Competition between Equity Crowdfunding Platforms: Network Effects vs Matching Efficiency

Abstract

We model the competition between two equity crowdfunding platforms that connect startups looking for capital with prospective investors as a two stage game. In the first stage each platform chooses its level of investment in the quality of service it offers to investors and in the second stage it chooses its fees. Given the heterogeneity in the populations of startups and investors in terms of the riskiness of the former population and the degree of risk aversion of the latter population, we investigate whether there exists an equilibrium where the two populations are segmented in order to ensure an improved match between them. At such a segmenting equilibrium, one platform acts as a matchmaker between more risky startups and investors with greater tolerance to risk and the second platform matches the opposite profiles of startups and investors. We find that the segmenting equilibrium can arise only when compatibility in terms of their risk profiles is of high importance to both investors and startups. Moreover, the importance of compatibility should be significantly higher than the size of the network externality considered by startups in order for segmentation to arise as equilibrium. We also find that the segmenting equilibrium is characterized by great asymmetries between the platforms, with one of them offering higher quality service and commanding a bigger share of both the investor and startup markets. This asymmetry arises even though a priori both platforms are identical in terms of their access to the technology that facilitates offering higher quality service. When the size of the network externality that is considered by the startups is relatively big segmentation can be supported only with the pricing regime that charges exclusively startups and not investors. In contrast, when the size of the network externality is relatively small, both a fee structure that charges exclusively investors and a fee structure that charges both sides of the market can support segmentation. In this latter case, the regime that charges both investors and startups leads to greater asymmetry between the platforms. The comparison of industry profits that accrue to the platforms under these two pricing regimes is ambiguous. However, when the size of the network externality is especially small, charging both sides of the market yields higher industry profits than charging exclusively only investors.

1. Introduction

While the venture capital industry is busy finding the next billion dollar idea set to disrupt yet another industry, disruption is creeping into the venture capital industry itself. Using technology, a new breed of firms called crowdfunding platforms are trying to bring transparency to the secretive and exclusive high stakes world of early stage venture investing. By allowing startups looking for capital to pitch their idea to the crowd of investors with access to capital, these platforms are democratizing the venture funding process. Following the Jobs act (2012) that allowed general public access to startup investing, equity crowdfunding platforms have been growing in importance and are capturing a sizable share of early stage funding. Equity crowdfunding platforms have raised more than $790 million since the regulations for Title II of the Jobs act came into effect in September 2013. With increasing interest from startups and investors, this new model of financing has the potential to accelerate the rate of innovation.

Crowdfunding platforms can be categorized into four types: donation-based, reward based, debt-based and equity-based. Our focus in this paper is on equity-based crowdfunding, where in return for their investment, investors receive an equity stake in the startup. While the other forms of crowdfunding are open to any individual, equity based crowdfunding is regulated by the SEC. Prior to the title IV of the Jobs Act, only accredited investors were allowed to participate in equity crowdfunding. An accredited investor is any individual with a minimum annual income of $200,000 or a million dollars in net worth (not including the value of primary residence). However, title IV of Jobs Act now allows any investor to participate in equity crowdfunding but with restrictions on how much he can invest. Specifically, it allows anyone with annual income below $100,000 to invest no more than 5% of their annual income, and for annual income above $100,000, the restriction is 10% of annual income. Equity crowdfunding platforms currently focus on early stage funding where startups raise the initial or seed capital required to get their idea off the shelf. While investing in early stage startups has the potential for huge returns, such investments are also extremely risky and illiquid. Anywhere from 75% to 90% of startups fail and investors should be prepared to wait on average for 7 years to realize their returns.

Several crowdfunding platforms have come into existence since the Jobs act (2012) passed. However, there are some leading platforms that capture a dominant share of the market. In the US, Angellist is the leading platform that attracts the majority of startups and investors, followed by Fundable and Circleup (in terms of dollar amount raised) that also have sizable shares of the market. Many smaller platforms

such as SeedInvest and Onecrowd are also trying to gain some traction among startups and investors. There is wide variation in the pricing strategies used by crowdfunding platforms depending on the side of the market that is being charged. The pricing models can be categorized as charging exclusively only investors, charging exclusively only startups, and charging both investors and startups. Table 1 includes information about the leading equity crowdfunding platforms in the US.

Platform	**Amount Raised**	**No of Deals**	**Revenue Model**	**Deal Flow**
Angellist	290M	835	Investors	Vetted through syndicates
Fundable	244M	108	Investors	Open
Circleup	185M	155	Startups	Vetted (2%)
FundersClub	55M	180	Investors	Vetted (2%)
WeFunder	16M	112	Startups and Investors	Open for listing, vetted (1%) for funding

Table 1: Leading Equity Crowdfunding Platforms

Equity crowdfunding platforms attract a wide spectrum of investors ranging from first time investors to experienced venture capital funds. There is high level of heterogeneity in the experience and risk attitude of such investors. For example, an investor with no experience of either working or investing in early stage startups and who is trying to gain some exposure to this asset class has a very high level of risk aversion. In contrast, an experienced and seasoned investor like Jason Calanicus, who has gained significant experience in investing in several early stage startups[1], has greater tolerance to the risk involved in startup investing. There is empirical and anecdotal evidence that the level of experience of investors is positively correlated with the performance of a funded-startup. Therefore, heterogeneity in the experience of investors also leads to variability in the value that investors can add to funded firms. Similarly, there is also great heterogeneity in the population of startups active on crowdfunding platforms in terms of the expected return they offer and the risk they impose on investors. There are different layers of risk associated with a startup including Founder risk, Product-Market risk, Competition risk, Technology risk, and Financing risk. For example, a startup with an experienced founding team has a lower Founding risk compared to one that has a founding team with an unproven track record. Startups such as Uber or Airbnb have a high-level of Product-Market risk because they have to overcome psychological and regulatory barriers to be successful. On the other hand, high-tech

[1] Including Thumbtack, Uber, and Connect

startups such as Airware that makes operating software for unmanned aircrafts have a high level of Technology risk.

Empirical (Hsu (2004)) and anecdotal evidence[2] strongly points to the fact that startups and investors experience higher returns when there is a better fit between them. The fit may be based on educational background, industry experience, portfolio, network, etc. Due to the importance of such a fit the literature in finance has demonstrated (Sorensen 2007, Bengtsson and Hsu 2010) that sorting arises in traditional venture capital markets where experienced VC's tend to invest in startups with higher potential for future returns. While crowdfunding solves the access problem by making the funding process open, it is less clear how it fulfills the matchmaking role of traditional venture capital models.

Given the heterogeneity in the populations of investors and startups, crowdfunding platforms can offer added value to the two sides of the market they serve by segmenting each population to ensure an improved match between the riskiness of the startup and the risk profile of the investor who chooses to invest in it. In this paper we investigate whether such segmentation can arise as equilibrium when two platforms compete in attracting both investors and startups. At the segmenting equilibrium, one platform acts as a matchmaker between more risky startups and experienced investors who tend to be more tolerant to risk and the second platform matches the opposite profiles of startups and investors, namely less risky startups with more highly risk-averse investors. We show that the existence of such a segmenting equilibrium ensures that both platforms can compete profitably, given that the populations they serve view them as being differentiated.

Besides its matchmaking function, another important characteristic of a platform that determines its value to each side of the market is the size of the opposite side served by the platform. The literature on two-sided markets has referred to this size related benefit derived by customers as positive network externalities. In the context of equity crowdfunding, such positive network externalities are definitely in place for the startup side of the market because the probability of successfully closing a funding round improves when the platform attracts a larger number of investors. While an investor may also benefit if a platform lists a bigger number of startups from which to choose, the number of startups listed is of lesser importance to the investor than their quality and the compatibility of the startups with the risk profile of the investor. This is especially true because the restrictions imposed by the SEC limit anyhow

[2] http://www.fastcompany.com/3039508/what-every-entrepreneur-should-know-before-taking-any-outside-investment
http://techcrunch.com/2012/04/08/things-to-consider-before-saying-i-do-to-investors/

the number of startups in which investors can invest. In formulating the environment facing the two crowdfunding platforms, we assume, therefore, that only startups and not investors care about the size of the other side served by the platforms. The literature on two-sided markets has referred to such an environment as one-sided network externalities.

