Utility Tokens as a Commitment to Competition*

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Abstract

We show that utility tokens can limit the rent-seeking activities of two-sided platforms with market power while preserving efficiency gains due to network effects. We model platforms where buyers and sellers can meet to exchange services. Tokens serve as the sole medium of exchange on the platform and can be traded in a secondary market. Tokenizing a platform allows a firm to give up monopolistic rents associated with the control of the platform and to make a credible commitment to long-run competitive prices. Crowd-funding through token sales or the threat of entrants can incentivize developers to tokenize platforms.

Keywords: Utility Tokens, Crowd-Funding, Blockchain, Financing.

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1 Introduction

Financial technology (FinTech) is promising to revolutionize the finance world. A key element in this vision is decentralization, aiming to break the market power of financial intermediaries and other large players in the financial industry. However, while FinTech focuses on increasing competition, the rise of technology in the economy at large is generating concerns of greater concentration of market power. Technology firms, such as Amazon, Facebook, Uber, and AirBnB, control and operate online platforms with a large network of users, often buyers and sellers of goods and services.[1] Such platforms can lead to efficiencies because of the network externalities — it is more efficient for riders and drivers when everyone is on the same ride-sharing platform — but also open the door to rent seeking and monopolistic behavior by the firms that develop and operate them. It is well known in economic theory that such rent seeking and monopolistic behavior have the potential to eliminate the welfare gains achieved from network externalities.

In this paper, we show that a financial innovation from recent years — tokens on the blockchain — can provide a solution by creating a commitment device for firms that are running platforms to maintain competitive pricing and avoid rent seeking over time. The tokens we focus on are similar to "utility" tokens that were common in the wave of Initial Coin Offerings (ICOs) that took over the world of FinTech some years ago. These are tokens that serve as the medium of exchange between buyers and sellers who meet on a platform to trade goods or services. For example, the Filecoin token is the utility token associated with the Filecoin platform, an online marketplace for file storage.[2] Filecoin is a blockchain-based interface which allows users who need additional storage to rent this space using Filecoin tokens from users who have excess storage on their devices. Importantly, while the tokens in our model are similar to the tokens in some ICOs, we highlight a few key features that are critical for them to serve the purpose of commitment to competition but were not always present in practice. For example, they have to be freely traded in a token market, where their price against an external currency fluctuates. Also, the price of goods or services on the

[1] The case of a platform like Facebook is more complicated, but has a similar spirit with a large network of advertisers and advertisees.

[2] See https://filecoin.io.

platform has to be fixed in token units.

Our model describes a firm, which runs a platform where competitive providers of services (or goods) are matched with consumers. Consumers are heterogeneous in their valuations of the service. In a benchmark model, we show that the firm acts as a monopolist. It charges consumers more than the marginal cost of service provision and reimburses service providers exactly their marginal cost of service provision. The firm can thus earn a spread from each service exchange and can fully control the quantity and pricing of the service. The firm will therefore optimally set an equilibrium price and quantity resembling that of a monopolistic service provider, rationing service to some consumers with lower valuations of it, even though service providers are perfectly competitive. Hence, the production and allocation do not maximize the surplus from services.

We then introduce tokens into this framework, such that services on the platform have to be paid for with tokens. We show that introducing tokens without a secondary market for them does not change the monopolistic outcome. The firm in this case is the sole seller and the sole redeemer of tokens. As the sole seller of tokens, it has the power to charge consumers any price for a token, and as the sole redeemer of tokens, it has full discretion over how much to pay a service provider for a token. In equilibrium, the firm will charge consumers more than the marginal cost of service provision for each token and reimburse service providers at a price per token that is equal to their marginal cost of service provision. It will then choose the same monopolistic production and allocation of services, as without tokens.

The key insight of the paper is that this outcome changes when the platform is tokenized and a secondary market for tokens exists. The fact that agents can trade tokens directly with each other commits the platform operator to give up pricing power over time. With a common marketplace for tokens, service providers, who receive tokens in exchange for their services, can resell them directly to future consumers instead of redeeming them with the platform. Therefore, each time the platform releases additional tokens, it increases the number of tokens that are sold in the future in the common marketplace, and consequently, the number of services exchanged on the platform, thereby generating competition for itself. Intuitively, in this case, we can think of the firm as having a limited stock of market power. Every time it wishes to monetize the platform, it has to create future competition for itself and uses up some of its market power. This intuition also highlights the importance of a fixed service price in token units as each time the firm sells a token (or equivalently, a certain number of service units), it also sells the right to resell that same number of service units in the future. Thus, the fixed token-to-service price helps commit to the durability of tokens over time. Without this feature, the platform would not be able to commit to give up actual market power.

With this insight, we solve for the equilibrium production and allocation of services in a dynamic framework, where the platform chooses how to release tokens over time. We show that, in the presence of a secondary market for the tokens, the platform optimally chooses to release tokens gradually, increasing the number of consumers who purchase the service over time. Eventually, enough tokens are released so that all consumers who value the service above its marginal cost of production are able to access the service. Over time, the equilibrium price of the service falls and the quantity increases, reaching levels that would occur in a competitive equilibrium. The long-run surplus is, therefore, always higher under this tokenized platform relative to that under a monopolistic platform. The intuition is that the platform can profit on a token only once, when it is released. It can enjoy monopolistic rents in an early period by releasing a limited number of tokens. Then, however, once tokens are released, the only way to continue to make profits is to release more tokens, pushing the price down and the quantity up. This leads to convergence to a competitive equilibrium.

An important question is whether having multiple platforms can improve welfare. Going back to the ride-sharing example, is there a benefit from having both Uber and Lyft? One would think this to be the case given the benefit from competition across platforms, reducing monopolistic rents. However, network externalities are also weaker when riders and drivers are spread across platforms. In this framework, we show that with network effects, a single tokenized platform provides a higher surplus than when multiple platforms compete with each other to eliminate monopolistic rent-seeking. Conditional on a particular pricing scheme, network effects make it efficient for all users to be on the same platform. By using tokens, competitive prices are achieved within a single platform, without resorting to competitive pressures across platforms. Therefore, a single tokenized platform can achieve the best of both worlds, unlike a solution with multiple platforms.

Another important question is whether firms operating platforms will have the incentive to tokenize them or whether policy intervention is needed to achieve tokenization. We show that in some cases such incentives can emerge naturally. One such case is when an incumbent platform operator is facing a threat of future entrants. Under such a threat, it may prefer to run a tokenized platform to deter entry. Another case emerges when considering the initial founding and financing of a platform. We show that if a platform developer is raising money from outside investors to start a platform, and these investors do not derive any value from consuming the services later on once the platform is operational (they only benefit from the return on their investment), the developer indeed always prefers to operate a monopolistic platform (as this generates higher returns on the investment). However, if the developer is raising money from investors who also get utility from consuming the service, she may prefer to tokenize the platform and be better off committing to long-run competition. Intuitively, consumers of the platform get higher surplus when prices are lower. In cases where consumers believe their investment may be pivotal to the platform's tokenization, they will take into account their future surplus from consuming the product as well as the return on their investment when they are funding the developer. The mechanism, therefore, gives rise to endogenous crowd-funding, in which future consumers of the tokenized platform are the only investors who can successfully fund its creation.

When such conditions do not arise, however, regulation may be needed to require large platforms to use tokenization and achieve the competitive solution. This leads to important policy implications. There has been an increased congressional focus on how best to regulate the monopolies of firms such as Facebook, Twitter and Amazon.[3] Some policy proposals recommend breaking up these companies.[4] However, in practice this may be inefficient due to network effects as users benefit from many other users being on the same platform. Our paper demonstrates an alternative way to limit the market power of large companies while preserving efficiency gains due to network effects — by requiring utility tokens. The token sale market collapsed in 2019 following many regulatory concerns and cases of fraud. However, given the benefits shown in our paper, it can be revived by, for example, introducing a special

[3]"Tech monopoly? Facebook, Google and Amazon face increased scrutiny," The Guardian, 3 June 2019.

[4]"Senator Elizabeth Warren Says 'It's Time To Break Up Amazon, Google And Facebook' — And Facebook CEO Mark Zuckerberg Fights Back," Forbes, October 2 2019.

regulatory regime for the issuance of utility tokens such as the "Token Safe Harbor" proposed by SEC commissioner Hester Pierce.[5]

In addition, while some companies already use currency on their platform similar to utility tokens, our model suggests that changes to some features of these currencies can lead to welfare gains. For example, Twitch, owned by Amazon and one of the largest live streaming platforms in the United States, has an in-app currency called Bits that users can buy at about 1.40 cents per Bit and use it to reward their favorite streamers. Streamers can redeem Bits for 1.00 cent per Bit.[6] Thus, Twitch as a sole redeemer of Bits is similar to a tokenized platform in our model without a secondary market. Our analysis suggests that establishing a secondary market for Bits trading would reduce rent seeking by the platform. This is something that regulators can require as part of a rule governing the operation of utility tokens in an attempt to gain from the economic benefits.

We extend the model in a variety of ways. In our main model, we model a single service. This assumption is well suited for some relatively homogenous services such as cloud storage but is less applicable to platforms in which consumers demand heterogeneous services. For example, for a ride-sharing platform, consumer demand may vary depending on peak/off-peak hours, distance, city of travel, etc. We extend the main model to a more general setting in which a platform allows the trade of several types of services. We demonstrate that, as in the main model, the service exchange on the platform can be organized through a single utility token which allows the firm to give up market power over time. Eventually, welfare is maximized and at the competitive level. The key is to set prices of services in token units based on an algorithm that accounts for factors, such as time, distance, and city of travel, in the ride-sharing example. The model then extends smoothly.

Another important issue in real-world platforms is the uncertainty of demand. We extend the model so that demand is uncertain in every period and our key insights continue to hold when the demand for the service is finite. We additionally show that if demand for the service grows every period and never stabilizes, it is possible that the competitive outcome may not

[5] According to the proposal, entrepreneurs would be required to file appropriate disclosures but tokens would be exempt from federal securities laws for three years since the first token sale—the time needed to achieve a level of platform decentralization that is sufficient for tokens to pass the SECâ€™s securities evaluations. The proposal is available at https://www.sec.gov/news/speech/peirce-remarks-blockress-2020-02-06.

[6] See https://www.twitch.tv/bits.

always be attained with tokens. However, the competitive outcome is more likely to obtain with tokens than without. In particular, perpetual demand growth has to be relatively high for tokenization to result in perpetually high monopolistic prices.

While our main framework translates most naturally to marketplaces whose main activity is to match buyers and sellers of products or services, it also applies to companies that focus on social media and have ad-based revenue models. Advertisers on these platforms looking to purchase ad slots constitute one side of the market while users, whose profiles advertisements are posted on, form the other side of the market. Most social media platforms are essentially subsidizing users by providing them their services for free and are selling advertising slots on their profiles. In the absence of tokens, the platform will charge monopolistic prices for the matching of advertisers to the relevant users. However, we can imagine a situation where platforms share their maintenance costs with users and, crucially, advertisers buy ad slots directly from users. In this case, our results show that introduction of tokens can help a platform commit to competitive pricing of ad slots increasing total surplus.

The commitment to competitive pricing through tokens is enabled and supported by blockchain technology. In particular, the key parameters of the platform such as the price of service in tokens and the permission to trade tokens in a secondary market constitute the computer code that is developed by the firm initially. The decision to utilize the blockchain implies that, when the platform is launched, this code is released to and adopted by all users. In order to use the platform, users run the common code on their devices. Once the platform is operational, if the firm decides to make any changes to the platform's code it will not be able to do so unilaterally. Instead, for any changes to take place, the majority of users need to reach a consensus and switch to running the new code. The firm will, therefore, need to come to an agreement with the users on any changes.[7] Thus, blockchain technology effectively commits the firm to adhere to the mechanism that is chosen when tokens are adopted.

An important feature of tokens in our framework which enables commitment to competitive pricing — a fixed token-to-service exchange rate — was not common in platforms that use utility tokens historically but has been a recent subject of interest in cryptocurrency projects. In particular, there has been a push towards asset-backed crypto-tokens in which the price of

[7] For more on decentralized consensus on blockchains, see Cong and He (2019).

a token is fixed to the value of an underlying asset. For example, a token called RealT ties the value of each token to a fixed ownership stake in a property.[8] Asset-backed cryptocurrencies are gaining in popularity with investors hoping that tying token values to assets will reduce uncertainty about the economic value of each token, thereby reducing volatility and generating stability in the cryptocurrency market. Our analysis demonstrates an additional advantage of having this feature in utility tokens in two-sided marketplaces — the facilitation of a commitment to competitive pricing.

