{\delta}{1-\delta} \psi(g^{(T+1)}(\mu_{t-1}), -(1-\delta)u)
$$

Which holds true since this is precisely the condition that it is optimal to grow $T+1$ times. Therefore, one-shot deviations by the entrepreneur to abuse the locked-in effect of the users are not profitable.

**Case 2($\mu_{t-1} > \bar{\mu}$):** For this case, deviations that decrease the user utility are not profitable, since they will result in all users leaving the platform and zero revenues. Now consider deviations that increase the users' utility. First, marginal increases will not change the user behavior on the equilibrium path and are not profitable. Second, the smallest deviation that changes the users' behavior on the equilibrium path is to increase the utility sufficiently to grow the platform one more time. However, by definition of $\bar{\mu}$ such deviations are not profitable when $\mu_{t-1} > \bar{\mu}$.

### A.C.2 Deviations by a user:

**Newly arriving users:** First, consider any histories on the equilibrium path. Then, there is no profitable deviation, since users are exactly indifferent between joining and not joining the platform. Now, consider deviations off the equilibrium path. For any histories that offer more utility than the equilibrium path, clearly it is still optimal to join the platform, such that not joining is not a profitable deviation. In contrast, any histories that have reduced utility imply that it is optimal to not join the platform, such that joining is not a profitable deviation.

**Users that are locked-in:** First, consider any histories on the equilibrium path. There are two cases. Before the exploitation phase begins, there are no profitable deviations since remaining in the platform provides 0 utility, while leaving gives utility $-u < 0$. During the exploitation phase, the users are indifferent between staying and leaving, such that leaving is not a profitable deviation.
Second, consider histories off the equilibrium path. Histories that result in increased user utility obviously do not offer profitable deviations. Now, consider histories such that the user's utility is reduced. Leaving the platform provides $-u$ utility, while remaining in the platform provides the user a utility level smaller than $-(1-\delta)u$ for the period in which he is alone in the platform and utility $-\delta u$ from leaving the platform the next period. Total utility is thus smaller than $-(1-\delta)u - \delta u = -u$, such that the deviation is not profitable.

## A.D Proof of Lemma 2

First, I show that the implicit function theorem is applicable in this situation. In particular, it has to be shown that the revenue function is differentiable. Clearly, it is piece-wise differentiable. However, it has to be shown that it is also differentiable at the point where the entrepreneur stops revenue sharing, i.e., when

$$\left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 = \frac{V(\mu_t) - \hat{u}}{k} \tag{A.55}$$

The two pieces of the function are

$$\mu_t V(\mu_t) + \frac{\phi(\mu_t)^2}{4k\mu_t} - \mu_t \hat{u} \tag{A.56}$$

and

$$\sqrt{\frac{V(\mu_t) - \hat{u}}{k}}\phi(\mu_t) \tag{A.57}$$

Consider differentiability regarding $\hat{u}$. The derivatives regarding $\hat{u}$ are

$$-\mu_t \tag{A.58}$$

and

$$-\frac{1}{2\sqrt{k}}\frac{1}{\sqrt{V(\mu_t) - \hat{u}}}\phi(\mu_t) \tag{A.59}$$

It is straightforward to verify algebraically that the two derivatives are equal to each other when $\left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 = \frac{V(\mu_t)-\hat{u}}{k}$

Next, I consider the derivatives regarding $\mu_t$. They are

$$V(\mu_t) + \mu_t V'(\mu_t) + \frac{2\phi'(\mu_t)\phi(\mu_t)4k\mu_t - 4k\phi(\mu_t)^2}{(4k\mu_t)^2} - \hat{u} \tag{A.60}$$

and

$$\frac{1}{\sqrt{k}}\left(\frac{V'(\mu_t)}{2}\frac{1}{\sqrt{V(\mu_t) - \hat{u}}}\phi(\mu_t) + \sqrt{V(\mu_t) - \hat{u}}\phi'(\mu_t)\right) \tag{A.61}$$