In addition to providing a website where startups can pitch their ideas and investors can learn about startups, platforms also provide tools and services that enable investors to search for available investment opportunities and to carry out the investment process. For example, there are around 600 startups listed on Angellist that are looking for funding. An individual investor does not have the time and resources required to learn about all 600 startups and to choose the ones matching his investment criteria. Angellist offers several features that help investors to filter startups and to assess their quality by publishing a quality score for every startup and by allowing them to follow the behavior of other investors. Such features are valued highly by investors and may drive their platform choice. Moreover, some platforms conduct a very rigorous vetting process of the startups. This vetting process may lead to only 1-2% of startups being approved for funding (in case of Circleup and Wefunder, according to Table 1), thus assuring investors about the quality of the startups listed with the platforms. Once the investment decision is made, platforms handle the legal, accounting, and financial procedures required to complete the investment. In our model, therefore, we assume that platforms compete along two dimensions: the quality of service they provide to investors and the fees they charge investors and startups. As far as the fee structure is considered, we consider three different regimes. A regime when both investors and startups pay fees, a regime when only investors pay a fee, and a regime when only startups pay a fee.

We model the competition between the two crowdfunding platforms as a two stage game where in the first stage each platform chooses its level of investment in the quality of service it offers to investors and in the second stage it chooses its fees. We find that the segmenting equilibrium can arise only when compatibility in terms of their risk profiles is of high importance to both investors and startups. Moreover, the importance of compatibility should be significantly higher than the size of the network externality considered by startups in order for segmentation to arise as equilibrium. We also find that the segmenting equilibrium is characterized by great asymmetries between the platforms, with one of them offering higher quality service and commanding a bigger share of both the investor and startup markets. This asymmetry arises even though a priori both platforms are identical in terms of their ability to access the technology that facilitates offering higher quality service. This asymmetry both in terms of

funds raised and number of deals closed is demonstrated in Table 1, where the leading platform Angellist raised about 18 times more funds than WeFunder, listed fifth in terms of funds raised. We find that when the size of the network externality that is considered by the startups is relatively big segmentation can be supported only with the pricing regime that charges exclusively startups and not investors. In contrast, when the size of the network externality is relatively small, both a fee structure that charges exclusively investors and a fee structure that charges both sides of the market can support segmentation. In this latter case, the regime that charges both investors and startups leads to greater asymmetry between the platforms. The comparison of industry profits that accrue to the platforms under these two pricing regimes is ambiguous. However, when the size of the network externality is especially small, charging both sides of the market yields higher industry profits than charging exclusively only investors. We show that with an especially small externality the regime that charges both sides of the market leads, on average, to higher fees and to lower investment in quality, thus leading to increased profitability of the platforms.

To the best of our knowledge, our paper is the first to analytically model the nature of competition between equity crowdfunding platforms. Our results indicate that by strategically choosing prices and the level of support to investors, competing platforms can implement an improved match between the risk profiles of startups and investors in comparison to random matching of the two sides. Startups and investors self-select between the two platforms by comparing their fees, the level of support they offer to investors, and the expectations of each side regarding the type of customers the platforms attract on the opposing side of the market. The improved match between startups and investors arises because at equilibrium one platform matches more risky startups with less risk-averse investors and the other matches the opposite profiles of startups and investors. With such segmentation of the two populations platforms can avoid the zero profit Bertrand outcome that arises with random matching and to earn strictly positive profits. Moreover, with expectations that profits are positive the platforms have incentives to invest in offering improved quality of service to investors.

While we focus our investigation on the matchmaking role of equity crowdfunding platforms in terms of the risk profiles of their customers, our analysis can be easily extended to consider improved matching based on alternative criteria such as type of industry or the demographics of the market served by the startup. Kim and Viswanathan (2016) demonstrate that the expertise of investors can enhance the probability of funding success and ex-post performance of startups in which they invest. Some crowdfunding platforms seem, in fact, to follow the strategy of segmenting the startup and investor

populations in order to ensure improved match between the two sides of the market. For example, Circleup is an equity-crowdfunding platform that is attracting mostly consumer product startups. It focuses on matching consumer product startups with investors experienced in consumer product and retailing. Similarly, platforms such as Appsfunder, Experiment, and Sofi that facilitate funding of apps, scientific research, and students, respectively, try to achieve improved match between startups and investors by focusing on specific types of projects and businesses. The literature on competition in two sided markets has demonstrated that the existence of heterogeneity in the populations matched by platforms does not generally lead to the segmentation of the populations (see, for instance, Damiano and Li (2008)) because of the incentive of each platform to take over the entire market. We characterize conditions that can facilitate such segmentation and illustrate that segmentation is conducive to the profitability of the platforms. We find that when the equilibrium is characterized by significant quality differentiation between the platforms, the incentive of each platform to deviate from segmentation to domination of the entire market disappears because such a deviation requires a significant cut in fees. Hence, in order to support the improved match that segmentation facilitates, our analysis predicts that there should be significant asymmetries between the platforms in terms of the quality of service they choose to provide in equilibrium. Such asymmetries seem to be present, indeed, among equity crowdfunding platforms, with the leading platform Angellist offering far greater support to investors than its smaller competitors.

2. Literature Review

Recent studies have examined the participation of crowds in various forms of funding mechanisms such as reward-based, debt-based, and equity-based funding. Most of this literature is empirical in nature and focuses on understanding the motivation and behavior of participants and factors affecting the outcomes of crowdfunded projects. In the context of reward-based crowdfunding, studies consider questions such as the ability of crowdfunding to help entrepreneurs overcome geographical barriers to funding (Agrawal et al. 2015 and Lin and Viswanathan 2015), factors that determine funding success (Mollick 2014), and issues related to funder behavior (Burtch et al. 2013, 2015 and Mollick and Nanda 2015). Recently, there have been several theoretical papers dealing with the role of crowdfunding as a price discrimination device and as a vehicle to learn information about the future demand for the product (Bender et al. 2015, Chen et al. 2015, and Hu et al. 2015). These papers relate, once again, to reward-based crowdfunding. In the context of debt-based crowdfunding and peer to peer lending where individuals and businesses borrow funds from multiple lenders, empirical studies have focused on

understanding funder behavior (Zhang and Liu 2012, Liu et.al. 2015), network effects (Lin et.al. 2012), and interaction between retail and institutional investors (Lin and Wei 2015). Wei and Lin (2016) provide a theoretical comparison of posted prices and auctions in terms of their effect on funding outcomes and social welfare. Description of the inner working of equity crowdfunding can be found in Agrawal et al. (2014) and in Belleflamme et al. (2015). Ahlers et al. (2015) is an empirical study that examines the effectiveness of signals used by entrepreneurs to induce investors to commit financial resources in an equity crowdfunding context. Similarly, Kim and Viswanathan (2016) examine the signaling role of the experience of early investors in affecting the behavior of later investors.

To the best of our knowledge, ours is the first analytical study to investigate the strategic aspects of equity crowdfunding platforms. Our approach has been motivated by increased competition in the equity crowdfunding market and the role platforms play in matching startups with investors. Given that startups and investors benefit when each side is matched with a partner of a compatible risk profile on the other side, we address the question of whether competition between platforms can enhance the efficiency of the matching process. Consistent with the earlier studies on matching markets with heterogeneous populations, we find that competition can lead to efficient matching through segmentation of the two sides. However, this literature shows that segmentation may be difficult to attain if the only strategic variable that is available to platforms is the price they charge. In this case platforms may have an incentive to overtake the entire market, thus eliminating the possibility for the coexistence of competing platforms. In contrast, we find that when platforms choose both price and the quality of service offered to customers two platforms can co-exist in equilibrium if there is significant asymmetry between the platforms in terms of the quality of service they choose to offer at the equilibrium. The commitment to quality investment in early periods reduces price competition and eliminates the incentive of platforms to dominate the entire market.