Related literature. Our paper contributes to the nascent but rapidly growing literature that studies financing through sales of tokens and ICOs: Catalini and Gans (2018), Canidio (2018), Chod and Lyandres (2021), Chod, Trichakis and Yang (forthcoming), Cong, Li and Wang (2020), Bakos and Halaburda (2019), Malinova and Park (2018), Li and Mann (2018), Sockin and Xiong (2018), Lee and Parlour (forthcoming), Gan, Tsoukalas and Netessine (2021), Gryglewicz, Mayer and Morellec (2021).[9]

Similar to our paper, You and Rogoff (forthcoming) study secondary market tradability of tokens and conclude that non-tradable tokens result in higher revenues for a platform. However, their model is closer to a model of loyalty points, such as airline miles, since the platform is one-sided and provides the service itself rather than matching consumers and service providers. In contrast, we show that utility tokens, when tradable, never return to the platform and this creates commitment to competitive service provision in the long run.

Other papers study the economics of blockchains more broadly including the benefits and limitations of adopting cryptocurrencies as a means of payment: Yermack (2013), Chiu and Koeppl (2018), Abadi and Brunnermeier (2018), Budish (2018), Pagnotta (2022), Hinzen, John and Saleh (2021), Biais, Bisière, Bouvard and Casamatta (2019), Chiu and Koeppl (2019), Saleh (2021), Easley, O'Hara and Basu (2019), Li and Mayer (2021).[10] Complimentary

[8]See https://realt.co/.

[9]Empirical literature on token sales is also rapidly expanding, see, e.g., Davydiuk, Gupta and Rosen (2018), Adhami, Giudici and Martinazzi (2018), Amsden and Schweizer (2018), Boreiko and Sahdev (2018), Bourveau, De George, Ellahie and Macciocchi (2018), Deng, Lee and Zhong (2018), Fisch (2019), Roosenboom, Kolk and Jong (2020), Howell, Niessner and Yermack (2020), Lyandres, Palazzo and Rabetti (forthcoming), Benedetti and Kostovetsky (2021).

[10]See Chen, Cong and Xiao (2021) for an overview of the recent research into blockchain economics. See also Hu, Parlour and Rajan (2019), Liu and Tsyvinski (2021), Hinzen, Irresberger, John and Saleh (2019), and Li, Shin and Wang (2018) for empirical analysis of cryptocurrencies.

to our paper is Huberman, Leshno and Moallemi (2021) who study how transaction fees incentivize miners to support the Bitcoin network and show that, in the long run, the network serves all users. Importantly, large miners are not able to affect transaction fees unilaterally. Although our focus is on utility tokens, we also show that a tokenized platform serves all consumers in the long run. We advance this result further by explicitly modeling competition between traditional platforms and comparing the outcomes to those delivered by a tokenized platform.

Relatedly, our paper contributes to a growing literature that highlights the commitment features of the blockchain technology. In Cong and He (2019), the blockchain helps overcome barriers to entry arising from information asymmetry and increases competition by allowing entrants to commit to delivering goods. In Cong, Li and Wang (2022), the blockchain enables commitment to dynamic token supply rules for a tokenized platform, which allows for optimal investment in platform quality over time. Similar to our paper, Sockin and Xiong (forthcoming) study decentralization of digital platforms that can be achieved through tokenization. In their paper, tokens allow a platform owner to commit to give up control over the platform through decentralized governance. In contrast, our focus is on how tokens can facilitate competitive pricing. While in Sockin and Xiong (forthcoming) tokenization can lead to reduced network effects due to removal of centralized subsidies that incentivize users to join a platform, in our setting, tokenization benefits network effects since competitive pricing can be achieved on a single platform.

Our paper is also related to the literature on durable goods monopolies originated by Coase (1972). This literature shows that, under some conditions, including a continuous infinite timeline and patient enough consumers, a durable goods monopolist charges competitive prices and immediately saturates the market due to competition with her future self. Similarly, in our paper, commitment to the tradability and durability of tokens creates competition for the firm in future token markets.[11] An important difference is that the service purchased with tokens is non-durable and consumers demand the service in every period. Even though the token is durable, there is no inherent convenience yield from holding a token and consumers

[11] In our model, as in Bulow (1982), if the durability and tradability of tokens is restricted the firm maintains market power.

have to exchange the token for the non-durable service to obtain utility. This difference results in long-run competitive pricing in a finite horizon model even if agents are infinitely patient. This difference also implies that commitment to token supply would not help the firm extract more rents.[12]

Our paper also contributes to the literature on inefficiencies and remedies in markets with natural monopolies (see Braeutigam, 1989, for a review). One strand of this literature relates to private market solutions without the need for government intervention. Papers in this literature (e.g., Chamberlin, 1989; Demsetz, 1968) focus on competition *for* the market rather than competition *within* the market. In our paper, we establish that, if platforms exhibit network effects, competition within a token market of a single tokenized platform delivers higher total welfare than several competing non-tokenized platforms. A second strand of the literature focuses on regulation of prices charged by a monopolist. Willig (1978) shows that non-linear tariffs in which consumers are charged different amounts for a good depending on how many units of the good they buy can lead to the first-best welfare and generate Pareto-improvements. In our paper, consumers, whose types are private, demand only one unit of the service each period and, therefore, non-linear tariffs cannot be used to improve efficiency.

Finally, our paper also relates to the work on the role of money in facilitating trade among agents (see Lagos, Rocheteau and Wright, 2017, for an overview). In these models, money is a good that does not have any intrinsic consumption value but it is used to facilitate trade when barter is inefficient. The models typically feature a double-coincidence of wants problem — i.e., when agents meet directly it is unlikely that one agent's production good is another agent's consumption good and vice versa. Money serving as a medium of exchange can help overcome the lack of coincidence of wants. In our framework, tokens are similar to "money" as they have no intrinsic value but are used only to exchange services on a platform. We differ in the underlying inefficiency that tokens help solve. We assume away the double coincidence of wants problem as a platform can match consumers with service providers ensuring that a match always results in a trade. In our model, the inefficiency arises due to the firm's monopoly power over the matching technology since consumers and providers

[12] Section 6 discusses the connection of our model with models of durable goods monopolies in more detail.

cannot meet outside the platform to trade directly. We show that this monopoly power is eroded over time due to tradability of tokens.

The rest of this paper is organized in the following way. In the next section, we setup and analyze the model. We discuss a benchmark model to highlight the main friction without utility tokens and then introduce the model with utility tokens. Section 3 introduces network effects and platform competition and discusses when tokenization results in a superior outcome to competing platforms. Section 4 discusses when a platform developer may have private incentives to adopt tokens. Section 5 extends the main model by introducing multiple service types and demand uncertainty into the model. Section 6 discusses how our model relates to durable goods monopolist models, the importance of the fixed token-to-service price, the parallels of our framework to existing token markets, the application of the model to platforms with ad-based revenue models and the commitment enabled by blockchain technology. The last section concludes. All proofs are in the Appendix.

2 Model Setup

The model comprises of T periods. There are three types of agents: a long-lived firm who operates a platform which matches service providers and consumers, long-lived service providers who produce a service and can sell it on the platform, and long-lived consumers who value the service and can buy it on the platform. All agents are risk-neutral and have a common discount factor $\delta \leq 1$.

2.1 Benchmark Model

We first setup a benchmark model without utility tokens and describe its equilibrium. In Section 2.2, we introduce tokens to the model and analyze how the equilibrium changes.

2.1.1 Platform and Agents

The platform is initiated by the firm at the beginning of the first period, $t = 1$, and matches consumers with service providers in all periods $t \geq 1$. We assume that the service can only be purchased through the platform and there is no other way for service providers to match with consumers looking for the service.[13] This assumption is the key friction that allows the firm to earn monopoly rents in the benchmark model.

Service providers: A unit mass of service providers can access the platform and sell their service. Their marginal cost of producing a unit of the service is c.

Consumers: There is a unit mass of consumers who each value only a single unit of the service per period. Consumers are composed of $N \leq T$ types. Each period t, a consumer of type i values a unit of service at $v_i \in [\underline{v}, \overline{v}]$ where $\delta \underline{v} \geq c$.[14] Without loss of generality, v_i is decreasing in i with $v_1 = \overline{v}$ and $v_N = \underline{v}$. The mass of type i consumers is equal to α_i and, therefore, $\sum_{i=1}^{N} \alpha_i = 1$. We assume that consumers are deep pocketed and, as such, unconstrained in their ability to pay for the service.

Firm's Problem: Each period t, the firm decides how many units of service, Q_t, to sell to consumers. Define p_t as the highest price the firm can charge consumers such that the market clears (i.e., the price at which consumers demand Q_t units of the service). The firm also decides at what price to reimburse service providers. Since service providers are competitive and produce the service at constant marginal cost c, the firm will optimally reimburse them at c per unit of service provided. The firm therefore chooses Q_t to maximize its profits and solves,

$$\max_{\{Q_t\}_{t=1}^{T}} \quad \sum_{t=1}^{T} \delta^{t-1} Q_t \cdot (p_t - c). \tag{1}$$

Definition (Equilibrium)**.** *A subgame perfect equilibrium of this model is given by the number of services Q_t (and the associated prices p_t) that the firm sells in each period t to solve (1) subject to the optimal actions of: i) consumers, who buy services whenever the price p_t is weakly below their value of the service; and ii) service providers, who provide services in all periods and are reimbursed at a price c.*

[13] Matching, in this case, can be more sophisticated than consumers and service providers simply being able to meet. Matching can involve using the platform's technology to facilitate the provision of a service. For example, on a platform that connects users looking for taxi rides, matching involves mapping technology and optimization to connect each user with the closest driver. We also assume away the problem of platform leakage, i.e., a pair of a provider and a consumer who matched at least once on the platform cannot use the related information to meet outside the platform.

[14] This assumption ensures that there are gains from trade between lowest-type consumers and service providers.

2.1.2 Equilibrium Analysis

The firm's multi-period problem (1) separates into T identical one-period problems, in which the firm trades off rents extracted from serving higher consumer types versus rents collected from serving a larger number of consumer types at a lower price. Irrespective of discounting, the firm determines the marginal consumer type that is served each period:

$$i_m = \arg\max_i \sum_{j=1}^{i} \alpha_j (v_i - c). \tag{2}$$

Accordingly, in every period t, the firm sells $Q_t = \sum_{j=1}^{i_m} \alpha_j$ services for the price $p_t = v_{i_m}$ to consumers and reimburses service providers at the price c.

In the benchmark model, Only a fraction $\sum_{j=1}^{i_m} \alpha_j$ of consumers are able to acquire the service every period. The remaining consumers are effectively priced out and are not able to obtain the service. Therefore, the firm acts like a monopolist who finds it optimal to exlude some consumers from the market. In the benchmark, there are thus gains from trade between consumers and service providers that are not realized since some consumers who value the service above its marginal cost are not able to purchase it.

2.1.3 Key Friction

If consumers and service providers could meet with each other directly without the platform, the equilibrium price of the service and the quantity of it exchanged would be equal to those in a competitive market such that every consumer who values the service above its marginal cost of provision would be able to obtain the service.

The main friction of the model arises because consumers and service providers can only match with each other if they use the platform developed by the firm. The platform's exclusive matching technology generates monopoly power for the firm. Indeed, as we have shown above, the firm finds it optimal to restrict the supply of the service sold on the platform which effectively excludes some consumers. We model the firm as determining the quantity of service sold in each period and reimbursing service providers accordingly. Alternatively, the firm could exercise its monopoly power by directly limiting consumer access to the platform. If granted access to the platform, consumers are freely matched with providers and can obtain

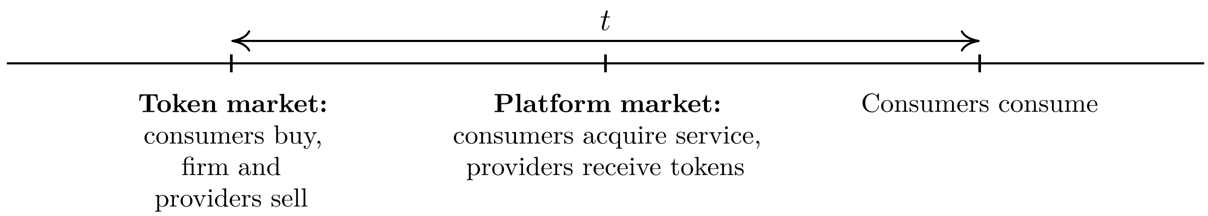

Figure 1: Sequence of events during a period t.

the service at competitive prices. Under this arrangement, the entrepreneur is able to extract monopoly rents by selling platform access to consumers at prices that are too high for some of them.[15]

2.2 Model with Tokens

We now introduce tokens to the model. The platform is designed such that tokens are the only means of payment on the platform. Each token can be exchanged for 1 unit of the service.[16] Thus, in order to acquire the service, consumers have to obtain tokens first. Each period t, there is a token market, in which the firm, the only agent who can create tokens, and service providers, who may hold tokens they received as payment for their services, sell tokens to consumers for a price p_t that is determined in equilibrium. Note, with a slight abuse of notation, p_t is now the price of a token in the token market. Since each token can be exchanged for one unit of service, p_t is also the price of the service at time t in numeraire. The sequence of events during a period t is summarized in Figure 1.