Using the identity $\left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 = \frac{V(\mu_t)-\hat{u}}{k}$ at the point of interest we can simplify the two derivatives to

$$\left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 k + \mu_t V'(\mu_t) + \frac{\phi'(\mu_t)\phi(\mu_t)}{2k\mu_t} - \left(\frac{\phi(\mu_t)}{2k\mu_t}\right)^2 k = \mu_t V'(\mu_t) + \frac{\phi'(\mu_t)\phi(\mu_t)}{2k\mu_t} \tag{A.62}$$

and

$$\text{(A.63)} \qquad \frac{1}{\sqrt{k}}\left(\frac{V'(\mu_t)}{2\sqrt{k}}\frac{2k\mu_t}{\phi(\mu_t)}\phi(\mu_t) + \frac{\phi(\mu_t)\sqrt{k}}{2k\mu_t}\phi'(\mu_t)\right) = \mu_t V'(\mu_t) + \frac{\phi'(\mu_t)\phi(\mu_t)}{2k\mu_t}$$

respectively, which are equal to each other. Therefore, the implicit function theorem applies. To shorten notation define

$$\text{(A.64)} \qquad F := \psi(g(\mu_t), \delta u) + \frac{\delta}{1-\delta}\psi(g(\mu_t), -(1-\delta)u) - \frac{1}{1-\delta}\psi(\mu_t, -(1-\delta)u)$$

and by the implicit function theorem it holds that

$$\text{(A.65)} \qquad \frac{\partial \bar{\mu}}{\partial u} = -\left.\frac{\frac{\partial F}{\partial u}}{\frac{\partial F}{\partial \mu_t}}\right|_{\bar{\mu}, u}$$

For the denominator, notice that the derivative is negative by the definition of $\bar{\mu}$.
For the numerator, notice that at $(\bar{\mu}, u = 0)$ it holds that $F > 0$. Moreover, note that the three parts of $F$ are decreasing and concave, increasing and concave, and decreasing and convex with respect to $u$ respectively. In order for $F$ to be equal to 0 at $(\bar{\mu}, u)$, the derivative of $F$ regarding $u$ has to be negative for at least some values of $u$. However, note that when the derivative of $F$ turns negative, it will remain negative. This holds, as the middle part of $F$ is increasing and concave, such that its growth slows down. When the derivative turns negative, the third part of $F$, $-\frac{1}{1-\delta}\psi(\mu_t, -(1-\delta)u)$ alone will keep the derivative negative, as $\mu_t < g(\mu_t)$. Thus, the negative slope is steeper than the positive slope of $\frac{\delta}{1-\delta}\psi(g(\mu_t), -(1-\delta)u)$. In particular, this implies that the slope of $F$ regarding $u$ at $(\bar{\mu}, u)$ is negative. Therefore, the numerator is negative and the fraction as a whole is negative.

## A.E Proof of Proposition 2

The degree of monetization follows from a simple optimization problem. Namely,

$$\text{(A.66)} \qquad \max_{\pi_t} V(\mu_t) - k\pi_t^2 + \frac{1-\alpha}{\mu_t}\pi_t\phi(\mu_t)$$

The equilibrium is confirmed by an application of the one-shot deviation principle. First, no user has an incentive to deviate in the degree of monetization in weakly dominant strategies. Second, as all users receive strictly positive utility from participation in the platform, there is no incentive to deviate into not joining.

Last, the entrepreneur's optimization problem in $t = 0$ equals

$$\max_{\alpha} \sum_{t=1}^{\infty} \left( \alpha \frac{1-\alpha}{2k} \frac{\phi(g^{(t)}(\mu_0))}{g^{(t)}(\mu_0)} \phi(g^{(t)}(\mu_0)) \right) \tag{A.67}$$

Where $g^{(t)}$ denotes the $t$-time chaining of the growth function. From this, it is straightforward to derive $\alpha^* = 0.5$

## A.F Proof of Lemma 3

Note that at $u = 0$ the strategy of the entrepreneur is to ensure 0 utility for the users in every period. Further, it holds that there is no value of $\bar{\mu}$ that makes the entrepreneur indifferent between growing the platform once more and exploiting the users in the future and exploiting the users right away. Namely, it will always be better to grow the platform as $g(\mu) - \mu \geq 0$. Therefore, at $u = 0$ the platform will grow every period, as it does with decentralized governance. However, since the choice set regarding monetization and revenue sharing is larger in centralized governance than it is in decentralized governance, her revenues are necessarily higher with centralized governance. Since the entrepreneur's revenues are continuous in $u$, this result also holds for $u > 0$, but sufficiently close to 0.