Even though we focus on one particular type of platform, our model contributes to the general literature on platforms serving two separate markets. The seminal papers (Caillaud and Jullien 2003, Rochet and Tirole 2003, Parker and Van Alystyne 2005, and Armstrong 2006, 2007) focused on understanding the pricing structures and the externalities that arise in such two-sided markets. While earlier studies on platform competition assume that users are homogenous and focus on the case of symmetric networks, later studies consider user heterogeneity and the equilibrium asymmetries that such heterogeneity generates. These later studies differ in terms of the main role platforms play in serving the two markets: to offer a large network of users (such as in the case of payment card services)

or to provide intermediation services (such as in matchmaking or recruitment services.) Network externalities arise when the benefit derived by users is determined by the size of the network that the platform serves. Concerns regarding compatibility arise when the main function of the platforms is to provide marketplaces for parties to match with each other. The literature has demonstrated that differentiation between platforms may arise endogenously by self-selection of segments of users on each side of the market either because of the existence of network externalities (Ambrus and Argenziano 2009 and Gabszewicz and Wauthy 2014) or because of the type of users who are expected to be active on each platform (Damiano and Li 2008). Due to the unique setting offered by crowdfunding markets, we present an integrated approach to study both network externalities and improved matching efficiency when platforms compete. Consistent with the earlier literature that considers only network externalities (Parker and Van Alystyne 2005, Armstrong 2006, Rochet and Tirole 2006, Hagiu 2009, and Weyl 2010), we find that the optimal pricing strategy of platforms tends to offer lower prices to the side of the market that cares less about the externalities, which in our case implies lowering prices to investors. Moreover, when network externalities are relatively weak and when users' appreciation for compatibility is relatively strong, we demonstrate that the strategies selected by the platforms may yield an improved matching process that arises due to the segmentation of the two sides of the market.

In addition to the above studies that consider the role of prices in coordinating the two sides, recent studies have also analyzed the role of non-price variables in coordinating the two sides served by the platform. Examples of such variables include content (Hagiu and Spulber 2013) and the extent of openness of the platform (Parker and Van Alstyne 2008, and Casadesus-Masanell and Lianes 2015). In the context of platforms offering intermediation services, Mukherjee et al. (2015) analyze how platforms can utilize information to authenticate or validate users in order to achieve improved segmentation of users. In our setting, the quality of service offered supplements prices in facilitating segmentation. We focus on segmentation that leads to an improved match between the risk profiles of the users on the two sides of the market.

3. Model

Startups:

While all startups are evaluated on their potential for future returns to investors, the potential of a startup to generate future returns depends on several factors such as the type of innovation, market characteristics, customer segment, and experience and motivation of founders. Each startup is unique in

terms of these characteristics and differs in its potential for future returns. For example, innovations can be either disruptive or incremental. Disruptive innovations are characterized by both high returns and high risk. Incremental innovations are characterized by lower risk but limited upside potential. Similarly, the customer segment that a startup is targeting may also indicate the extent of risk involved in the startup. Some markets are tougher to penetrate and grow than others. For example, markets that have been historically controlled by large corporations, such as financial or energy markets are harder to crack than consumer electronics or online retailing.

To capture the heterogeneity among startups, we use a measure called growth score, designated by the variable s that indicates the potential of a startup to generate future returns. It can be calculated based on several observable factors such as target market, pervious startup experience of the founders, customer traction, social media metrics, and so on. Startups with a greater potential for future growth have a higher growth score. Growth score is also a widely accepted measure in practice for evaluating startups[3]. The distribution of this variable in the population of new startups is assumed to be uniform on the unit interval $[0,1]$. The growth potential of the startup determines both its expected return and risk. Specifically, we assume that both the mean μ_s and variance σ_s^2 of the return are linearly increasing functions of the growth score of the startup[4]. We specify these functions as:

$$\mu_s = b_1\, s,\ \sigma_s^2 = b_2\, s, \text{where } b_1 > 0 \text{ and } b_2 > 0. \tag{1}$$

The underlying rationale behind (1) is that when choosing among investment opportunities there is generally a tradeoff between expected return and risk. This is especially true regarding startups where high potential for future growth is accompanied sometimes with substantially increased levels of risk. For example, Airware is a startup that makes operating software for unmanned aircrafts. The company has very high potential for growth due to its innovative technology and focus on a relatively untapped market. However, there is also higher risk associated with investing in this company, as very few investors have prior experience in this industry or the necessary expertise to assess this new technology. In contrast, a startup like MELT that makes organic butter replacement, has limited potential for growth when compared with Airware. However, it is also associated with reduced risk, because investors have far greater experience with investing in consumer product companies.

[3] A company called Mattermark publishes growth scores for startups and these scores are widely used by investors to evaluate startups for funding.

[4] Even though we refer to s as growth potential of the new venture, this variable can capture any other characteristic of the venture that yields both a high return and increased volatility.

Investors:

There is usually heterogeneity in the type of investors that are participating in equity-based crowdfunding platforms. While some are highly experienced or high net-worth investors who have made successful investments in the past, others may have only limited prior experience or limited assets to invest. Investors with prior experience in startup investing are better equipped to assess the risks associated with an investment opportunity, and therefore, may be willing to invest in riskier startups. This is also the case with high net-worth investors who can tolerate a higher level of risk that is associated with high growth potential startups. However, given the high risk of investing in any type of startup and the fact that the invested amount is completely illiquid, we assume that all investors regardless of net worth exhibit some degree of risk aversion. The degree of risk aversion varies, though, in the population of investors. We designate the degree of risk aversion of an investor by *r,* and assume it to be uniformly distributed in the population of investors on the unit interval $[0,1]$. The expected utility of an investor of type *r* when investing in a startup of type *s* is given as:

$$EU(r) = K_I + \mu_s - r\sigma_s^2, \text{ where } K_I, r > 0. \quad (2)$$

Hence, investors derive higher utility from investing in startups that yield higher return and a lower variance of the return, with more risk-averse investors experiencing more significant disutility when the riskiness (variance) of the project rises. The specification in (2) is consistent, for instance, with a utility function over wealth exhibiting Constant Degree of Absolute Risk Aversion and a Normal distribution of the return on the investment. We assume that the constant K_I is sufficiently big to ensure that all investors find it optimal to sign up with one of the platforms.

Platforms:

Crowdfunding platforms help prospective startups raise capital for their business by providing a marketplace that connects startups looking for capital with potential investors. In addition to their intermediary function, platforms also provide information tools and support services to aid investors in the investment process. Crowdfunding platforms help investors to find and evaluate startups by providing timely and accurate updates of business and investment milestones and of market and investor intelligence about the startup. In addition, platforms provide support services such as accounting, legal, and financial services required for the completion the investment. With the entry of several platforms into the equity crowdfunding market following the Jobs Act, platforms are trying to differentiate themselves from competitors by providing better quality of information and support services. In particular, the quality of information tools that they provide to investors seems to be a

strong basis for differentiation between crowdfunding platforms. For example, Angellist provides superior intelligence information to investors when compared to other crowdfunding platforms such as SeedInvest and Fundable. In particular, Angellist ranks startups based on their popularity with other investors and provides networking tools that allow investors to observe the investment activity of experienced investors.

With the above in mind, we assume that two competing platforms choose the quality of services they provide and use it as a strategic variable in the competition. We designate by q_i the quality of services offered by platform $i; i = 1,2$. Platforms use a variety of pricing models in the market. Sometimes they charge fees from both investors and startups. Sometimes they charge only investors, and sometimes they charge only startups. The fee structure itself varies and can take either the form of a fixed membership fee or a transaction fee as referred to in the literature of two-sided markets (Caillaud and Jullien 2003, and Armstrong 2006). In the latter case, the platform charges a percentage of the return earned when charging investors (referred to as carry fee) or a percentage of the total investment round when charging startups. In order to simplify the derivations, in our analysis we will focus on the case that investors and startups pay fixed membership fees. In Appendix A we consider alternative fee structures where investors pay a percentage of the return on the investment and startups pay a percentage of the investment round[5].