Service providers accept tokens at t as payment for the service knowing that they can resell the tokens in the next period, at $t+1$. We also assume that service providers can redeem their tokens with the firm for a price c at the end of each period, which is just enough to make tokens a credible medium of exchange on the platform in a finite horizon model. It also ensures that the firm has no incentives to release an amount of tokens that would

[15] Specifically, the firm would charge a price $p_t = v_{i_m} - c$ for platform access while consumers on the platform would spend an additional c, the competitive price charged by service providers, to obtain the service.

[16] The exchange rate between tokens and the service being equal to 1 is without loss of generality. However, as we discuss later, it is important that the rate is fixed.

push the token price below the marginal cost of service provision.[17] We assume that service providers have a weak preference for selling tokens to consumers over redeeming them with the firm when their payoff from both actions is the same.

Firm's Problem: Each period t, the firm decides how many tokens, $q_t \geq 0$, to sell to consumers in the token market. With a slight abuse of notation, we define the total number of tokens released by the firm up to date t as $Q_t = \sum_{s=1}^{t} q_s$. In the benchmark model, we used Q_t to represent the amount of services the firm decides to sell to consumers at time t. Here, we choose the same notation because we later show that the total number of tokens (which are subsequently exchanged for units of service) sold in the token market in every period t is Q_t.

Importantly, the firm understands that the amount of tokens it decides to release each period will affect the current token price as well as future token prices. Thus, the firm solves the following problem

$$\max_{\{q_t\}_{t=1}^{T}} \quad \sum_{t=1}^{T} \delta^{t-1} q_t \cdot p_t(q_1, ..., q_T) - \delta^{T-1} \sum_{t=1}^{T} q_t \cdot c. \tag{3}$$

The first term in the firm's problem is the discounted sum of revenues from tokens sold each period while the second term is the amount it is committed to pay to service providers in the final period when they redeem their tokens.[18] As with the service price in the benchmark model, we assume that the price of tokens in the token market is given by the value of the marginal buyer.

Definition (Equilibrium)**.** *A subgame perfect equilibrium of this model is given by the number of tokens q_t (and the associated token prices p_t) that the firm sells in each period t to solve (3) subject to the optimal actions of: i) consumers, who buy tokens whenever the price p_t is weakly below their value of the service; and ii) service providers, who can participate in the common token market or redeem tokens with the firm at a price c in all periods.*

[17] The assumption of redemption of tokens at a price of c with the firm can be relaxed in an infinite horizon model. However, then, the firm must commit to a fixed token supply at $t = 0$ to not have an incentive to saturate the market with tokens.

[18] We show that in the equilibrium service providers only redeem tokens with the firm in the final period.

2.2.1 Example with $T = 2$ and $N = 2$

To illustrate the intuition behind our main results that tradable tokens reduce the monopoly power of the firm, we start the analysis with an example, in which we set $T = 2$ and $N = 2$. Thus, the platform operates for two periods and there are two types of consumers. We refer to the two consumer types as high-type (H) and low-type (L). Their respective values of the service are v_H and v_L, where $v_H > v_L \geq \frac{c}{\delta}$. Additionally, in most of our analysis, we assume that $\delta = 1$ and only briefly discuss how results change when $\delta < 1$.[19]

Benchmark Model without Tokens: As we have shown above, if the platform operates without tokens, the firm finds it optimal to sell the same quantity of service in all periods. In particular, it will choose $q_1 = q_2 = \alpha_H$ units of the service, serving only high-type consumers, for a price $p_1 = p_2 = v_H$ if

$$\alpha_H(v_H - c) \geq v_L - c. \tag{4}$$

In this case, extracting the maximum rents from high-type consumers is more profitable than selling to both high- and low-type consumers. Thus, there is under-provision of the service. The firm's total profit over the two periods is $2\alpha_H(v_H - c)$. If condition (4) does not hold, the firm will optimally sell $q_1 = q_2 = 1$ units of service, serving both types of consumers for a price $p_1 = p_2 = v_L$. We focus on the more interesting case when (4) holds as this is when the firm's monopoly power leads to lower total welfare compared to a competitive market.

Model with Non-Tradable Tokens: We can show that the outcome in the benchmark model can be replicated by the firm if it operates with tokens but makes them non-tradable. Indeed, assume that there is no secondary market for tokens in which service providers, who have been paid in tokens for their service, can resell tokens directly to consumers. This implies that providers' only option is to redeem their tokens with the firm in every period. Thus, the firm is the sole seller and redeemer of tokens.

As the firm gets back all tokens it sells in a period at the end of that period, its choice q_t is the same in both periods. Thus, The firm can simply replicate the monopoly outcome by selling α_H tokens for a price v_H in the first and the second period while redeeming the tokens at a price c. At this price, only high-type consumers will buy tokens and exchange them

[19]See Appendix C for a complete analysis of the example with $\delta < 1$.

for the service each period. Service providers will accept the tokens as payment since they can redeem them with the firm and just recover their cost of service provision. Therefore, non-tradable tokens do not reduce the monopoly power of the firm.

Model with Tradable Tokens: We now show that when tokens are tradable in a secondary market open to service providers, the firm's monopoly power is gradually weakened. In this case, while the firm is the only seller of tokens at $t = 1$ when the platform is initiated, this is no longer the case at $t = 2$. Specifically, if the firm sells q_1 tokens at $t = 1$ to consumers, the consumers exchange these tokens for the service at $t = 1$. At $t = 2$, service providers sell q_1 tokens, that they received from consumers in exchange for the service at $t = 1$, in the token resale market. This implies that consumers purchase tokens at $t = 2$ both from the firm and from providers who are competing with each other in the token market.

Since the platform operates for two periods, the firm is committed to redeem all tokens owned by service providers for c at the end of $t = 2$. Absent such a commitment, in a finite horizon model, tokens have no value after $t = 2$ and, thus, cannot act as a credible medium of exchange.[20]

Depending on the firm's token release schedule, there are three candidate equilibrium price schedules p_t:[21]

1. If $q_1 \leq \alpha_H$ and $q_2 \leq \alpha_H - q_1$, the equilibrium price in both periods is high, $p_1 = p_2 = v_H$.

2. If $q_1 > \alpha_H$, the equilibrium price in both periods is low, $p_1 = p_2 = v_L$.

3. If $q_1 \leq \alpha_H$ and $q_2 > \alpha_H - q_1$, the equilibrium price is high in the first period and it is low in the second period, $p_1 = v_H$ and $p_2 = v_L$.

Note that the third case is never an equilibrium in the benchmark model since the firm's problem is identical in each period in the benchmark. Thus, the optimal price will either always be high v_H or always be low v_L. In contrast, we show that with tokens, the equilibrium

[20]The absence of the commitment will cause service providers to refuse the provision of service at $t = 2$. This will cause the market for tokens to break down at the start of the period as consumers will not want to purchase tokens they cannot exchange for the service. This will further cause the market to break down at $t = 1$ as service providers will know that tokens will be worthless at $t = 2$.

[21]Note that the firm never wants to release tokens such that $q_1 + q_2 > 1$, since this would cause the market price to fall to c which is not profitable for the firm since it is committed to redeeming tokens for c.

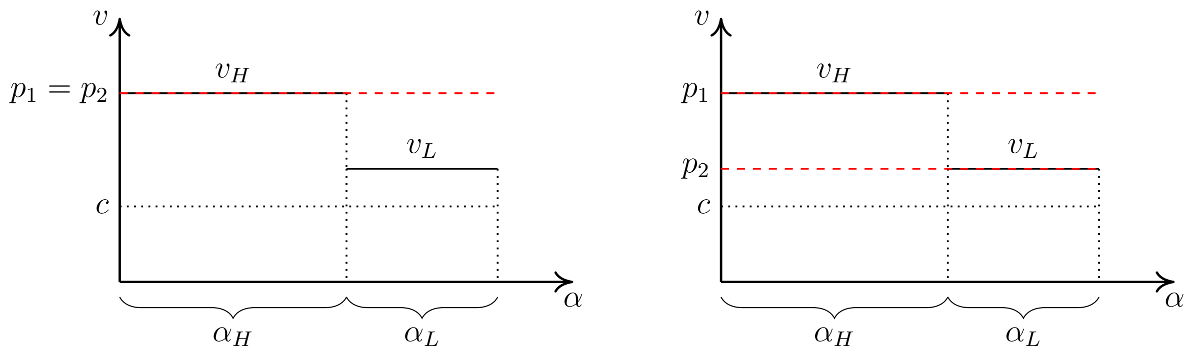

Figure 2: Token prices in the two periods (dashed lines) in the benchmark model (left), and in the model with tokens (right).

price schedule follows the third case above, in which the token price is v_H at $t = 1$ and it falls to v_L at $t = 2$.

In particular, consider the first candidate price schedule, in which there is a high price for tokens in both periods. It is optimal for the firm to issue the maximum amount of tokens possible that can be sold at this price, i.e., $q_1 + q_2 = \alpha_H$. Therefore, the firm's total profit over the two periods is $\alpha_H(v_H - c)$. The firm can do strictly better by selling all α_H tokens at $t = 1$ and selling an additional $(1 - \alpha_H)$ tokens at $t = 2$ since such a token release schedule would yield a total profit of

$$\alpha_H v_H + (1 - \alpha_H)v_L - c > \alpha_H(v_H - c). \tag{5}$$

Next, consider the second candidate price schedule, in which there is a low price for tokens in both periods. Again, it is optimal for the firm to issue the maximum amount of tokens possible that can be sold at this price, i.e., $q_1 + q_2 = 1$. Therefore, the firm's total profit over the two periods is $v_L - c$. The firm can do strictly better by selling α_H tokens at $t = 1$ and $(1 - \alpha_H)$ tokens at $t = 2$. Such a token release schedule allows the firm to make v_H instead of v_L on the first α_H tokens sold. Therefore, the equilibrium features the third price schedule (see Figure 2).

There are two key factors affecting the firm's token release schedule and token price. First, each time the firm wants to monetize the platform by selling additional tokens, it increases competition for itself with service providers in the token resale market in subsequent periods.

Indeed, any tokens released by the firm will be subsequently resold by service providers. Over time, as the total quantity of tokens in circulation grows, competition in the resale market increases, reducing the price of tokens.

Second, the firm can only profit from each token once, since any released tokens will be subsequently resold by service providers but not the firm. Thus, the firm gradually sells tokens, progressively lowering their price, in order to extract the maximum possible rent from each token. Intuitively, we can think of the firm as having a limited stock of market power that eventually runs out.

As a result, in the equilibrium, not every consumer is served at first but, eventually, everyone who values the service more than its marginal cost will be able to obtain the service. Absent discounting when $\delta = 1$, such a competitive allocation of the service is reached in exactly two periods. As we show in the analysis of the general model with N types, this competitive outcome is reached in exactly N periods when $\delta = 1$.

When $\delta < 1$, the firm might choose to sell tokens to multiple consumer types at once, thus lowering the price faster.[22] In the example, the firm prefers to release tokens to both consumer types at $t = 1$ if $v_L > \alpha_H v_H + \delta(1 - \alpha_H)v_L$. A smaller δ can, therefore, speed up the process of getting to the competitive allocation of the service. In the general model, this competitive outcome is reached in *at most* N periods.

2.2.2 Equilibrium Analysis

We now consider the general model setup, which lasts T periods and has N consumer types. The total supply of tokens sold in the token market at every period t is Q_t. In particular, this is the case because service providers and consumers have no incentives to hoard tokens in order to sell or redeem them in future instead of doing so at the earliest opportunity.[23] Of this total supply, $q_t = Q_t - Q_{t-1}$ are tokens that are newly sold by the firm, and the remaining Q_{t-1} are tokens that are sold by service providers and have been in circulation before.

[22] See Appendix C for a complete analysis of the example with $\delta < 1$.

[23] Since service providers are competitive, they cannot manipulate the price of tokens. We show that in equilibrium, the price of tokens weakly decreases over time. Therefore, service providers want to sell tokens as soon as possible. Similarly, consumers have no incentive to hoard tokens and delay consumption.

The equilibrium in the full model is similar to the example. When $\delta = 1$, the firm finds it optimal to release $q_t = \alpha_i$ tokens in period $t = i$, where α_i is the mass of consumers who have the highest value for the service among consumers who have not yet obtained the service before this period. Specifically, at $t = 1$, the firm releases α_1 tokens, which is equal to the measure of consumers who have the highest value for the service, and the resulting token price is $p_1 = v_1 = \overline{v}$. At $t = 2$, providers sell these tokens, received as payment for their service in the first period, and the firm releases an additional α_2 tokens. As a result, the token price falls to the new level $p_2 = v_2$. This gradual release of tokens continues until period N, in which the firm sells tokens to the group of consumers who value the service the least and the token price falls to $p_N = v_N = \underline{v}$. By employing this delayed token release schedule, the firm is able to maximize its profit. When $\delta < 1$, the firm discounts future revenues and may choose to release new tokens to more than one type of consumers in a given period.