## A.G Proof of Proposition 3

Corollary 1 established that decentralized governance is preferred over centralized governance if $u$ is sufficiently large, i.e. $u > u^*$. Further, lemma 3 established that centralized governance is preferred if $u$ is sufficiently small. To derive the result of the proposition, note that the entrepreneur's revenue with decentralized governance is independent of $u$. Thus, it is sufficient to show that centralized revenue is decreasing in $u$ to prove the proposition. Now, consider the change in the entrepreneur's revenue with centralized governance as $u$ increases. Note that the entrepreneur does not exploit the locked-in effect in the first periods of growth, that is, she sets $\hat{u}_t = 0$ for all periods of growth except the last period. Now, consider the last period of growth and the following periods of exploiting the locked-in effect. Note that the size of the platform in all of those periods is the same. Then the first order effect from increasing the size of the locked-in effect is equal to

$$\delta \psi_u(\mu, \delta u) - (1-\delta) \frac{\delta}{(1-\delta)} \psi_u(\mu, -(1-\delta)u) \tag{A.68}$$

This is negative if

$$\psi_u(\mu, \delta u) \leq \psi_u(\mu, -(1-\delta)u) \tag{A.69}$$

Now there are three options to compare. They are 1) both sides of the equation are in the linear part of $\psi$. 2) The LHS is in the linear part and the RHS is in the concave part of $\psi$. 3) Both sides are in the concave part of $\psi$. The first case holds trivially. The second case holds as

$$-\mu \leq -\frac{1}{2\sqrt{k}}\frac{1}{\sqrt{V(\mu)+(1-\delta)u}}\phi(\mu) \tag{A.70}$$

$$\iff \left(\frac{\phi(\mu)}{2k\mu}\right)^2 < \frac{V(\mu)+(1-\delta)u}{k} \tag{A.71}$$

Which is a true statement, as it is precisely the condition from lemma 5 that ensured that the RHS is in the concave part of the function.

Last, I show that the inequality holds if both the RHS and the LHS of the equation are in the concave part of $\psi$.

$$-\frac{1}{2\sqrt{k}}\frac{1}{\sqrt{V(\mu)-\delta u}}\phi(\mu) \leq -\frac{1}{2\sqrt{k}}\frac{1}{\sqrt{V(\mu)+(1-\delta)u}}\phi(\mu) \tag{A.72}$$

$$\iff u \geq 0 \tag{A.73}$$

For the second order effect, note that the maximum platform size $\bar{\mu}$ is dependent on u. In particular, lemma 2 showed that $\bar{\mu}$ is decreasing in $u$. Further, the entrepreneur's revenue $\psi$ is increasing in $\mu$, such that the decrease in the maximum size of the platform decreases the entrepreneur's revenues. Thus, the total effect of an increase in $u$ on the entrepreneur's revenues is negative.

## A.H Proof of Lemma 4

Revenue from decentralizing at size $\mu$ is equal to

$$\sum_{t=0}^{T}\delta^t\frac{1}{8}\frac{\phi(g^{(t)}(\mu_t))^2}{kg^{(t)}(\mu_t)} \tag{A.74}$$

and can be approximated by

$$\frac{1}{1-\delta}\left(\frac{1}{8}\frac{\phi(\mu_t)^2}{k\mu_t}+\epsilon(\mu_t)\right) \tag{A.75}$$

and given that $g(\mu_t)-\mu_t \to 0$ as $\mu_t \to \infty$ it holds that $\epsilon(\mu_t) \to 0$ as $\mu_t \to \infty$. Revenue from staying centralized and exploiting (given that $\mu_t$ is large enough) is equal to

$$\frac{1}{1-\delta}\psi(\mu_t, -(1-\delta)u) \tag{A.76}$$

Thus, it is not sequentially optimal to remain centralized if

$$\frac{1}{1-\delta}\psi(\mu_t,-(1-\delta)u) > \frac{1}{1-\delta}\left(\frac{1}{8}\frac{\phi(\mu_t)^2}{k\mu_t}+\epsilon(\mu_t)\right) \tag{A.77}$$

$$\iff \psi(\mu_t,-(1-\delta)u) - \frac{1}{8}\frac{\phi(\mu_t)^2}{k\mu_t} > \epsilon(\mu_t) \tag{A.78}$$

Now, I show that the LHS of this inequality positive and increasing in $\mu_t$. Once that has been shown, the inequality follows, since the RHS of the inequality goes to 0 for $\mu_t$ large enough. To establish that the LHS of the inequality is positive and increasing in $\mu_t$, consider both possible cases for $\psi(\mu_t,-(1-\delta)u)$. First, consider

$$\mu_t\left(V(\mu_t)+\frac{\phi(\mu_t)^2}{4k\mu_t^2}+(1-\delta)u\right)-\frac{1}{8}\frac{\phi(\mu_t)^2}{k\mu_t} = \mu_t\left(V(\mu_t)+\frac{\phi(\mu_t)^2}{8k\mu_t^2}+(1-\delta)u\right) \tag{A.79}$$