We designate by R_i the fee that platform i charges startups and by p_i the fee it charges investors. For simplicity, we assume that the level of investment in the startups featured on the platform is the same for all investors. We normalize this level to 1. Our model can be easily extended to allow for investors of different degrees of risk aversion to invest different amounts in their selected startup. We later discuss how such an extension is likely to affect the results. We assume that both sides of the market served by the platforms are fully covered, namely each investor and each startup choose to subscribe to one of the platforms. With such a formulation, the strategic variables chosen by the platforms (quality and fees) do not affect the total size of the market served. Instead, when a platform offers higher quality or lowers fees it simply steals market share from the competing platform.

The expected utility an investor derives when using a given platform depends on the quality of information provided by the platform. More information and better quality of data make the estimates

[5] We find that when startups pay a percentage of the investment round the equilibrium is identical to that obtained when startups pay a fixed membership fee. When investors pay a percentage of the return on the investment the derivations become very cumbersome and do not yield a closed form solution.

of μ_s and σ_s^2 associated with an investment opportunity more reliable, and therefore, enhance the utility of the investor. We modify the expected utility in (2) by adding a component that reflects the quality of information provided by the platform that the investor selects as follows:

$$EU^i(r) = K_I + \mu_s - r\sigma_s^2 + \theta q_i \text{ , where } \theta > 0. \quad (3)$$

The parameter θ measures the importance of quality of information offered by the platform in determining the investor's utility[6]. This parameter is smaller, for instance, when investors have access to other reliable sources to discover and evaluate opportunities. These sources may include the investor's own network or services provided by business intelligence firms such as Mattermark and CB Insights. Such data is currently very expensive to obtain for individual investors.

Startups looking for capital are not merely interested in attracting as many investors as possible but in finding the right profile of investors for their business. In particular, startups benefit from attracting the right investors that can tolerate the particular risks involved in their business. On their journey of transforming new ideas to marketable products, speed and agility are essential for the success of startups. However, the diffused ownership structure that crowdfunding generates may complicate the ability of the management team to remain flexible and quick in responding to unanticipated events. In an era of increased activism on the part of shareholders, the success of startups may depend on limiting the extent of disruptions caused by disagreements between investors and the management team of the startup. Hence, the value of the platform can be enhanced if it can ensure an improved match between the profiles of investors and startups that it serves. For instance, when connecting startups facing higher risk with experienced and knowledgeable investors who are willing to assume higher risks, the platform increases the value of the match for both the startup and the investor.

In any platform based business model, the challenge is to achieve coordination between the two sides of the market served by the platform. Platforms use various instruments to achieve such coordination including fee structure, content, and quality of service. While each side served by the platform may benefit when the size of other side is larger, participants derive also greater utility if the platform can ensure an improved match between the two sides. Given that both investors and startups benefit from such an improved match, we restrict attention to equilibrium where agents choose to subscribe to only

[6] For simplicity we assume that θ is common to all investors irrespective of their degree of risk aversion. It is possible that the valuation of quality is higher for individuals who are more risk averse. This possibility would result in higher likelihood that the platform that serves the more risk-averse segment of investors to offer higher quality. This is not necessarily the case in our setting.

one of the platforms, the one they believe will offer them a more compatible match with the other side of the market (This environment was termed two-sided single homing in Armstrong 2006). In a competitive environment, platforms can achieve such improved alignment by using their strategic decision variables, such as price and quality of service, to segment the two sides of the market. In the case of equity crowdfunding platforms, the segmentation on the investor side may be based on their degree of risk aversion, and on the startup side, the segmentation may be based on the growth potential (and therefore, riskiness.) In Figure 1, we illustrate the segmentation of the populations of new startups and investors that is consistent with such improved alignment.

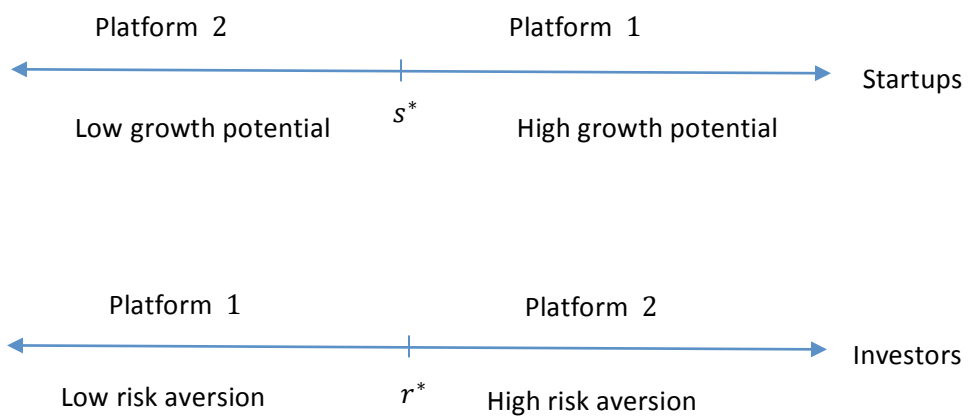

Figure 1: <u>Segmentation of the Populations to Improve Compatibility</u>

In Figure 1, platform 1 plays the role of "matchmaker" between high growth potential startups and low risk-averse investors, and platform 2 matches the opposite profiles of startups and investors, namely, low growth startups and highly risk-averse investors. This segmentation of the two sides arises because startups of growth potential higher than s^* self select to be listed on platform 1 and companies of growth potential lower than s^* choose the competing platform. Similarly investors choose the platform to fit their risk profile. Specifically, those that have relatively low aversion to risk $(r < r^*)$ choose platform 1 and those with high aversion to risk $(r > r^*)$ choose platform 2. In our analysis, we will investigate which parameters of the models and strategic variables selected by the platforms can support the type of segmentation described in Figure 1.

To capture the importance of compatibility between the risk profiles of startups and investors, we specify the payoff function of a startup using the platform as follows:

$$E\pi(s) = K_S + \beta[expected\ size\ of\ T_s] + \alpha E_r[(s-r)^2 \mid r \in T_s], \text{ where, } K_S, \beta, \alpha > 0. \quad (4)$$

T_s designates the segment of investors who consider investing in a startup of type s a viable option. In Figure 1, for instance, $T_s = [0, r^*]$ for $s \geq s^*$ and $T_s = [r^*, 1]$ for $s < s^*$. We assume that the constant K_S is sufficiently big to ensure that all startups find it optimal to sign up with one of the platforms.

According to (4) startups benefit from attracting investors whose risk attitudes are compatible with the risk profile of the company. While the second term in (4) measures the importance of the number of potential investors, the third term measures the importance of compatibility between the risk profiles of the startup and its investors. This third term is bigger when a high growth potential startup is matched with low risk-averse investors, or inversely, when a low growth potential startup is matched with high risk-averse investors. The ratio of the parameters $\frac{\beta}{\alpha}$ in (4) measures the relative importance to the startup of the number of investors and their compatibility.

Upon inspection of the expressions for the expected benefit of investors in (3) and startups in (4), note that we assume that while startups benefit from a larger number of investors listed with the platform (size of T_s), investors do not derive higher utility if a larger number of startups are listed with the platform. The literature on two-sided markets has referred to such an assumption as one sided network externalities. Given SEC regulations that restrict individual investments in crowdfunding platforms to less than 5% of annual income or $2000 for individuals with annual income below $100,000 (less than 10% for individuals with annual income above $100,000) and the fact that platforms feature hundreds of startups, individual investors can only invest in a limited number of startups per year. As a result, the number of startups listed on the platform is of lesser importance to investors. It is high level of assurance regarding the quality of the startup and the extent to which the profile of the startup is consistent with the risk tolerance of the investor that is important in the investor's choice. In contrast, startups wish to raise large amounts of capital by pooling investments from several investors, implying that the number of investors listed with the platform is very important to them. When a platform attracts a large number of investors, the probability of the startup successfully closing its funding round increases and the startup may also benefit from gaining exposure to a larger number of potential users. We can easily change the formulation of the utility of investors to allow it to increase with the number of startups listed with the platform, thus introducing two sided network externalities in our model. As long as investors care about the size of the opposite side of the market less than startups do, our qualitative results are unlikely to change.