Proposition 1. *In the model with tokens, there is a unique equilibrium, in which the total quantity of tokens released Q_t increases over time while the token price p_t decreases over time. With N different consumer types, the competitive outcome in the token market is achieved in exactly N periods if $\delta = 1$. If $\delta < 1$, the competitive outcome is achieved in at most N periods.*

Intuitively, the firm has a limited stock of market power when it adopts utility tokens that can be traded freely.[24] Whenever the firm wants to monetize the platform by selling tokens, it also necessarily creates competition for itself in future token resale markets, as more tokens will be resold by service providers. The more tokens the firm sells, the less market power it has in the token markets going forward. As time passes, a competitive outcome is eventually reached in this market, in which all consumers who value the service above its marginal cost of provision are able to obtain a token and, therefore, the service. Thus, utility tokens enable commitment to a long-run competitive outcome.

[24] The firm is not able to profitably buy back any tokens to regain market power. Suppose that was an equilibrium strategy, then the decreased amount of tokens in circulation, due to a buyback, leads to higher expected token prices in the future. In turn, higher expected token prices place a lower bound on the price at which providers are willing to sell tokens back to the firm making buybacks unprofitable.

2.2.3 Utility Tokens as a Solution to the Key Friction

As discussed previously, the key friction of the model arises because consumers and service providers cannot match with each other directly to exchange the service. Instead, they must use the platform developed by the firm. This allows the firm to exercise monopoly power since it controls access to the platform and, therefore, can restrict the supply of the non-durable service.

When the service on the platform is exchanged through utility tokens, the tokens can be thought of as durable access keys to the platform. In this case, the firm resembles a classic durable goods monopolist who has to compete in the resale market. The firm slowly loses control over access to the platform as it sells more and more access keys, which resolves the main friction in the long-run. Specifically, in this scenario, service providers can be seen as competing with the firm in the market for the access to the platform. As we have shown, this market gradually reaches the competitive outcome and, thus, the access to the platform becomes unrestricted.

Two features of utility tokens are key to achieving the competitive outcome in the long run. First, there must be a resale market for tokens. Absent a token resale market, the firm maintains complete control over access to the platform. In this scenario, consumers can only buy tokens from the firm and providers can only redeem tokens with the firm. This allows the firm to regain all tokens each period and gives it full control over how many tokens are sold and consequently, how much of the service will be exchanged on the platform. Essentially, the firm becomes a durable goods monopolist who can rent out their good — platform access — each period. The firm therefore preserves its monopoly power.

Second, tokens must allow transfer of the service between providers and consumers at a fixed exchange rate. This feature ensures that every time the firm sells a token — an access to a unit of the service — a service provider will get to sell this access in the future. This feature imparts durability to the ability to exchange the service, even though the service itself is non-durable. If, instead, service providers were competing on how many tokens they require in exchange for service provision, the market power would remain with the firm. Appendix B illustrates this point by allowing a floating token-to-service price in the example.

Section 6 further discusses the importance of this assumption in generating durability.

2.3 Profits and Welfare

We now compare the firm's profits and total welfare in the model with tokens to the benchmark model. To help distinguish the two scenarios, we refer to the platform in the benchmark model as a *monopolistic* platform and the platform in the model will tokens as a *tokenized* platform.

Proposition 2. *A monopolistic platform earns higher profits than a tokenized platform.*

The firm can profit from each token only once when it operates a tokenized platform. With a monopolistic platform, on the other hand, the firm earns continued profits as it maintains its market power every period. Indeed, in this scenario, the firm can choose, if it wishes, quantities and prices of the service to replicate those of a tokenized platform. However, it is more profitable for the firm to follow the alternative strategy described in the equilibrium of the benchmark model.

With tokens, competitive pricing, which maximizes the total per-period surplus is always achieved in equilibrium. However, this outcome is reached only after some time. If the monopolistic platform makes enough profit by providing a large mass of consumers with the service, the total welfare in the benchmark model may be higher. Specifically, the per-period surplus will be lower under a tokenized platform relative to that under a monopolistic platform for the first i_m periods. Formally, when $\delta = 1$, we can establish the following proposition.

Proposition 3. *The total welfare under a tokenized platform is higher than the total welfare under a monopolistic platform when the number of periods T is sufficiently high. The opposite is true if T is small and i_m is high, i.e., when the monopolistic platform serves a relatively large mass of consumers.*

If $\delta < 1$, the qualitative results are similar but there are two additional forces. On the one hand, the competitive outcome in the token market is reached sooner and, therefore, total welfare is more likely to be higher under a tokenized platform. On the other hand, the discounted surplus from future periods contributes less to the total surplus and the initially higher price reduces welfare under the tokenized platform compared to that under the monopolistic platform.

3 Platform Competition under Network Effects

In the previous section, we have shown that the introduction of utility tokens to the platform can reduce monopolistic rents extracted by the firm. Another potential, and more traditional, mechanism of reducing rents is through competition between platforms. In this section, we compare the relative efficiency of the two approaches in the presence of network effects. Specifically, we model such competition and study how the welfare under a tokenized platform compares to the welfare generated by two competing platforms that operate as in the benchmark model without tokens. In the following analysis, the two competing platforms are called *standard* as opposed to a *tokenized* platform of our main model.

We establish that in the presence of network effects, a tokenized platform delivers higher total welfare than two competing standard platforms. Intuitively, if network effects are positive, it is efficient to exchange the service on a single platform. Although competition between platforms reduces their rents, compared to the monopolistic scenario, it also implies that consumers are spread across multiple platforms, which can lead to lower total welfare when the network effects are significant. In contrast, by employing tokens, it is possible to obtain competitive prices within a single platform without splitting consumers between platforms. Therefore, a single tokenized platform delivers the highest total welfare in the long run.

Formally, we model network effects in the following way. We assume that a higher mass of consumers on a platform leads to a higher value of service unit for each consumer. For instance, the more riders and drivers that use a single ride-sharing platform, the easier it is to optimize matching efficiency and minimize waiting times for rides. In particular, a consumer of type i values a unit of the service at

$$v_i + b(\alpha), \tag{6}$$

where the network benefit $b(\alpha)$ is a strictly increasing function on $\alpha \in [0,1]$ and α is the mass of consumers on a given platform.

Proposition 4. *If the platform exchange exhibits network effects, the welfare under a tokenized platform in the long run (i.e., if T is sufficiently greater than N) is higher than the welfare under two competing standard platforms.*

To explain the intuition behind this result, we compare the equilibrium masses of consumers served in the two scenarios. As we noted in the analysis of the main model, in the *long run* a tokenized platform operates at full capacity — the price in the token market is set competitively so that all consumers are able to obtain the service. Therefore, as the total mass of consumers is equal to 1, the network benefit that each consumer enjoys is equal to $b(1)$.

In contrast, consider two standard platforms that compete à la Bertrand by setting the price of the service. In the unique symmetric equilibrium, prices on the platforms are equal to the marginal cost of the service provision c. Indeed, if this was not the case, one of the platforms would find it optimal to undercut another one by price. As in the case of the tokenized platform, all consumers are able to obtain the service. However, since the prices are the same on the two platforms, the consumers are split evenly between the two. Therefore, the mass of consumers served by each platform is equal to $1/2$ and the network benefit that each consumer enjoys is equal to only $b(1/2)$.

When the network effects are absent, i.e., $b(\alpha)$ is constant, the two standard platforms achieve the same outcome and welfare as the tokenized platform in the long run. However, when the network effects are positive, $b(1/2) < b(1)$, the long run welfare generated by the tokenized platform is higher.

Compared to the benchmark case of a monopolistic platform, rents are fully dissipated when platforms are competing. However, consumers are inefficiently split between several platforms. In fact, it can be shown, that if network effects are strong enough, a monopolistic platform is welfare superior to competing platforms. In this case, the efficiency gains due to network effects are higher than the efficiency gains due to competition between platforms. In contrast, a tokenized platform can eliminate monopolistic rents while maintaining all consumers on the same platform. Indeed, even if network effects are small but positive, welfare under the tokenized platform is higher than that under competing platforms given a long enough time horizon.

4 Incentives to Tokenize Platform

We now explore the firm's incentives to tokenize its platform. Since, as we have shown in our main analysis, profits are higher when the firm operates as a monopolist, it might seem that the only way to achieve the welfare-superior outcome of a tokenized platform is through a policy mandate. Contrary to this conclusion, in this section, we demonstrate that, the firm might have private incentives to build and operate a tokenized platform. First, we show that a firm may voluntarily choose to run a tokenized platform to prevent the entry of a competitor. Second, we establish that incentives to tokenize can arise even in the absence of competition if they are provided before the platform is developed — during fundraising.

4.1 Future competition

The analysis of the previous section can be extended to show how potential future competition can create incentives to tokenize a platform. We focus on the case when network effects exist but are not too large. As discussed in Section 3, in this case, two standard competing platforms deliver higher welfare than a monopolistic platform because platform rents are dissipated under competition. However, as long as some network effects exist, a tokenized platform delivers higher welfare than two standard competing platforms because it eliminates rents while preserving gains from network effects. The consumer surplus in the three scenarios can be ordered similarly.

Corollary 1. *If the platform exhibits network effects, the long-run consumer surplus on a tokenized platform* CS_t*, the long-run consumer surplus on standard competing platforms* CS_c*, and the long-run consumer surplus on a monopolistic platform* CS_m *are such that* $CS_t > CS_c > CS_m$*.*

Now, consider a setting of a monopolistic platform that faces potential future competition.

Since the consumer surplus delivered by two competing platforms CS_c is higher than the surplus in the scenario with the monopolist CS_m, once the second platform is established, consumers will find it profitable to leave the monopolistic platform and join the competing platform. In this case, the monopolist would want to lower prices to deter entry. However, as in the benchmark model, the monopolist cannot credibly commit to keep prices low in the long run if all users are on its platform, making it difficult to credibly deter entry.

In contrast, a platform can credibly commit to keeping prices low, thereby deterring entry of the competing platform, through the adoption of tokens. Indeed, since the consumer surplus delivered by two competing platforms CS_c is lower than the surplus in the scenario with the tokenized platform CS_t, consumers will not find it optimal to leave the tokenized platform in order to join the competing platform. Thus, the competing platform will not have incentives to enter the market.

4.2 Endogenous Crowd-Funding

In this section, we show that incentives to tokenize a platform might arise before the platform is developed — during fundraising. Importantly, such incentives can only arise if the investors funding the platform also get utility from consuming the service that will be available on the platform in the future.

Specifically, we extend our main model by adding a financing stage at the beginning of $t = 1$. At this stage, the developer of the platform needs to raise an investment I and can choose between operating a monopolistic platform without tokens or tokenizing the platform. We first consider the developer's choice when raising money from investors who do not value consuming the service on the platform through an equity contract. Next, we consider the developer's choice if she can raise money from investor-consumers who value consuming the service on the platform once operational. In particular, we model a token sale in which the developer can pre-sell tokens to investor-consumers if raising money to develop a tokenized platform.[25] If the fundraising is successful, service providers and consumers can

[25] We can show that for a tokenized platform when selling to investor-consumers, an equivalent result obtains if the developer writes an equity contract instead of pre-selling tokens. We focus on the sale of tokens rather than an equity contract to map the model more closely to ICOs in practice. Appendix D shows this equivalence in the example.

access the platform at $t = 1$ and the economy continues as in the main model. Additionally, we normalize the rate of return on outside investment options for all investors to 1.

If the developer can raise funds only from outside investors who do not value the service available on the platform, she will always choose to operate a monopolistic platform without tokens. Indeed, to get funded by outside investors, the developer has to offer for sale an equity share equal to the ratio of the required investment to the platform's profit. Since profit is always higher with a monopolistic platform compared to a tokenized platform, the developer can offer a smaller share of the monopolistic platform's profits to investors relative to that of the tokenized platform. It also follows that the developer's total payoff is higher following financing with a monopolistic platform since she will own a larger share of a more profitable platform. Therefore, when trying to raise funds from investors who do not value service consumption, the developer prefers to operate a monopolistic platform.

Lemma 1. *If investors of the platform do not obtain any benefit from service consumption on the platform, the developer prefers to operate a monopolistic platform without tokens.*

In contrast to fundraising from outsiders, when the developer can crowd-fund the required investment from future consumers of the service, she may prefer to tokenize the platform. Intuitively, if investors of the platform value the service, the investor-consumers expect lower prices of the service in future periods and, thus, higher consumer surplus when the platform is tokenized. They might be willing to subsidize the developer by sharing with her some of their future consumer surplus at the financing stage if they think their investment is pivotal for the developer to choose to issue tokens rather than to operate a monopolistic platform. Consequently, the developer may find it optimal to commit to tokenizing the platform. The key intuition is that since total surplus is higher under a tokenized platform, consumers can transfer some of this additional surplus to the developer to incentivize her to operate a tokenized platform. In particular, we can establish the following proposition.