Which is both positive and increasing in $\mu_t$. Next, consider the second case:

$$\sqrt{\frac{V(\mu_t)+(1-\delta)u}{k}}\phi(\mu_t)-\frac{1}{8}\frac{\phi(\mu_t)^2}{k\mu_t} = \phi(\mu_t)\left(\sqrt{\frac{V(\mu_t)+(1-\delta)u}{k}}-\frac{1}{8}\frac{\phi(\mu_t)}{k\mu_t}\right) \tag{A.80}$$

Note that to be in the square root part of $\psi(\cdot)$ it holds that $\frac{\phi(\mu_t)}{2k\mu_t} < \sqrt{\frac{V(\mu_t)+(1-\delta)u}{k}}$, which implies that the LHS of the equation above is positive and increasing in $\mu_t$.

## A.I Proof of proposition 4

I start by proving the first statement of the proposition. That is, I show that it is optimal to delay decentralization by at least 1 period. Suppose it is optimal for the entrepreneur to decentralize in $t=0$. Now, specifically consider the entrepreneur's revenue in $t=1$. If she delays decentralization, that is, the platform is centralized in $t=1$, she can choose optimal levels of revenue sharing $\alpha_t$ and monetization $\pi_t$ for that period, offer utility level $\hat{u}_t=0$ and users will join the platform. If she decided to decentralize in $t=0$, her revenue in $t=1$ would necessarily be lower, as the user utility level in the decentralized platform is strictly larger than 0 and the entrepreneur cannot choose $\alpha_t$ and $\pi_t$. Now, compare the entrepreneur's overall revenue from being centralized in $t=1$ and decentralized for all the future periods to the entrepreneur's revenue from decentralizing in $t=0$. Clearly, the revenues from period 2 onwards are identical. Thus, delaying decentralization for at least one period increased the entrepreneur's revenue.

Now, I prove the second statement of the proposition. Suppose that it is barely not optimal for the entrepreneur to decentralize her platform in $t=0$, that is, the present value of centralized revenues exceeds that of decentralized revenues by some small amount $\epsilon>0$. The argument made in the paragraph above shows that delaying decentralization by 1 period increases the entrepreneur's revenue by the amount with which centralized revenues exceed decentralized revenues in $t = 1$. For $\epsilon$ small enough, the present value of revenues when decentralizing in $t = 2$ now necessarily exceed those of staying centralized. Thus, the range of locked-in effects for which decentralization is optimal is increased.

## A.J Proof of equilibrium of section III.B and proof of proposition 5

### A.J.1 Proof of equilibrium of section III.B

First, consider why these strategies constitute a sub-game perfect equilibrium by checking for one shot deviations.

**Deviations by the entrepreneur:** Given the users strategies, and the fact that the entrepreneur's revenue is decreasing in $\hat{u}_t$, clearly there are no profitable deviations for the entrepreneur. Increasing $\hat{u}_t$ lowers her revenue without changing the users' behavior on the equilibrium path. Decreasing $\hat{u}_t$ causes all users to leave the platform, resulting in 0 revenues for the entrepreneur. When the entrepreneur is being punished and there are no users in the platform, the entrepreneur is indifferent between all of his choices, such that there is no inventive to deviate.

**Deviations by the users:** Consider some user $i$. Fix the strategies of the entrepreneur and the other users. For sub-game perfection, the user cannot have any incentive to (one-shot) deviate from the equilibrium strategy at any history of the game.

First, consider histories of the game such that the entrepreneur has offered at least utility level $\hat{u}_t$ in every period. Suppose user $i$ is already locked into the platform. If user $i$ leaves, his utility will be equal to $-u$. If he stays, his utility will be equal to $\sum_{t=0}^{\infty}\left(\delta^t V(g^{(t)}(\mu_t)\right) - u$ which is larger than $-u$, such that leaving is not a profitable deviation. Now consider the case where user $i$ is newly arriving to the platform. Again, his utility is $\sum_{t=0}^{\infty}\left(\delta^t V(g^{(t)}(\mu_t)\right) - u$. This will be larger than 0 for $\delta$ large enough, such that there is no incentive to deviate.