We formulate the environment as a two stage game. In the first stage, each platform decides on the amount of resources to invest to gather data and intelligence about startups listed with the platform and offer tools and services that help investors. This investment determines the quality of service offered by the platform, q_i. In the second stage, each platform chooses the listing fee it charges from startups and investors, R_i and p_i, respectively. The sequence of the decisions reflects the long term process of designing the information tools and business intelligence software required to gather and analyze data about startups. Such investment constitutes a long term commitment of resources in technology and personnel that cannot be easily adjusted in the short run. In contrast, platforms have greater flexibility to change the fees they charge. We assume that providing quality level q_i requires upfront investment cost equal to:

$$TC(q_i) = \gamma {q_i}^2. \tag{5}$$

Hence, the cost of the investment increases at an increasing rate. Both platforms face the same cost function. Other than this upfront, fixed investment cost, we assume that platforms do not incur any additional cost to serve either investors or startups. Hence, once the infrastructure in terms of technology and personnel is in place, platforms do not incur any additional variable cost[7].

A startup looking to raise capital chooses a crowdfunding platform to maximize (4) net of the fee R_i charged by the platform. To characterize this choice we define by $\Delta\pi(s)$ the additional payoff derived by a startup of type s when choosing platform 1 instead of its competitor, platform 2. Assuming the segmentation depicted in Figure 1, we obtain from (4):

$$\Delta\pi(s) = \left[\beta r^* + \alpha \frac{\int_o^{r^*}(s-r)^2 dr}{r^*}\right] - \left[\beta(1-r^*) + \alpha \frac{\int_{r^*}^{1}(s-r)^2 h(r) dr}{[1-r^*]}\right] - (R_1 - R_2). \tag{6}$$

After some algebraic manipulation we can express (6) as:

$$\Delta\pi(s) = \beta(2r^* - 1) + \alpha s - \alpha\left[\frac{1+r^*}{3}\right] - (R_1 - R_2). \tag{7}$$

Note that $\Delta\pi(s)$ is an increasing function of s, given that the coefficient of s in (7) is positive. According to the segmentation depicted in Figure 1, low risk averse investors choose to list with platform 1. Because startups derive added benefits from compatibility with the risk profile of investors, the benefit

[7] The role of variable cost in mitigating some of the adverse consequences on pricing of network externalities in two-sided markets has been discussed in studies that focus primarily on price competition between platforms (see Armstrong 2006). Given our goal of understanding the matchmaking role of platforms, we normalize variable cost to zero. Our analysis can be easily modified to include such costs.

a startup derives from listing with platform 1 increases as its growth potential, and therefore riskiness, increases. Put differently, startups having relatively high growth potential are more inclined to choose platform 1 because this platform attracts also investors who are relatively more tolerant to risk. Assuming that both platforms have positive shares of the market, there exists an $s^* \in (0,1)$ such that $\Delta\pi(s^*) = 0$, and $\Delta\pi(s) \geq 0$ for $s \geq s^*$ and $\Delta\pi(s) < 0$ for $s < s^*$. Specifically, startups self-select between the two platforms as depicted in Figure 1. Solving for s^* from (7), we obtain:

$$s^* = \frac{(R_1 - R_2)}{\alpha} + \frac{[\alpha + 3\beta - r^*(6\beta - \alpha)]}{3\alpha}. \tag{8}$$

Note that the market share of platform 1 $(1 - s^*)$ increases the lower the listing fee to startups of platform 1 relative to that of platform 2. However, gaining market share among startups by lowering fees becomes more difficult for the platforms as the parameter α increases. Hence, the value of the parameter α can be interpreted as a measure of the degree of differentiation between the platforms as viewed by startups. When this parameter assumes a bigger value, price competition between the platforms on the startup side of the market is alleviated. As well, the sign of the expression $(6\beta - \alpha)$ determines the relationship between the market share of platform 1 among startups and its market share among investors. If $(6\beta - \alpha) > 0$, the effect of increasing market share among investors (higher r^*) has a positive externality on the market share among startups ($(1 - s^*)$ increases). When $(6\beta - \alpha) < 0$, increasing market share among investors imposes a negative externality on the market share among startups. In our analysis we will focus on the case that $(6\beta - \alpha) > 0$. This assumption implies that despite the importance of compatibility with the profile of investors (i.e., the parameter α is positive), attracting a large population of potential investors is still weighed quite heavily by startups (i.e., the parameter β is sufficiently big.) This assumption (compatibility parameter α is smaller than six times the size parameter β) is quite sensible, given that crowdfunding is mostly used by early stage startups, and such firms value highly exposure to a large number of investors.

The net benefit derived by an investor from listing with platform i is obtained by subtracting the listing fee p_i charged by the platform from the gross benefit expression in (3). Hence, this net benefit is equal to $K_I + \mu_s - r\sigma_s^2 + \theta q_i - p_i$. Investors choose the platform that offers them the higher net benefit. We define by $\Delta U(r)$ the added benefit derived by an investor of risk profile *r* when listing with platform 1 instead of its competitor, platform 2. For the segmentation depicted in Figure 1, we can obtain $\Delta U(r)$ as follows:

$$\Delta U(r) = b_1 \Delta E(s) - r b_2 \Delta E(s) + \theta(q_1 - q_2) - (p_1 - p_2),$$

where $\Delta E(s) = E(s \mid s \geq s^*) - E(s \mid s < s^*)$. Simplifying the above expression yields:

$$\Delta U(r) = \frac{b_1}{2} - r\frac{b_2}{2} + \theta(q_1 - q_2) - (p_1 - p_2). \quad (9)$$

Note that the added benefit of listing with platform 1 instead of 2 is decreasing the more risk averse the investor is, because according to the segmentation in Figure 1, platform 1 attracts relatively risky startups. Assuming that each platform is preferred by some investors, it follows that there exists $r^* \in (0,1)$ so that $\Delta U(r^*) = 0$, and $\Delta U(r) \geq 0$ for $r \leq r^*$ and $\Delta U(r) < 0$ for $r > r^*$. Solving for r^* from (9) yields:

$$r^* = \frac{b_1}{b_2} + \frac{2(p_2 - p_1)}{b_2} + \frac{2\theta(q_1 - q_2)}{b_2}. \quad (10)$$

Hence, the market share of platform 1 among investors rises the more highly correlated the growth score is with the expected rather than the variance of the return on the investment. Specifically, as the ratio $\frac{b_1}{b_2}$ is bigger, the rate of increase in the expected return on the investment in a startup of a higher growth score is more significant than the rate of increase in the extent of riskiness of the startup. Hence, when $\frac{b_1}{b_2}$ is bigger, the platform that attracts high growth score startups (platform 1 in Figure 1) becomes more attractive to investors and gains a bigger market share among them. The market share of platform 1 among investors increases also when the platform charges investors a lower membership fee and offers them higher quality services. Note the parameter b_2 determines how sensitive market shares in the investor market are to the gaps in qualities and prices selected by the platforms. As this parameter assumes a bigger value market shares are less sensitive to such gaps, and the extent of competition between the platforms on the investor side of the market weakens.

Equations (8) and (10) describe the segmentation when platform 1 matches high growth score startups with low risk-averse investors. Similar expressions can be derived when platform 1 matches the opposite profiles of startups and risk-aversion degrees. Note that s^* and r^* were derived based upon optimal self-selection by startups and investors. When the platforms choose their fees and quality levels, they are aware of the fact that their choice will determine their market shares among startups and investors as characterized in (8) and (10). If the objective of the platforms is to maximize profits we can express the maximization problems of the platforms as follows:

$$\max_{q_1, R_1, p_1} V_1 = p_1 r^* + (1 - s^*) R_1 - \gamma q_1^2 \quad (11)$$

$$\max_{q_2, R_2, p_2} V_2 = p_2(1 - r^*) + s^* R_2 - \gamma q_2^2,$$

where s^* and r^* are given by (8) and (10).