Proposition 5. *If consumers participate in financing, the developer may prefer to operate a tokenized platform than operating a monopolistic platform.*

In the proof of Proposition 5, we show the exact conditions under which the developer prefers to tokenize the platform. An important thing to note is that for token issuance to be an equilibrium, future users need to believe that their investment is pivotal for the platform's success. One way to induce such belief is by having a minimum fundraising threshold specifying that a tokenized platform will be built if the threshold is met and if it is not met then any funds raised will be returned to investor-consumers. In practice, many token sales have had this feature and include such minimum fundraising limits referred to as *soft caps*.

To summarize, the developer will optimally choose to operate a tokenized platform only if future consumers participate in the financing of the platform. Our model, therefore, endogenously calls for crowd-funding as imperative for the success of a token sale to raise financing.

5 Extensions

In this section, we demonstrate that our main results remain qualitatively unchanged in two more general settings. First, we consider the case when the platform allows the exchange of several types of services. Second, we analyze the case when consumer demand is uncertain.

5.1 Multiple Service Types

In our main analysis, we considered a platform that allows consumers and providers to exchange only one type of service. This setup is best suited for homogenous services such as cloud storage. However, in practice, platforms might seek to intermediate the exchange of multiple types of services. In this subsection, we show that our main results extend to the more general setting in which a platform allows trade of several types of services. We demonstrate that, as in the main model, the service exchange on the platform can be organized through a single utility token and that this enables the firm to give up market power over time. Eventually, the competitive outcome is obtained.

In particular, assume that the platform offers K service types which can be defined by their underlying parameters. For example, in a ride-sharing platform, one service type can be a ride in one city and another service type can be a ride in another city. In addition to a

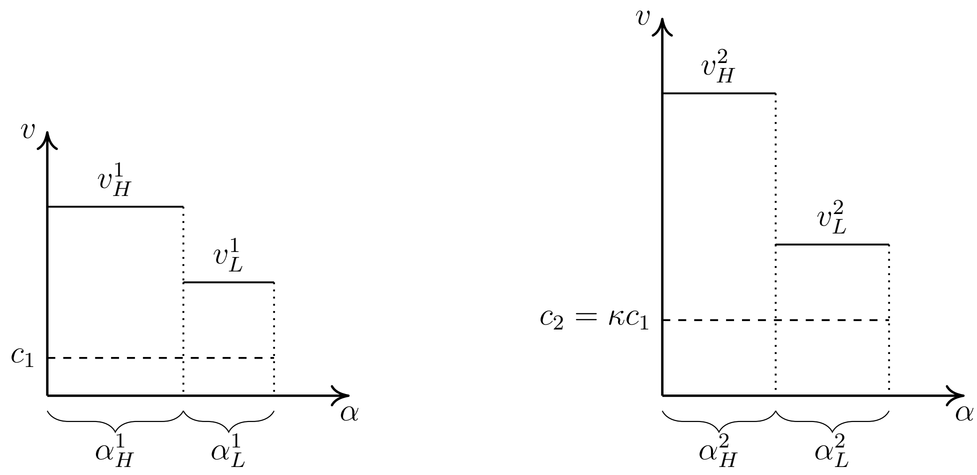

Figure 3: Consumers' inverse demand and providers' cost per unit produced for the service type $k = 1$ (left), and the service type $k = 2$ (right).

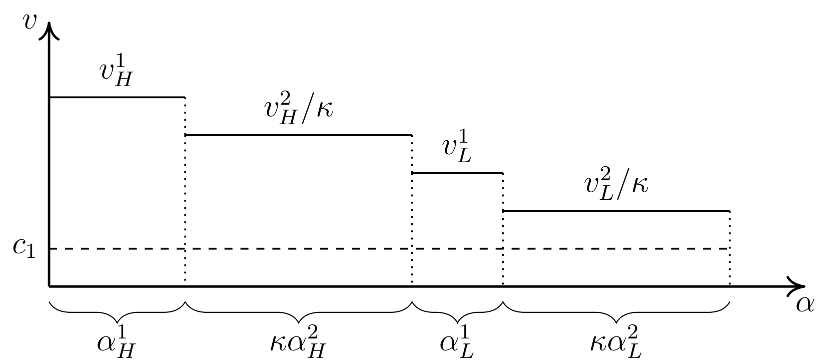

Figure 4: Aggregated consumers' inverse demand and providers' cost per token.

city of travel, the underlying parameters can be peak/off-peak hours, distance traveled, etc. A larger number of parameters will naturally span a larger number of services types. We assume that at any given time, there are multiple demand curves, each associated with a different service type.

To illustrate how our main results obtain in this setting, we extend our example with $N = 2$ consumer types by allowing $K = 2$ different types of services. Denote by c_k the marginal cost of provision for the service of type $k = 1, 2$ and, without loss of generality, assume that $c_2 > c_1$, i.e., the second service type costs more to produce for service providers. We define $\kappa = \frac{c_2}{c_1}$ as the ratio of the two costs. For simplicity, we assume that consumer groups of the two service types do not overlap and that consumption preferences of each group have the same form as in the example. In particular, for each service type k, we denote by α_H^k and α_L^k the masses of consumers with service valuations of v_H^k and v_L^k, respectively (see Figure 3). Finally, if service providers can provide multiple services (for example, a short ride or a long ride in the same city) we assume that the platform fixes their relative prices in tokens to make them indifferent between which service they provide. Specifically, a unit of the service of type $k = 1$ can be acquired on the platform for 1 token, while a unit of the service of type $k = 2$ can be obtained for κ tokens. To implement this, the platform has to know the relative costs of the two services. This can either be directly specified in advance or the platform's algorithm needs to be able to dynamically evaluate the relative cost of each service type depending on the underlying parameters.

Under these assumptions, the two service demand curves can be aggregated into a single per-period demand curve for tokens (see Figure 4). Indeed, the maximum price that a consumer of type $i = \{H, L\}$, looking for the service of type $k = 1$, is willing to pay for a token is v_i^1 and the total per-period token demand of such consumers is α_i^1. Additionally, the maximum price that a consumer of type $i = \{H, L\}$, looking for the service of type $k = 2$, is willing to pay for a token is $\frac{v_i^2}{\kappa}$ and the total per-period token demand of such consumers is $\kappa\alpha_i^2$. Thus, the maximum total token demand per period is $1 + \kappa$.

Given the single demand curve for tokens, the firm will follow the same strategy as in the main model and give up its market power over time. Specifically, since there are 2 consumer types and 2 service types, there are at most 4 unique token prices and the firm releases all tokens in at most 4 periods. In the first period, the firm will sell tokens to the consumer type that can be charged the highest price for a token. In the second period, the firm will compete with service providers in the market for tokens and will sell tokens to the consumer type that can be charged the second highest price for a token. This continues until the total supply of tokens released reaches $1 + \kappa$. For example, given the demand in Figure 4, the firm sells α_H^1 for a price v_H^1 in $t = 1$, $\kappa\alpha_H^2$ tokens for a price v_H^2/κ tokens in $t = 2$, α_L^1 tokens for a price v_L^1 in $t = 3$, and, finally, $\kappa\alpha_L^2$ tokens for a price v_L^2/κ in $t = 4$.

This reasoning can be extended to arbitrary K and N. In general, if there are K possible service types that the platform's algorithm can evaluate and, for each service type $k = 1, ..., K$, there are N_k different consumer valuations-types, it will take $\sum_{k=1}^{K} N_k$ periods to get to the competitive pricing of tokens and, thus, the competitive allocation of services. As in the main model, time-discounting will speed up this process. Note that an alternative solution with multiple different service types could simply be to have K distinct tokens, one for each type of service. While this solution may lead to competitive pricing being achieved sooner, it may be impractical to implement in practice.

5.2 Demand Uncertainty

As discussed in the main analysis, our results for a tokenized platform rely on the assumption that the platform sets a fixed price in tokens at which the service can be acquired from providers. A natural concern is whether this assumption poses any limitations if the demand for the service changes over time. In this subsection, we extend the setup to incorporate demand uncertainty and show that the general intuition of our main results is preserved. In the long run, the firm loses market power and the competitive outcome is reached.

Specifically, suppose the consumer demand, which is defined in the main model by the masses α_i of different consumer types and their respective valuations for the service v_i, can vary between periods. Formally, we denote by α_i^t the measure of consumers who value the service at v_i at period t and keep the assumption that the total mass of consumers at any period is equal to 1, $\sum_{i=1}^N \alpha_i^t = 1$. Thus, we interpret changing demand across periods t as variable masses α_i^t. We further assume that, at any period, there is a positive measure of consumers of each type, i.e., $\alpha_i^t > 0$ for all i and t.

In this extended setup, the competitive outcome in the token market is reached over time as in the main model. First, we demonstrate that the firm cannot get market power back in periods where the demand for tokens is low relative to the number of tokens that have been already released. Formally, we show that the firm cannot make a positive profit by buying back tokens and selling them at a higher price in the future. In other words, market power is not returned to the firm if the demand is low.

Lemma 2. *Service providers do not redeem tokens with the firm for c at time t if the expected token price in any future period s is greater than c, i.e., if $\mathbb{E}[p_s] > c$ for some $s > t$. This implies that, if there is a period t in which the total number of tokens released is $Q_t = 1$, the price at any future period $s > t$ will be $p_s = \underline{v}$.*

The first part of the lemma is straightforward — if a service provider expects to obtain more than c for a token in future periods, it is a dominant strategy to hold on to the token and sell it later when the price is higher rather than redeem the token with the firm in the current period. The second part of the lemma follows naturally from the first. For a future price p_s to be higher than $\underline{v}$, it has to be the case that $Q_s < 1$. However, since it is assumed that $Q_t = 1$, this means that the total supply of tokens outstanding decreases between t and s. Thus, at some point between t and s, some tokens are sold back to the firm. This contradicts the first part of the lemma since no service provider redeems tokens with the firm between t and s if they expect the price of tokens at period s to be higher than $\underline{v}$ (recall that $\underline{v}$ is higher than c).

Given Lemma 2, we can show that if T is sufficiently large, the competitive outcome in the token market is eventually reached. The key intuition here is similar to that in the main model — it is optimal for the firm to sell tokens gradually — only to one consumer type at a given period, moving from high value types to low value types. With demand uncertainty, the firm's optimal strategy is to wait until it sells tokens to the maximum measure of consumers $\max_t \alpha_i^t$ of each type i before moving to the next. The time it takes to reach the competitive outcome will, therefore, depend on the evolution of the demand uncertainty given by the variations in α_i^t. Formally, we can establish the following proposition.

Proposition 6. *The total quantity of tokens released Q_t increases over time while the token price p_t decreases over time. In the long run, if T is sufficiently high, the service is priced competitively.*

Therefore, even with multiple service types, tokens can achieve competitive pricing in the long-run.

5.2.1 Growing Demand Over Time

The previous analysis assumes the total mass of consumers is stationary. In this subsection, we show that if consumer demand grows perpetually, it is possible that the token market never reaches competitive pricing. Instead, the firm might follow a strategy on a tokenized platform similar to the one used on a monopolistic platform. Intuitively, each period, the firm may prefer to sell tokens only to the newly added mass of consumers with relatively high value for the service rather than to gradually release tokens to all consumers as in the main model. Under this strategy, the token price might never decline and, therefore, some consumers might never be able to obtain the service.

As an illustration, consider the following extension to our example with two types. Assume that, between periods $t = 1$ and $t = 2$, the mass of high-type consumers increases at a rate g_H to $\alpha_H(1 + g_H)$ and the mass of low-type consumers increases at a rate g_L to $\alpha_L(1 + g_L)$. Then, at period $t = 2$, the firm will prefer to sell tokens only to the new high-type consumers for the price v_H rather than to all consumers, who have not yet obtained the service, for the price v_L if

$$\alpha_H g_H(v_H - c) > [\alpha_H g_H + \alpha_L(1 + g_L)](v_L - c). \tag{7}$$

If the above condition holds, the pricing on the tokenized platform is the same as on a monopolistic platform. However, since some tokens are sold by service providers in the former case, the firm makes a lower profit on a tokenized platform. Thus, if the demand of high-type consumers does not grow fast enough, the firm is more inclined to lower prices if it adopts tokens. Indeed, the condition (7) for a tokenized platform is stricter than its counterpart for the monopolistic platform, under which the platform only serves high-type consumers

$$\alpha_H(1 + g_H)(v_H - c) > [\alpha_H(1 + g_H) + \alpha_L(1 + g_L)](v_L - c). \tag{8}$$

Therefore, even though it is possible for prices to remain high on a tokenized platform, it requires a relatively high level of perpetual demand growth.

6 Discussion

In this section, we discuss some important features and applications of our model.