Next, consider histories of the game such that the entrepreneur is offering a utility level $\tilde{u}_t < \hat{u}_t$ in some period $t$. If user $i$ leaves, his utility will be equal to $-u$. If user $i$ stays on the other hand, his utility will be equal to

$$\tilde{u}_t - V(g(\mu_{t-1})) - \delta u \tag{A.81}$$

Staying is optimal iff

$$\tilde{u}_t - V(g(\mu_{t-1})) - \delta u > -u \tag{A.82}$$

$$\iff \tilde{u}_t > V(g(\mu_{t-1})) - (1-\delta)u \tag{A.83}$$

Which cannot hold since $V(g(\mu_{t-1})) - (1-\delta)u = \hat{u}_t > \tilde{u}_t$. Therefore, staying in the platform is not a profitable deviation for user $i$.

### A.J.2 Proof of proposition 5

First, I show the instability of the equilibrium where users coordinate on utility level $\hat{u}_t = V(g(\mu_{t-1})) - (1-\delta)u$. I compare a user's incentives to stay and leave. A user prefers to stay rather than leave if

(A.84)
$$(1-p)(V(g(\mu_{t-1})) - (1-\delta)u - \epsilon - V(g(\mu_{t-1})) - \delta u) + p\left(\sum_{t=0}^{\infty}\delta^t V(g(\mu_{t-1})) - (1-\delta)u - \epsilon\right) \geq -u$$

Where with probability $(1-p)$ the users will be the only user in the platform and receive utility $V(g(\mu_{t-1})) - (1-\delta)u - \epsilon - V(g(\mu_{t-1}))$ in that particular period, and discounted utility $-\delta u$ from future periods. With probability $p$ all other users stay and the user gets utility $V(g(\mu_{t-1}) - (1-\delta)u$ in every period, with the reduction of utility by $\epsilon$ for the current period.
The utility of staying can be bounded from below by

(A.85)
$$(1-p)(V(g(\mu_{t-1})) - (1-\delta)u - \epsilon - V(g(\mu_{t-1})) - \delta u) + p\left(\frac{1}{1-\delta}V(g(\mu_{t-1})) - u - \epsilon\right)$$

Rearranging this lower bound and comparing it to the utility of staying yields

$$\frac{p}{1-\delta}V(g(\mu_{t-1})) \geq \epsilon \tag{A.86}$$

Which holds true for $\epsilon$ small enough.

Now, consider the equilibrium presented in the main section of the paper. I compare two scenarios, i.e. the entrepreneur deviating during the growth and during the exploitation phase of the equilibrium.

Since users are always kept indifferent between joining and not joining, as well as staying and leaving, any reduction in utility offered by the entrepreneur will cause users to not join the platform / leave the platform. This holds, as if the other users unexpectedly decide to join/stay, and the user in question joins / stays, the total utility is reduced by $\epsilon$, breaking the indifference. If the other users decide to not join/leave, the utility is decreased by more than $\epsilon$.

## A.K Extension: Pre-commitment to revenue sharing path in decentralized governance

Suppose that the entrepreneur can pre-commit to the full path of revenue sharing for all periods $t = 1, 2, ...$ at the start of the game in $t = 0$. Now, note that for any pre-committed level of $\alpha_t$, the user's optimal choice of monetization $\pi_t$ is derived analogously to the optimal monetization $\pi_t^*$ for a fixed percentage of revenue sharing, and thus equals

$$\frac{1-\alpha_t}{2k}\frac{\phi(\mu_t)}{\mu_t} \tag{A.87}$$

and that the user's utility level for the period thus is

$$V(\mu_t) + \frac{1}{4k}\left((1-\alpha_t)\frac{\phi(\mu_t)}{\mu_t}\right)^2 \geq 0 \tag{A.88}$$

such that the user's choice of monetization implies that it is always optimal for new users to join. Then the entrepreneur's maximization problem in $t = 0$ is equal to

$$\max_{\{\alpha_t\}_{t=1}^{\infty}} \sum_{t=1}^{\infty}\left(\delta^t \frac{\alpha_t(1-\alpha_t)}{2k}\frac{\phi(\mu_t)}{\mu_t}\right) \tag{A.89}$$

Now, straightforward maximization over the $\alpha_t$ implies that in the optimum $\alpha_t = \alpha = 0.5$ for all $t = 1, 2, ....$

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