The revenues of platform 1 accrue from investors in the lower tail of the distribution of r, less than r^*, and the upper tail of the distribution of s, more than s^*. The revenues of platform 2 accrue from the upper tail of the distribution of r, more than r^*, and the lower tail of the distribution of s, less than s^*. Net profits are derived by subtracting from revenues the cost of investing in the quality of service offered to investors. To ensure sub-game perfect equilibrium, we derive the equilibrium of the two stage game by backward induction. We first solve for the second stage equilibrium fees as a function of given levels of qualities selected by both platforms in the first stage. Subsequently, we solve for the equilibrium of the entire game by deriving the quality levels selected in the first stage. When optimizing with respect to quality each platform incorporates the effect of its choice on the equilibrium fees anticipated in the second stage. Proposition 1 follows directly from this two stage optimization process. The proofs of all Propositions are included in Appendix A.

Proposition 1

(i) At equilibrium the market shares of the platforms are determined as follows:

$$(2r^* - 1) = \frac{27\alpha\gamma(2b_1 - b_2)}{\Delta},\ (1 - 2s^*) = \frac{3\gamma(6\beta - \alpha)(2b_1 - b_2)}{\Delta}, \tag{12}$$

where $\Delta \equiv [\gamma[81\alpha b_2 - 4(6\beta - \alpha)^2] - 36\alpha\theta^2] > 0$ to ensure that the condition for stability of reaction functions is satisfied (convergence to the equilibrium is guaranteed.)

(ii) The gap between the quality levels selected by the platforms at the equilibrium is:

$$q_1 - q_2 = \frac{9\alpha\theta(2b_1 - b_2)}{\Delta}. \tag{13}$$

(iii) The gaps between the listing fees charged by the platforms from startups and investors are:

$$R_1 - R_2 = \frac{3\alpha\gamma(6\beta - \alpha)(2b_1 - b_2)}{\Delta}, p_1 - p_2 = \frac{(2b_1 - b_2)\gamma}{2\Delta}[27\alpha b_2 - 2(6\beta - \alpha)^2]. \tag{14}$$

From equations (12)-(14), we can observe that when $(2b_1 - b_2) > 0$ platform 1 gains the larger share among both sides of the market ($r^* > \frac{1}{2}\ and\ s^* < \frac{1}{2}$, in this case). When $b_1 > \frac{b_2}{2}$, the expected return increases at a faster rate than half of the expected risk with a rise in the growth score. As a result, startups with higher growth scores become more appealing to investors and the platform that attracts such startups is preferred by a larger number of investors. Due to our assumption of positive network externalities ($(6\beta - \alpha) > 0$), platform 1 attracts also a larger number of startups. Because of its advantage in market size, platform 1 has a stronger incentive to invest in quality ($q_1 - q_2 > 0$, in this case), a result that further strengthens its position. It is noteworthy that the dominance of platform 1 in this case would further increase if we relaxed the assumption that each investor invests the same amount in his selected startup. If investors could optimally choose their level of investment, it is easy to

show that lower risk-averse investors would choose to invest bigger amounts in their selected startup. Because platform 1 attracts this type of investors its appeal to startups would further increase, thus allowing it to further increase its market share.

The comparison of the membership fees implies that while platform 1 unambiguously charges a higher membership fee from startups relative to platform 2 (i.e., $R_1 - R_2 > 0$), it does not necessarily charge the higher membership fee from investors, because the sign of $p_1 - p_2$ is unclear, even after incorporating the reaction functions stability restriction that $\Delta > 0$. This can be best explained by the presence of one-sided network externalities. Although platform 1 offers higher quality when $(2b_1 - b_2) > 0$, it may find it optimal to charge a lower price to investors to remain attractive to startups, because startups value the number of investors that a platform attracts (our assumption that $(6\beta - \alpha) > 0$ ensures that the network externality is positive). This result is consistent with the earlier literature on platform competition that has demonstrated that the existence of network externalities (where the size of one side of the market determines the value of the platform to the other side) may lead platforms to lower fees and even subsidize one side of the market they serve (see, for instance, Armstrong 2006) In spite of this possible ambiguity regarding the sign of the gap between the fees that platforms charge investors, we will restrict attention to the case that the dominant platform charges the higher fee not only from startups but from investors as well, namely that $(p_1 - p_2) > 0$ when $(2b_1 - b_2) > 0$. Hence, in spite of its concern of losing share among startups, the bigger platform finds it optimal to take advantage of its dominant position to charge even investors higher fees. From (8) the value of $(6\beta - \alpha)$ determines the strength of network externality that the investor side of the market imposes on the startup side. When this value is relatively small, network externalities from the investor side are quite weak and concerns about losing share among startups are lower. Therefore, the dominant platform is more inclined to take advantage of its larger share in the investor market to charge higher fees to investors. Moreover, from (10) when b_2 is sufficiently high, the extent of price competition between the platforms in the investor market is relatively weak as platforms are viewed as being more highly differentiated. This explains why in (14) when $[27\alpha b_2 - 2(6\beta - \alpha)^2] > 0$ the dominant platform charges investors higher fees. This condition ensures that $(6\beta - \alpha)$ is indeed sufficiently small in comparison to b_2. Note that the condition for stability of reaction functions (i.e., $\Delta > 0$) also requires that b_2 be sufficiently high in comparison to $(6\beta - \alpha)$. However, this requirement may be less demanding than the one to guarantee that $(p_1 - p_2) > 0$.

The characterization of the equilibrium is reversed when $(2b_1 - b_2) < 0$. Higher growth score startups become less appealing to investors in this case, because the higher return is insufficient to compensate for the higher riskiness of these startups. It is platform 2 that gains the advantage in this case. It obtains larger market shares, offers a higher level of quality, and charges higher membership fees from startups. There is still ambiguity in the comparison of the membership fees charged from investors. However, when $[27\alpha b_2 - 2(6\beta - \alpha)^2] > 0$, platform 2 charges investors higher fees. If we relaxed the assumption that all investors invest the same amount in their selected startup, the dominance of platform 2 in this case would diminish. Because higher risk-averse investors tend to invest smaller amounts and because platform 2 attracts this type of investors, its appeal to startups would diminish. In Corollary 1, we summarize the properties of the equilibrium and report some comparative statics results.

Corollary 1

(i) When $(2b_1 - b_2) > 0$ the platform that matches high growth score startups with low risk averse investors (platform 1) gains the larger market shares and offers higher quality. When $(2b_1 - b_2) < 0$, the platform that matches low growth score startups with high risk averse investors (platform 2) gains the larger market shares and offers higher quality.

(ii) The advantage of the dominant platform diminishes as $\alpha, and\ \gamma$ increase or as $\beta, and\ \theta$ decrease. As well, when $(2b_1 - b_2) > 0$, the advantage of platform 1 over platform 2 diminishes as b_2 increases and b_1 decreases. When $(2b_1 - b_2) < 0$, the advantage of platform 2 over platform 1 diminishes as b_2 decreases and b_1 increases.

According to part (ii) of the Corollary, the dominant platform loses some of its appeal when compatibility with the profile of investors becomes relatively more important to startups than the size of the investor population listed with the platform (i.e., when the ratio $\frac{\alpha}{\beta}$ is bigger). In this case the size advantage of the dominant platform diminishes. Similarly, if providing higher quality becomes more expensive (i.e., γ increases) or when investors place less emphasis on higher quality (i.e. θ declines) the quality advantage of the dominant platform diminishes. The effect of changes in the parameters b_1 and b_2 on the relative advantage of the dominant platform depends on whether the dominant platform caters to lower or higher risk-averse investors. In the former (latter) case, the advantage diminishes when the ratio $\frac{b_2}{b_1}$ increases (decreases), respectively. To explain, consider the case that $(2b_1 - b_2) > 0$, namely that b_1 is sufficiently big so that higher growth score startups offer a sufficiently higher rate of

return to compensate for their increased risk. When b_2 increases, the advantage of the platform that serves higher growth score startups diminishes, given that riskiness facing the investors they serve increases. A similar explanation can be used when $(2b_1 - b_2) < 0$.