6.1 Parallels to Durable Goods Monopolist

Our paper is closely related to the literature on durable-goods monopolies originated by Coase (1972). In this literature, under certain conditions, including a continuous infinite timeline and patient consumers, a durable goods monopolist charges competitive prices and immediately saturates the market due to competition with her future self. Specifically, if a monopolist is able to sell a durable good at a high price to high-value consumers in earlier periods, she is tempted to lower the price in subsequent periods in order to sell the good to low-value consumers. Anticipating lower prices of the good in subsequent periods, high-value consumers want to hold off buying in earlier periods hoping to purchase the durable good at a lower price in the future. This logic prevents the monopolist from charging high prices in earlier periods. In the limit, as the time between periods shrinks, the durable goods monopolist immediately saturates the market and charges competitive prices.

Similarly, in our paper, commitment to the tradability and durability of tokens creates competition for the firm in future token markets. After selling tokens to high-value consumers in earlier periods, the firm sells additional tokens to low-value consumers in subsequent periods. Crucially, the tokens sold in earlier periods are resold by service providers in subsequent token markets, creating competition for the firm.

An important difference between our model and the models of durable goods monopolies is that the service purchased with tokens is non-durable and consumers demand the service in every period. Even though the token is durable, there is no inherent convenience yield from holding a token and consumers have to exchange the token for the non-durable service to obtain utility from tokens. Thus, high-value consumers do not have incentives to hold off buying tokens in earlier periods when they know that the token price will decrease. Rather, they optimally purchase the service, through tokens, at a high price in earlier periods and, additionally, purchase the service at lower prices in subsequent periods. This implies that the firm does not immediately saturate the market with tokens but instead releases them slowly over time.

This difference also implies that, when selling tokens, the firm does not benefit from commitments that can increase the profit of a standard durable goods monopolist. In particular, a durable goods monopolist can benefit from commitment to a quantity or a price schedule. Indeed, if she could, the monopolist would prefer to commit to selling the durable good only for a high price (or, equivalently, in limited quantity) and not selling the good in subsequent periods for a lower price. In this case, high-value consumers do not hold off buying the good as there is no longer a benefit of waiting for a lower price. Thus, they purchase the good in the earlier periods for a high price and the monopolist is able to increase her profits. In contrast, in our setting, since consumers demand the service every period, the firm does not benefit from commitment to selling lower quantities in future periods.

Similarly, in the models of durable goods monopolies, competitive pricing requires an infinite horizon if agents are patient enough. In a finite horizon model, the monopolist can credibly commit to serving only high-value consumers by waiting until the last period and selling only then. This strategy is another way for the monopolist to increase her profit. In our model, the firm has no reason to delay token sales as it does not generate extra profit. Instead, it starts selling tokens in the first period and gradually saturates the market with tokens over time.

6.2 Fixed Token-to-Service Price

The fixed token-to-service price is a key element of our model that allows tradable tokens to serve as a commitment to competitive pricing. Importantly, this feature does not imply that the price of the service is fixed in numeraire since the token price in numeraire is floating in the token market.

The fixed token-to-service price is a crucial aspect of token durability. It implies that each time the firm sells a token (or equivalently, a unit of the service due to the fixed price), it is allowing someone else to sell another unit of the service through the resale of the token in future. Using the analogy of utility tokens as access keys to the platform, with a fixed token-to-service price, a token is a completely durable access key — it grants the same access to the platform in every period.

As we show in Appendix B, if the token-to-service price was floating, competition between service providers would result in an increasing price of the service in tokens. Thus, the number of tokens required to purchase a unit of the service would increase over time. In this case, a token becomes “less durable” since each token purchases less and less of the service over time. With a floating price, a token is a less durable access key over time since it grants only partial access to the platform and more tokens must be purchased to obtain full access. This reduced durability of tokens returns market power to the firm. In fact, the firm is able to generate the same profit as in the case when tokens are completely non-tradable.

It follows that commitment to a fixed token-to-service price is crucial to achieve competitive service provision in the long run. It is worth noting that if the token-to-service price is floating, the firm might be able to avoid the negative consequences of token depreciation through other means. For example, as we discuss in the Appendix, the firm can commit to a token release schedule that would supply enough tokens to avoid under-provision of the service. In practice, while commitment to a token release schedule can also be coded into a smart contract, it may be harder to implement than simply having a fixed token-to-service price since it requires foresight of consumer demand for the service every period.[26]

6.3 Parallels to the Existing Token Market

A tokenized platform in the model requires two key features to enable the commitment to competitive pricing — tokens have to be exchanged for the service at a fixed rate and there has to be a token resale market.

In practice, utility tokens tend to be the sole currency on their associated platform and are freely traded on crypto exchanges. Additionally, smart contracts can be leveraged to implement a fixed token-to-service rate. For example, asset-backed cryptocurrencies use smart contracting on the blockchain to maintain a fixed exchange rate between their tokens and another asset. Historically, the fixed token-to-service price has not been a common feature for utility tokens, with most utility tokens having a floating price between a token and a service. However, there has been a growing interest in asset-backed cryptocurrencies, which tie token values to an underlying economic good, since many market participants find this stability attractive. While asset-backed cryptocurrencies are more common in security tokens, our analysis suggests that a fixed token-to-service rate can be useful in providing economic value to utility tokens and may be a good feature for token markets to adopt going forward.[27]

[26]Cong et al. (2022) discusses how dynamic token supply can be committed to on the blockchain.
[27]See also the discussion of product tokens which have a fixed token to good price in Cong and Xiao (2021).

6.4 Application to Platforms with Ad-Based Revenue Models

Our framework can also be applied to companies with market power that have ad-based revenue models. Often, such platforms are free to use and provide utility to their users through a service they specialize in. Examples of such platforms are Facebook and Twitter, which offer social networking services to their users.

To map these platforms to our model, advertising slots can be interpreted as a good being sold, advertisers as buyers of the slots, and users as sellers of the slots. Tokenization of a platform means that advertisers would directly pay users in tokens to buy advertising slots on their profiles. Then, according to our model, the competitive long-run price for an advertising slot should be close to the marginal cost of providing such a slot. This cost, faced by users, can be thought of as a cost of maintaining an online profile plus any disutility that users experience from having advertising on their profiles minus any benefit they obtain from socializing on the platform.

In the absence of tokens, a platform will use its market power, often generated by network effects, and charge monopolistic prices for matching advertisers to the relevant users and the advertising slots on their profiles. In contrast, tokens can help a platform to commit to competitive pricing and give users the ability to monetize their data.[28]

6.5 Equivalent Commitment Technology

In this subsection, we discuss the characteristics that are necessary for an alternative commitment technology to achieve the same outcome as that of a tokenized platform. Since smart contracts are written ex ante before the platform is operational, they allow for commitment to competitive pricing and the firm cannot deviate from the smart contract ex post.

Recall that in the main model, each period, the service is homogenous and consumer demand and the cost of service provision are deterministic. In Section 5.1, we show that tokens can be applied to platforms which sell many services with different features. Additionally, in Section 5.2, we extend the model to incorporate demand uncertainty. We show that under

[28]Note that while tokenization can break pricing monopolies, our analysis does not apply to informational monopolies that may be facilitated by social networking websites.

general modeling assumptions, tokens allow for commitment to competitive pricing even if future service demand is uncertain.

If tokenization is not available, an alternative commitment technology trying to achieve the same outcome would, therefore, need to enable the firm to commit at $t = 0$ to charging competitive prices in a state-contingent manner. This means, for example, that a ride-sharing company would have to commit to the pricing algorithm that ensures that all consumers who value the service at above its marginal cost of provision are able to acquire the service. In the absence of smart contracts, such commitments would have to be enforced by sufficiently severe ex post punishments, either through the legal system or other means, to prevent deviations from competitive pricing by platform insiders. However, to detect the deviations, the outsiders would need to have access to and the ability to understand the platform's proprietary algorithm and data — likely a distant possibility. Moreover, the data might be difficult to verify and platform insiders can potentially tamper with it to their benefit. We, therefore, believe that such alternative commitment seems a priori unlikely in practice.

7 Conclusion

Decentralization is a key element of the FinTech revolution, aiming to break the market power of large players in the financial industry. However, while FinTech focuses on increasing competition, technology in other parts of the the economy is leading to concentration of market power. Due to network effects, many online platforms, which require a critical number of users to be operational, are natural monopolies and give rise to inefficient rent-seeking by their developers.

This paper shows that tokenization can allow firms who run two-sided platforms to give up market power and commit to competitive pricing. Moreover, in the presence of network effects, tokenization of a single platform can improve welfare even relative to competing platforms. We show that tokens can generate long-run competitive pricing even if demand on the platform is uncertain and if the platform sells many types of services.

In some cases, it is possible to generate private incentives for firms to tokenize. When such conditions do not arise, however, regulation may be needed to require large platforms to use tokenization. This leads to important policy implications. Our paper demonstrates that instead of breaking up large firms, which may be inefficient, tokenization may be an alternative way to limit their market power.

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Appendix A: Proofs

Proof of Proposition 1. We formally prove the proposition by backward induction. In Section 2.2.1, we have already shown that the statement of the proposition holds when there are 2 consumer types. Therefore, we need to show that if the firm optimally releases tokens to $N-1$ different consumer types in $N-1$ periods, then it finds it optimal to release tokens to N consumer types in N periods.

Without loss of generality, suppose the additional N-th consumer type is the one that has the highest value for the service. Define also the firm's optimal payoff that it obtains when it releases tokens to $N-1$ lower consumer types in $N-1$ periods as $V^*_{N-1}(\alpha_2, \ldots, \alpha_N)$. Given this definition, if the firm serves all consumers of the highest type in the first period, we reach the induction step and the firm optimally releases the remaining tokens in the remaining $N-1$ periods for the payoff $V^*_{N-1}(\alpha_2, \ldots, \alpha_N)$. Consequently, we need to show that the firm does not have incentives to speed up the release of tokens by serving two or more consumer types in the first period or delay the release until the next periods.

Specifically, consider the two possibilities. If the firm releases $q_1 = \alpha_1$ tokens in the first period then the token price is $p_1 = v_1 = \overline{v}$ and its continuation payoff is $V^*_{N-1}(\alpha_2, \ldots, \alpha_N)$. There is no incentive to release $0 < q_1 < \alpha_1$ tokens since the token price is the same when $q_1 = \alpha_1$. If, however, the firm releases slightly more tokens $q_1 = \alpha_1 + \epsilon$ then their price falls below the value of the highest consumer type, $p_1 = v_2 < v_1$, and the firm's continuation payoff, which is continuous, decreases $V^*_{N-1}(\alpha_2, \ldots, \alpha_N) > V^*_{N-1}(\alpha_2 - \epsilon, \ldots, \alpha_N)$, because its remaining stock of tokens gets smaller. Finally, since

$$\alpha_1 v_1 + V^*_{N-1}(\alpha_2, \ldots, \alpha_N) > (\alpha_1 + \epsilon) v_2 + V^*_{N-1}(\alpha_2 - \epsilon, \ldots, \alpha_N), \tag{A.1}$$

the former release schedule yields a higher total payoff. Thus, it is suboptimal for firm to speed up the release of tokens in the first period.

It is also suboptimal for the firm to delay the release of tokens, by setting $q_1 = 0$, since this means that it will have to speed up their release in the remaining $N-1$ periods. Therefore, it finds it optimal to release tokens to N consumer types in N periods. This also serves as an upper bound on the number of periods to achieve competitive pricing when $\delta < 1$, since, in this case, the firm discounts future revenues and may choose to release new tokens to more than one type of consumers at once, starting from the first period.

Note that in any equilibrium, the firm cannot profitably buy back tokens. For the firm to do so, the future expected price at which it can sell tokens has to be higher than the price it pays to buy back tokens. However, service providers will not want to sell tokens back to the firm at a lower price than what they expect to get by holding on to the tokens and selling them in the future. Finally, to insure that the firm does not conduct profitable buybacks off the equilibrium path, we need to clarify the off-equilibrium beliefs of service providers. For this, we specify that if providers observe negative sales by the firm $q_t < 0$, they believe that tokens prices will increase in future commensurate with the number of tokens bought. The higher expected token prices increase reservation values of providers inflating the current token prices and making the deviation to buy back tokens unprofitable.

□

Proof of Proposition 2. The total profit of a monopolistic platform is the lifetime sum of one-period profits:

$$T \sum_{j=1}^{i_m} \alpha_j (v_{i_m} - c). \tag{A.2}$$

The total profit of the tokenized platform is

$$\sum_{j=1}^{N} \alpha_j (v_j - c) = \sum_{j=1}^{N} \alpha_j v_j - c. \tag{A.3}$$

The monopolistic platform always earns a higher profit than the tokenized platform. First, note that, if $T > N$ the monopolistic platform earns a positive profit after period $t = N$ while the tokenized platform sells all its tokens by that time and earns zero in subsequent periods. Second, even if the number of periods T is small the monopolistic platform mantains greater market power and can always choose to replicate the cash flow that is optimal for the tokenized platform. In particular, the monopolistic platform achieves this by selling α_t tokens for v_t at every period $1 \leq t \leq N$ while still redeeming them from providers at c in each period. Therefore, any alternative equilibrium strategy chosen by the monopolistic platform must be more profitable. $\square$

Proof of Proposition 3. The total welfare in the scenario with the monopolistic platform is the lifetime sum of its per-period profits and per-period surpluses of consumers who are able to obtain the service:

$$T\sum_{j=1}^{i_m}\alpha_j(v_{i_m}-c)+T\sum_{j=1}^{i_m}\alpha_j(v_j-v_{i_m})=T\sum_{j=1}^{i_m}\alpha_j(v_j-c). \tag{A.4}$$

Since the monopolistic platform charges the same token price $p_t = v_{i_m}$ in every period, each term in the sum is a per-period surplus of the respective agent type multiplied by the total number of periods T.

The total welfare in the scenario with the tokenized platform, is the sum of platform's, consumers', and providers' surpluses:

$$\begin{aligned}\sum_{j=1}^{N}\alpha_j(v_j-c)+\sum_{j=1}^{N}\sum_{i=1}^{j-1}\alpha_i(v_i-v_j)+\sum_{j=1}^{N}\sum_{i=1}^{j-1}\alpha_i(v_j-c)+(T-N)\sum_{i=1}^{N}\alpha_i(v_i-c)&\\ =\sum_{j=1}^{N}\sum_{i=1}^{j}\alpha_i(v_i-c)+(T-N)\sum_{i=1}^{N}\alpha_i(v_i-c).&\end{aligned} \tag{A.5}$$

The sum of the first three terms represents the total surplus in the first N periods when the firm gradually releases tokens to consumers. Specifically, in period j, the firm releases α_j tokens, in addition to the current outstanding stock of tokens $Q_{j-1} = \sum_{i=1}^{j-1}\alpha_i$, and the token price is v_j. In this period, the total surplus generated by consumers of type $i < j$ is split between consumers and service providers while the surplus generated by consumers of type j is entirely captured by the firm.

Finally, the last term in the sum (A.5) is the total surplus from periods $t > N$ when the token market reaches the competitive outcome, in which all N consumer types are able to obtain a token, and, thus, the service. At this time, the per-period surplus is maximized and is strictly higher than the per-period surplus under the monopolist who does not serve all consumers, which is the case when $i_m < N$.

Therefore, if T is sufficiently large, the total surplus under the tokenized platform is higher than that under the monopolistic platform since (A.4) is smaller than the last term in (A.5). Alternatively, if T is small and i_m is sufficiently close to N, the total surplus under the monopolistic platform can be higher since (A.4) can be larger than (A.5). □

Proof of Proposition 4. To prove the proposition, we first write out the long-run equilibrium outcomes under network effects in the two scenarios: with a tokenized platform and with two competing standard platforms. Next, we compare the welfare across these scenarios.

Tokenized platform. As we noted in the analysis of the main model, in the long run a tokenized platform operates at full capacity and achieves the competitive outcome. The total per-period welfare in this scenario is

$$TS_t = \sum_{i=1}^{N} \alpha_i (v_i - c) + b(1). \tag{A.6}$$

Two standard competing platforms. Now, consider two standard platforms that compete à la Bertrand by setting a price of the service to consumers. In a symmetric equilibrium, prices on the platforms are equal to the marginal cost of the service provision c. As the prices are the same on the two platforms, the consumers are split evenly between the two. Thus, the total per-period welfare in this scenario is

$$TS_c = 2\left[\sum_{i=1}^{N} \frac{\alpha_i}{2}(v_i - c) + \frac{1}{2}b(1/2)\right] = \sum_{i=1}^{N} \alpha_i (v_i - c) + b(1/2). \tag{A.7}$$

Comparing the total per-period welfare in the two scenarios, we can prove the proposition. It can be seen that as long as $b(1) > b(1/2)$, the surplus is higher in the former scenario. Since the network benefit $b(\alpha)$ is strictly decreasing, this equality holds.

□

Proof of Corollary 1. From Proposition 4, it follows that consumers are able to obtain tokens or service at the competitive price c in the scenarios with a tokenized platform and competing platforms, respectively. Therefore, the long-run consumer surplus in the former scenario is $CS_t = TS_t$ while the long-run consumer surplus in the latter scenario is $CS_c = TS_c$ and thus $CS_c < CS_t$.

In the scenario with the monopolistic platform, the consumer surplus is

$$CS_m = \sum_{i=1}^{i_m} \alpha_i [v_i + b(\overline{\alpha}_{i_m}) - v_{i_m} - b(\overline{\alpha}_{i_m})] = \sum_{i=1}^{i_m} \alpha_i [v_i - v_{i_m}], \tag{A.8}$$

where $\overline{\alpha}_j = \sum_{i=1}^{j} \alpha_i$ and $i_m = \arg\max_i \sum_{j=1}^{i} \alpha_j (v_i + b(\overline{\alpha}_j) - c)$. Since, in this scenario, the network benefit is extracted by the firm and some consumers are potentially excluded from the market, the surplus CS_m is lower than CS_c.

□

Proof of Lemma 1. If investors obtain no utility from service consumption, the developer offers them a share of profits in order to provide the competitive return on their investment. Let V_m represent the profit that the developer obtains from a monopolistic platform and V_t represent the profit that she makes from a tokenized platform. We know from Proposition 2 that $V_m > V_t$.

Next, if the developer operates a monopolistic platform, she has to offer investors the share of the profit s_m such that:

$$s_m = \frac{I}{V_m}, \tag{A.9}$$

while if the developer operates a tokenized platform she has to offer investors the share of the profit s_t such that:

$$s_t = \frac{I}{V_t}. \tag{A.10}$$

Since $V_m > V_t$ it follows that $s_t > s_m$.

Finally, the developer's payoff when operating a monopolistic platform is

$$(1 - s_m)V_m = V_m - I, \tag{A.11}$$

while the developer's payoff when she operates a tokenized platform is

$$(1 - s_t)V_t = V_t - I. \tag{A.12}$$

Therefore, the developer is always better off by operating a monopolistic platform. □

Proof of Proposition 5. To prove the proposition, we determine the set of the parameters, for which the developer prefers to hold a token sale to raise financing. To derive it, as in the example, we first need to calculate the fraction of tokens that a developer would sell in the sale. Since consumers of higher type derive more surplus from an operational platform and, thus, are willing to pay higher prices for a token during the sale, we need to determine the marginal consumer type that participates in fundraising, call it i_t. If a consumer of this type i_t believes that he is pivotal, he will pay up to

$$v_{i_t} + \sum_{j=1}^{N-i_t} (v_{i_t} - v_{i_t+j}) + \Big(T - (N - i_t + 1)\Big)(v_{i_t} - \underline{v}) \tag{A.13}$$

for a token. In the expression, the first term is a utility derived in the first period, the second term is a utility derived in subsequent periods when tokens are gradually released, and the third term is a utility derived in remaining periods when tokens are completely released and the market reaches competitive outcome.

Thus, if the developer sets the price at (A.13), everyone with type $i \leq i_t$ is willing to buy a token and the maximum mass of consumers participating in the token sale is $\sum_{j=1}^{i_t} \alpha_j$. The developer then optimally chooses i_t to maximize the surplus extracted from these consumers, i.e.,

$$i_t = \arg\max_i \sum_{j=1}^{i} \alpha_j \left(v_i + \sum_{j=1}^{N-i} (v_i - v_{i+j}) + \Big(T - (N - i + 1)\Big)(v_i - \underline{v}) \right) \tag{A.14}$$

Note that each type $i \leq i_t$ needs to believe that their participation is pivotal for the financing of the platform. This can be implemented by setting a minimum fundraising amount of:

$$\sum_{i=1}^{i_t} \alpha_i \left(v_{i_t} + \sum_{j=1}^{N-i_t} (v_{i_t} - v_{i_t+j}) + \Big(T - (N - i_t + 1)\Big)(v_{i_t} - \underline{v}) \right) \tag{A.15}$$

If this amount is not met, the investment collected from consumers is returned. Under this condition, all types $i \leq i_t$ purchase a token during the token sale at a price given by (A.13) with the type i_t being just indifferent between financing and not-financing the platform.

Finally, we can write down the condition when the developer chooses to adopt tokens rather than run a monopolistic platform. This happens if her profit in the former scenario is higher:

$$\sum_{i=1}^{i_t} \alpha_i \left(v_{i_t} + \sum_{j=1}^{N-i_t} (v_{i_t} - v_{i_t+j}) + \Big(T - (N - i_t + 1)\Big)(v_{i_t} - \underline{v}) \right) + \sum_{j=1}^{N-i_t} \alpha_{i_t+j}(v_{i_t+j}) - c - I$$
$$\geq T \sum_{j=1}^{i_m} \alpha_j (v_{i_m} - c) - I. \tag{A.16}$$

The above can be simplified to

$$T(\sum_{i=1}^{i_t} \alpha_i v_{i_t} - \sum_{j=1}^{i_m} \alpha_j v_{i_m}) + \sum_{j=1}^{N-i_t} v_{i_t+j} \left(\alpha_{i_t+j} - \sum_{i=1}^{i_t} \alpha_i \right) - \Big(T - (N - i_t + 1)\Big)\underline{v} \sum_{i=1}^{i_t} \alpha_i$$
$$- c \left(1 - T \sum_{j=1}^{i_m} \alpha_j \right) \geq 0. \tag{A.17}$$

□

Proof of Lemma 2. We can prove the first part of the lemma by contradiction. Assume a service provider redeems his token with the firm for c and $\mathbb{E}[p_s] > c$ for some $s > t$. Then the service provider has a profitable deviation. They can keep the token and sell it at a future period s when $\mathbb{E}[p_s] > c$, thereby in expectation making more than c.

The second part of the lemma follows from the first. Once $Q_t = 1$ tokens are released, for any future price in period $s > t$ to be higher than $\underline{v}$, it has to be that $Q_s < 1$. This implies that between period t and period s, at least some service providers need to redeem tokens with the firm. However, since $\mathbb{E}[p_s] > \underline{v} > c$, according to the first part of the lemma, this will never happen. □

Proof of Proposition 6. To prove the proposition, we show that there is a period t such that $Q_t = 1$ when T is large enough. For this, denote by $d_i^t = \sum_{j=1}^{i} \alpha_j^t$ the measure of consumers who value the service at or above v_i in period t, and define the maximum of such measure as $\overline{d_i} = \max_t d_i^t$.

We first show that in any equilibrium, prices have to be weakly decreasing over time in periods in which a positive amount of tokens are sold. We can prove this by contradiction.

Consider an equilibrium with a period $t < s$ such that $p_t < p_s$ and a positive measure of tokens are sold in both periods. Then any service provider who sells a token in period t has a profitable deviation. The provider can keep the token and sell it in period s instead. Therefore, in any equilibrium, prices are weakly decreasing over time in periods in which token sales happen.

We can further prove that there are no "dry" periods in which no tokens are sold. We prove this by contradiction. Consider an equilibrium with a period $t < s$ such that zero tokens are sold in period t but a positive measure of tokens are sold in period s. From consumers' preferences and service providers' cost of production, $c \leq p_s \leq v_1$. Since there is a positive measure of consumers of each type in every period, at time t there is a strictly positive measure of consumers who value the service at or above p_s. Since service providers would prefer to sell to these consumers at or above price p_s, trade will take place and no token trade cannot be an equilibrium.

Therefore, in any equilibrium, tokens will be sold every period and the token price will weakly decrease over time.[29] Next, we show that if the firm is selling tokens at time t to consumers of type i who value the service at v_i and $Q_t = \overline{d_{i-1}}$, it is always weakly optimal for the firm to sell tokens to all consumers who value the service at v_i in that period, i.e., $q_t \geq \alpha_i^t$. In other words, if the number of tokens released equals the maximum measure of consumers who value the service above v_{i-1}, the firm will sell tokens to at least everyone who values the service at i.

We can prove this by contradiction. Assume the firm chooses to sell tokens in period t to type i consumers such that $q_t < \alpha_i^t$. Then, if, at some time $s > t$, demand from the group who values the service at v_i is higher than α_i^t, the maximum profits the firm can make from this group is

$$(\alpha_i^s - q_t)(v_i - c) + q_t(v_i - c) \tag{A.18}$$

The firm can do as well by selling α_i^t tokens. On the other hand, if, at some time $s > t$, demand from the group who values the service at v_i is lower than α_i^t, the firm does strictly better by selling α_i^t tokens at t.

[29] This implies, as in the benchmark model, that consumers have no incentive to hoard tokens.