It is noteworthy that the asymmetric equilibrium characterized in Proposition 1 arises even though, a priori, both platforms are identical, given that they face the same cost function for providing high quality of information. To ensure that the local equilibrium we characterize in the Proposition is global, it should be the case that for a fixed quality gap between the platforms established at the end of the first stage, no platform has an incentive to deviate from the local equilibrium by cutting its fees to such an extent that it dominates the entire market. In our setting, the smaller platform that earns lower profits at the local equilibrium (platform 2 when $2b_1 - b_2 > 0$) has the stronger incentive to deviate. In Appendix B we demonstrate that when the platforms are considered sufficiently differentiated from the perspective of both investors and startups (i.e., when b_2 and α are sufficiently big[8]) and when the quality gap between the platforms that is established in the first stage is sufficiently big, the smaller platform does not have an incentive to deviate from the interior equilibrium because it earns higher profits at this equilibrium than by deviating in order to dominate the market. Essentially, when the quality gap is sufficiently big, to dominate the market the deviating platform would have to cut its fees to such an extent that deviation becomes unprofitable. From Corollary 1 this gap is big when γ is relatively small and/or when θ is relatively big. The possible existence of pure-strategy equilibrium with segmentation that we obtain in our model contradicts the result derived in Damiano and Li (2008), where such equilibrium fails to exist when platforms move simultaneously. In this earlier paper the only strategic variable that is available to each platform is the fee it sets. In such an environment the authors demonstrate that one of the platforms always has an incentive to take over the market, thus eliminating the possible existence of equilibrium where both platforms co-exist. In contrast, in our environment the strategy of each platform consists both of fees and quality investment. When the equilibrium is characterized by significant quality differentiation between the platforms, the incentive of the smaller platform to deviate from its inferior equilibrium position disappears because the deviation requires a significant cut in fees. With significant quality differentiation, the bigger platform has a significant share

[8] When $2b_1 - b_2 > 0$ the restrictions imposed on α and b_2 are $\frac{\alpha}{\beta} > \frac{6}{37}$ and

$$b_2 > Max\left\{\frac{4\left(3b_1(13\alpha+3\beta)+13\alpha^2-48\alpha\beta+63\beta^2\right)}{243\alpha}\ ,\ \frac{2\left(14\alpha^2+30\alpha\beta+45\beta^2\right)}{9(4\alpha+3\beta)}+\frac{(24\beta-13\alpha)b_1}{3(4\alpha+3\beta)}\right\}.$$

of the market at the segmented equilibrium, and its deviation to domination of the market requires a significant cut in fees as well, thus making such deviation unprofitable.

In Proposition 2, we fully characterize the segmented equilibrium.

Proposition 2

(i) The equilibrium levels of qualities and fees are as follows:

$$q_1 = \frac{\theta[27\alpha b_2 - 2(6\beta-\alpha)(3\beta+\alpha)]}{2\gamma T} + \frac{9a\theta(2b_1-b_2)}{2\Delta},$$

$$q_2 = \frac{\theta[27\alpha b_2 - 2(6\beta-\alpha)(3\beta+\alpha)]}{2\gamma T} - \frac{9a\theta(2b_1-b_2)}{2\Delta}, \text{where } T \equiv [81\alpha b_2 - 4(6\beta-\alpha)^2],$$

$$R_1 = \alpha(1-s^*) = \frac{\alpha}{2}\left[1 + \frac{3\gamma(6\beta-\alpha)(2b_1-b_2)}{\Delta}\right],\ R_2 = \alpha s^* = \frac{\alpha}{2}\left[1 - \frac{3\gamma(6\beta-\alpha)(2b_1-b_2)}{\Delta}\right],$$

$$p_1 = \frac{b_2}{2}\left[r^* - \frac{2(6\beta-\alpha)}{3b_2}(1-s^*)\right] = \frac{b_2}{4} - \frac{6\beta-\alpha}{6} + \frac{\gamma(2b_1-b_2)[27\alpha b_2 - 2(6\beta-\alpha)^2]}{4\Delta},$$

$$p_2 = \frac{b_2}{2}\left[(1-r^*) - \frac{2(6\beta-\alpha)}{3b_2}s^*\right] = \frac{b_2}{4} - \frac{6\beta-\alpha}{6} - \frac{\gamma(2b_1-b_2)[27\alpha b_2 - 2(6\beta-\alpha)^2]}{4\Delta}.$$

(ii) The equilibrium profits of the platforms can be expressed as follows:

$$\pi_1 = \alpha(1-s^*)^2 + \frac{b_2}{2}r^{*2} - \frac{(6\beta-\alpha)}{3}(1-s^*)r^* - \gamma {q_1}^2,$$

$$\pi_2 = \alpha s^{*2} + \frac{b_2}{2}(1-r^*)^2 - \frac{(6\beta-\alpha)}{3}s^*(1-r^*) - \gamma {q_2}^2.$$

Inspecting the expressions derived in the Proposition, we can identify the main factors that determine the level of fees charged at the equilibrium. First, fees charged from a given side of the market served by the platforms depend on the extent to which this side regards the platforms to be differentiated. The parameters that measure this degree of differentiation are α for the startup side of the market and b_2 for the investor side of the market. When the parameters α and b_2 assume a bigger value, compatibility is more important for startups and investors, respectively, and the matchmaking role of the platforms is more highly appreciated. As the matchmaking role of platforms is valued highly by the two sides, platforms are considered to be more highly differentiated and price competition is alleviated. Therefore, on average, startup and investor fees increase when α and b_2 increase, respectively. The second factor that determines the fees is the direction and strength of the network externalities that the investor side of the market imposes on the startup side as captured by the parameter $(6\beta - \alpha)$. The second term of the expressions derived for the investor fees captures this effect ($-\frac{2(6\beta-\alpha)}{3}(1-s^*)$ for platform 1, for instance.) Hence, when the network externality is stronger ($6\beta - \alpha$ is bigger), platforms charge lower fees from investors. Note that if we considered two sided instead of one sided network externalities in our model, the expressions derived for startups fees R_i would have to be similarly reduced as the

incentive of platforms to defend their shares among startups would intensify. As well, we restrict attention to an environment where fees to investors remain positive in spite the network externality effect (i.e., b_2 is sufficiently big.) However, the earlier literature on platforms has reported that when the size of a given side of the market served by the platform is very important to the other side, the platform may decide not to charge any fee from this side (or even subsidize it.) This can happen in our environment as well when $(6\beta - \alpha)$ is relatively big in comparison to b_2. Lastly, the fee a given platform can charge increases with the share of the market that the platform commands. Hence, platform 1 (platform 2) commands higher fees on both sides of the market if $2b_1 - b_2 > 0$ ($2b_1 - b_2 < 0$), respectively (assuming that $[27\alpha b_2 - 2(6\beta - \alpha)^2] > 0$.)

The profit expressions derived in the proposition also capture the three factors we discuss above. The first and second terms of the profit expressions capture the revenues from startups and investors, respectively, gross of the network externality effect. Because of the intensified competition in the investor market that the latter effect introduces, the third term measures the reduction in revenues that is caused by the heightened downward pressure on investor fees. Finally, market shares determine the revenues of the platforms in the first three terms of the profit expressions.

In Appendix A we demonstrate that additional constraints have to be imposed on the parameters of the model to ensure the coexistence of both platforms and positive fees and qualities selected at the equilibrium. These constraints all require that the parameter b_2 has to be sufficiently big in comparison to $(6\beta - \alpha)$, the measure of network externalities in our model. To obtain greater insight to the role the parameters of the model play in determining the equilibrium characterized in Proposition 2, next we explore the manner in which changes in the parameters affect the average fees charged and average quality offered by the platforms. We report the results of this investigation in the next Corollary. In the Corollary we designate by $\bar{R}, \bar{p}$, and $\bar{q}$ the average fee to startups, average fee to investors, and average quality, respectively.