Therefore, conditional on the firm selling tokens to a consumer of type i in period t, it is weakly optimal to sell to all consumers with the same valuations. From here, it is straightforward to see that the firm will release all tokens. With a large enough N and with $\delta = 1$, the firm will serve the maximum measure of consumers of the highest type, and once that the market is saturated, i.e., once $Q_t = \overline{d_1}$, serve the maximum measure of consumers of the next type and so on. Eventually, since T is large, consumers who value the service the least will be served and from then on the price will stay at the competitive level. $\square$

Appendix B: Competitive Pricing of Service

In this appendix, we relax the assumption that each token can be exchanged for one unit of the service and, instead, let market forces determine the price of the service in tokens each period. We show that, in this case, the monopoly power stays with the firm. The firm can release tokens in such a way that the competition between service providers creates an increasing token-to-service price over time. This allows the firm to release additional tokens each period to only service high-type consumers. This release schedule of tokens allows the firm to extract surplus from the same consumers more than once preserving its monopoly power.

We illustrate the argument in our example with $T = 2$ and $N = 2$. Define the price of a service unit in tokens at period t as r_t. In contrast to the main model that fixes $r_1 = r_2 = 1$, in this appendix, the two prices are determined in the equilibrium. As before, we can analyze the model through backward induction.

Staggered release of tokens. First, we show what happens if the firm follows the equilibrium token release schedule of the main model, under which all high-type consumers are served at $t = 1$ and the remaining consumers are served at $t = 2$. Since, at the end of the second period, service providers redeem each token with the firm for c, the competition between them will result into the service price of $r_2 = 1$. To serve all consumers, the firm will release $q_2 = \max\{\frac{\alpha_L + \alpha_H}{r_2} - q_1, 0\}$ tokens in the market for tokens at $t = 2$ in addition to q_1 issued at $t = 1$. Thus, the total supply of tokens will be equal to $\frac{\alpha_L + \alpha_H}{r_2}$ and each consumer will purchase r_2 tokens for the price $p_2 = \frac{v_L}{r_2}$. Substituting in $r_2 = 1$, at $t = 2$, the token and service markets are identical to the main model with the fixed exchange rate of 1 token per one unit of the service.

Next, at $t = 1$, the competition between service providers will result into the price of r_1 tokens per unit of the service such that $r_1 p_2 = c$, i.e., with this price providers break even when they resell their tokens at $t = 2$. Substituting in $p_2 = v_L$, the service price is $r_1 = \frac{c}{v_L}$. Then, to serve all high-type consumers the firm sells $\alpha_H r_1$ tokens at $t = 1$ for a price of $p_1 = \frac{v_H}{r_1}$ with each high-type consumer purchasing r_1 tokens. Substituting in r_1, the token price is $p_1 = \frac{v_H v_L}{c}$.

Computing the firm's profit under this release schedule and flexible r_t, it is higher than its profit under the fixed exchange rate of the main model. Specifically, the firm's profit is

$$\begin{aligned} &\alpha_H r_1 p_1 + (\alpha_L + \alpha_H - \alpha_H r_1)\, r_2 p_2 - 1 \cdot c = \alpha_H v_H + \alpha_L v_L - c + \alpha_H (1 - r_1) v_L \\ &= \alpha_H v_H + \alpha_L v_L - c + \alpha_H (v_L - c), \end{aligned} \tag{B.1}$$

where the last term is the additional profit the firm is able to obtain with the flexible r_t. This gain is the transfer from the profit of service providers who now earn

$$\alpha_H (r_1 p_2 - c) + 1 \cdot (r_2 c - c) = 0, \tag{B.2}$$

compared to their profit of $\alpha_H (v_L - c)$ in the main model. The competition between providers erodes their profits and allows the firm to extract the same surplus at $t = 1$ by selling fewer tokens since $r_1 < 1$. This, in turn, implies that the firm sells more tokens at $t = 2$ receiving additional profit.

Finally, consumers' profit is identical to the one in the main model, with the fixed service price:

$$\alpha_H (v_H - r_1 p_1) + \alpha_H v_H + \alpha_L v_L - 1 \cdot r_2 p_2 = \alpha_H (v_H - v_L). \tag{B.3}$$

Equilibrium release of tokens. Next, using the same arguments, we can show that the firm might achieve even higher profit by choosing the token release schedule that differs from the one in the equilibrium of the main model. First, we show that serving all consumers at $t = 1$ is suboptimal, as in the main model. In this case, the competition between providers will cause $r_2 = 1$ with $p_2 = v_L$, and $r_1 = \frac{c}{v_L}$. Thus, if the firm serves both types of consumers at $t = 1$, she will sell $q_1 = 1 \cdot r_1$ tokens for the token price of $p_1 = \frac{v_L}{r_1}$. Since, the firm's profit is $v_L - c$, which is less than its profit under the staggered release, serving all consumers at once is suboptimal.

However, in contrast to the main model, the firm might prefer to serve only high-type consumers in both periods when the service price in tokens is flexible. Indeed, under this release schedule, the firm will sell $q_2 = \max(\alpha_H - q_1, 0)$ at $t = 2$ with the service price of $r_2 = 1$ and the token price of $p_2 = v_H$. At $t = 1$, the competition between providers will result into the service price of $r_1 = \frac{c}{v_H}$. Thus, the firm will sell $r_1\alpha_H$ tokens at $t = 1$ for the price $p_1 = \frac{v_H}{r_1}$. In this case, the firm's profit is

$$\alpha_H r_1 p_1 + (\alpha_H - \alpha_H r_1)\, r_2 p_2 - \alpha_H c = \alpha_H(v_H - c) + \alpha_H(v_H - c) = 2\alpha_H(v_H - c). \tag{B.4}$$

Similarly to the staggered release, the competition between providers allows the firm to extract the same surplus at $t = 1$ by selling fewer tokens since $r_1 < 1$. Thus, when the price of the service increases at $t = 2$, $r_2 > r_1$, the firm can continue extracting surplus only from the high-type consumers. In contrast, in the main model, the condition $r_1 = r_2$ implies that the firm has to switch and serve the lower type at $t = 2$ if all high-type consumers are served at $t = 1$.

Comparing the firm's profits in (B.1) and (B.4), the firm will prefer to serve only high-type consumers when $\alpha_H(v_H - c) > v_L - c$, which is the same as (4), i.e., precisely when the monopoly outcome is inefficient.[30]

Commitment to a Token Schedule: Note that with a floating token-to-service price, if the firm can commit to releasing $q_2 = \alpha_H + \alpha_L - q_1$ tokens rather than $q_2 = \alpha_H - q_1$ tokens in the second period, than competitive pricing will also be achieved. Therefore, commitment to a token supply schedule can allow for commitment to competitive pricing in the absence of commitment to a fixed token-to-service price.

[30]This intuition carries to a model with $T > 2$. In this case, in period t, the equilibrium token-to-service price will equal $r_t = \left(\frac{c}{v_H}\right)^{T-t}$. Each period t, the equilibrium price in the token market equals $p_t = \frac{v_H}{r_t}$ and the total supply of tokens is $Q_t = \alpha_H r_t$. As in the two period example, the equilibrium token-to-service price increases over time allowing the firm to sell additional tokens each period to only high-type consumers and preserve monopoly profits.

Appendix C: Example ($T = 2$ and $N = 2$) with $\delta < 1$

In this Appendix, we solve the example with discounting, i.e., $\delta < 1$. We explicitly show that the results derived for $\delta = 1$ carry over.

Monopolistic Platform's profit. If $\alpha_H(v_H - c) \geq v_L - c$, the monopolistic platform's profit is

$$(1 + \delta)\alpha_H(v_H - c). \tag{C.1}$$

Alternatively, if $\alpha_H(v_H - c) < v_L - c$, the monopolistic platform's profit is

$$(1 + \delta)(v_L - c). \tag{C.2}$$

Tokenized Platform's profit. The firm buys back tokens from service providers in the end of the last period for c. With discounting, the cost of this buyback is δc. Since providers offer the service upfront and get paid only in the next period when they sell tokens, it is necessary that

$$\delta v_L \geq c \tag{C.3}$$

for the platform to be operational. This condition guarantees that, in the second period, when they participate in the token market, service providers recoup their costs incurred in the first period, i.e., the discounted token price from the second period v_L is higher than the cost c.

If $\alpha_H v_H + \delta(1 - \alpha_H)v_L \geq v_L$, the firm releases tokens gradually, in 2 periods, and its profit is

$$\alpha_H v_H + \delta(1 - \alpha_H)v_L - \delta c. \tag{C.4}$$

Alternatively, if $\alpha_H v_H + \delta(1 - \alpha_H)v_L < v_L$, the firm releases all tokens at once, in the first period, and its profit is

$$v_L - \delta c. \tag{C.5}$$

In this case, the profit is lower than monopoly profits, while welfare is higher.

Appendix D: Crowd-funding through Equity Contracts on a Tokenized Platform

Consider our example with $T = 2$ and $N = 2$.

Fundraising from outsiders. To get funded by outside investors, a developer with a monopolistic platform has to offer for sale a fraction s_m of the platform such that:

$$s_m = \frac{I}{2\alpha_H(v_H - c)}, \tag{D.1}$$

which is the ratio of the required investment to the platform's monopoly profit. Buying this equity share for I makes outside investors just break even. Analogously, a developer with a tokenized platform has to offer a fraction s_t of the platform to outsiders such that:

$$s_t = \frac{I}{\alpha_H v_H + (1 - \alpha_H)v_L - c}, \tag{D.2}$$

which is the ratio of the required investment to the tokenized platform's profit.

Since the monopolistic platform's profit is higher, the developer can offer a smaller equity share to investors to generate the same return, i.e., $s_m < s_t$. It also follows that the developer's total payoff is higher by operating a monopolistic platform. Therefore, when trying to raise funds from investors who do not value service consumption, the developer does not adopt tokens.

Crowd-funding through Equity on Tokenized Platform. In contrast to fundraising from outsiders, when the developer can crowd-fund the required investment from future consumers of the service, she may prefer to raise funds by selling tokens and subsequently operate a tokenized platform.

Suppose that the developer raises funds with an equity contract. She can now offer the profit sharing contract to future consumers of the service. Specifically, suppose that each high-type consumer invests an amount $\frac{I}{\alpha_H}$ to fund the platform's creation in return for a share $\frac{\tilde{s}_t}{\alpha_H}$ of the platform's profit. Then the total utility of a high-type consumer, who values the service at v_H, and whose investment is pivotal for the platform's successful development, is

$$\frac{\tilde{s}_t}{\alpha_H}(\alpha_H v_H + (1-\alpha_H)v_L - c) - \frac{I}{\alpha_H} + (v_H - v_L), \tag{D.3}$$

where the first two terms are shares of profit and investment attributed to the consumer while the last term is the consumer's utility from service consumption over the lifetime of the platform. The consumption utility is positive only in the second period and equal to $(v_H - v_L)$ since the consumer is able to obtain a token in the first period for the price $p_1 = v_H$ and for the price $p_2 = v_L$ in the second period.

The developer will optimally choose $\tilde{s}_t$ such that a high-type consumer breaks even:

$$\tilde{s}_t = \frac{I - \alpha_H(v_H - v_L)}{\alpha_H v_H + (1-\alpha_H)v_L - c}. \tag{D.4}$$

Thus, if the developer crowd-funds with an equity contract from consumers, the share of the firm she needs to sell is lower than the share she needs to offer if the investment is raised from outsiders, $\tilde{s}_t < s_t$. The high-type consumers anticipate that token prices will decline at $t = 2$ and expect to obtain the positive consumer surplus in the second period. Therefore, these consumers are willing to accept a lower share of the platform's profit in return for the investment.

Comparing this financing to the previous scenario, the developer will choose to operate a tokenized platform and offer a profit-sharing contract to consumers rather if

$$(1-\tilde{s}_t)(\alpha_H v_H + (1-\alpha_H)v_L - c) \geq (1-s_m)2\alpha_H(v_H - c), \tag{D.5}$$

which is equivalent to

$$(v_L - c)(1 - 2\alpha_H) \geq 0. \tag{D.6}$$

Crowd-funding through a Token Sale on a Tokenized Platform. As an alternative to crowd-funding with a profit sharing contact, the developer can also crowd-fund by pre-selling tokens directly to high-type consumers at $t = 1$. It can be shown that these two options are, in fact, equivalent.

Suppose the developer sells $q_1 = \alpha_H$ tokens in the first period to raise the required investment I. In this case, a high-type consumer, who believes that their participation is pivotal for the development of the platform, is willing to pay up to $v_H + (v_H - v_L)$ for a token. The first term v_H is the utility that the consumer gets from exchanging a token for the service in the first period while the second term $(v_H - v_L)$ is the future consumer surplus the consumer expects to obtain in the second period. Therefore, the maximum proceeds from the token sale in the first period are $\alpha_H(2v_H - v_L)$.

Comparing this crowd-funding option to the previous scenario of fundraising from outsiders, the developer will choose to operate as a token issuer for consumers rather than become a monopolist if

$$\alpha_H(2v_H - v_L) + (1 - \alpha_H)v_L - c - I \geq (1 - s_m)2\alpha_H(v_H - c), \tag{D.7}$$

which simplifies to the same condition (D.6). Therefore, the two crowd-funding options from future consumers, with a profit-sharing contract and with a token sale, are equivalent.