Corollary 2

$(i)\, \frac{\partial \bar{R}}{\partial \alpha} > 0,\ \ \frac{\partial \bar{p}}{\partial b_2} > 0,\ \ \frac{\partial \bar{p}}{\partial \beta} < 0,\ \ \frac{\partial \bar{p}}{\partial \alpha} > 0.$

$(ii)\, \frac{\partial \bar{q}}{\partial \theta} > 0,\ \frac{\partial \bar{q}}{\partial \gamma} < 0,\ \ \frac{\partial \bar{q}}{\partial b_2} \begin{cases} < 0 \ if\ \alpha < \frac{3\beta}{5} \\ > 0 \ if\ \alpha > \frac{3\beta}{5} \end{cases},$

$$\frac{\partial \bar{q}}{\partial \alpha} \begin{cases} > 0 \ if\ 1)\ \alpha < 3\sqrt{0.4}\beta \ and\ \ b_2 < \frac{4\beta(6\beta-\alpha)^2}{3(18\beta^2-5\alpha^2)} \ or\ if\ 2)\ \alpha > 3\sqrt{0.4}\beta \\ < 0 \ if\ \alpha < 3\sqrt{0.4}\beta \ \ and\ \ b_2 > \frac{4\beta(6\beta-\alpha)^2}{3(18\beta^2-5\alpha^2)} \end{cases},$$

$$\frac{\partial \bar{q}}{\partial \beta} \begin{cases} < 0 \; if \; 1) \; \alpha < \frac{12\beta}{11} \; and \; b_2 < \frac{4(6\beta-\alpha)^2}{9(12\beta-11\alpha)}, \; or \; if \; 2) \; \alpha > \frac{12\beta}{11} \\ > 0 \; if \quad \alpha < \frac{12\beta}{11} \; and \; b_2 > \frac{4(6\beta-\alpha)^2}{9(12\beta-11\alpha)} \end{cases}.$$

Part (i) of the Corollary summarizes what we discussed following Proposition 2. Average fees to startups and investors increase with an increase in the extent of differentiation between platforms (captured by α and b_2). In addition, the average investor fee increases when the extent of network externality is smaller (i.e., when $6\beta - \alpha$ is smaller.)

Part (ii) states the intuitive result that average quality declines when investors appreciate quality to a lesser extent (θ smaller) or when it is more costly to improve quality (γ bigger). To understand the remaining comparative statics results reported in part (ii), it is important to understand the countervailing effect of the value of the parameters relevant to one side of the market served by the platform on the extent of competition on the opposite side of the platform. When a platform offers higher quality it attracts additional investors, a fact that is also appreciated by startups. As b_2 reflects the extent of differentiation between platforms, a change in the value of b_2 has two counteracting effects. On the one hand, an increase in b_2 makes the platforms more highly differentiated and alleviates competition in the investor market both in terms of fees and in terms of quality levels, thus reducing the incentive of the platforms to invest in quality. On the other hand, increased differentiation allows platforms to charge higher fees from investors, and therefore, defending the platform's share in this market becomes more important, thus indicating an incentive to increase investment in quality. The values of the parameter β and α determine which of the two effects dominate. The former effect dominates when β is relatively big in comparison to α, as stronger network externalities lead to lower investor fees and reduced incentives to defend share in this market. There are similarly two counteracting effects on the incentive to invest in quality when the parameters α or β change. On the one hand, a strong network externality (a bigger value of β or a smaller value of α) incentivizes platforms to preserve their shares of the investor market in order to remain attractive to startups by offering higher quality. On the other hand, a strong network externality reduces the investor fee, and therefore, weakens the incentive of platforms to preserve their shares in the investor market. The latter effect dominates, for instance, when b_2 is relatively small as reduced differentiation puts downward pressure on the fees that can be charged from investors and weakens the incentive to defend shares in the investor market.

In order to further understand the properties of the segmented equilibrium, we use the expressions derived in Proposition 2 to obtain the equilibrium joint industry profits of the platforms, which we designate by π_B^J. (The superscript *J* designates joint and the subscript *B* stands for both sides of the market paying a fee.)

$$\pi_B^J = \underbrace{\left[\frac{\alpha}{2} + \frac{b_2}{4} - \frac{(6\beta-\alpha)}{6}\right]}_{average\ fees\ collected} - \underbrace{\frac{\theta^2[27\alpha b_2 - 2(6\beta-\alpha)(3\beta+\alpha)]^2}{2\gamma T^2}}_{investment\ cost\ in\ \bar{q}} + \underbrace{\frac{9(2b_1-b_2)^2\alpha\gamma(\Delta+18\alpha\theta^2)}{4\Delta^2}}_{payoff\ from\ asymmetry}. \quad (15)$$

The expression derived for joint profits consists of three terms. The first corresponds to the sum of the average fees collected from the two sides of the market. As discussed earlier, average fees increase with the extent of differentiation between the platforms from the perspective of startups and investors, and decrease with the extent of network externality. The second term is proportional to the cost of investing in the equilibrium average quality $\bar{q}$ (this term is equal to $2\gamma\bar{q}^2$). This cost is higher when investors appreciate quality to a greater extent (θ bigger) or when it is less costly to improve quality (γ smaller). Hence, joint industry profits may actually increase when investors appreciate quality to a lesser extent or when it becomes more expensive to invest in improved quality. In such instances, platforms compete less aggressively on quality, and profitability improves. The last term reflects the added industry profits that are the result of the existence of asymmetry between the two platforms. Note that this last term increases when the value of $|2b_1 - b_2|$ is bigger. This bigger value implies from (13) that the gap in the equilibrium levels of quality chosen by the two platforms is bigger. Hence, even if the smaller platform earns lower profits when $|2b_1 - b_2|$ is bigger the increase in the profits of the dominant platform is more significant, thus leading to higher industry profits earned at the equilibrium. The reason greater asymmetry yields higher industry profits is that with greater asymmetry the environment becomes more similar to a monopolistic market. Hence, competition between the platforms weakens and industry profits rise.

Table 1: Changes in the values of the parameters and the profitability of the platforms

	β	α	b2	b1	θ	ϒ	Profit P1	Profit P2	Joint Profit
α	**2**	**2**	**45**	**40**	**8**	**1**	11.7756	0.1888	11.9644
	2	**3**	**45**	**40**	**8**	**1**	11.6187	0.5075	12.1261
	2	**4**	**45**	**40**	**8**	**1**	11.7495	0.8274	12.5769
	2	**5**	**45**	**40**	**8**	**1**	11.9780	1.1448	13.1228
	2	**6**	**45**	**40**	**8**	**1**	12.2512	1.4603	13.7115
β	**1**	**4**	**45**	**40**	**8**	**1**	12.0204	1.2116	13.2320
	1.5	**4**	**45**	**40**	**8**	**1**	11.8436	1.0210	12.8646
	2	**4**	**45**	**40**	**8**	**1**	11.7495	0.8274	12.5769
	2.5	**4**	**45**	**40**	**8**	**1**	11.7556	0.6354	12.3910
	3	**4**	**45**	**40**	**8**	**1**	11.8941	0.4531	12.3472
b1	**2**	**4**	**45**	**36**	**8**	**1**	9.6701	1.2445	10.9146
	2	**4**	**45**	**38**	**8**	**1**	10.6830	1.0091	11.6922
	2	**4**	**45**	**40**	**8**	**1**	11.7495	0.8274	12.5769
	2	**4**	**45**	**42**	**8**	**1**	12.8697	0.6993	13.5689
	2	**4**	**45**	**43**	**8**	**1**	13.4498	0.6553	14.1052
b2	**2**	**4**	**43**	**40**	**8**	**1**	12.9630	0.6304	13.5934
	2	**4**	**43.5**	**40**	**8**	**1**	12.6162	0.6646	13.2808
	2	**4**	**44**	**40**	**8**	**1**	12.3007	0.7099	13.0105
	2	**4**	**44.5**	**40**	**8**	**1**	12.0128	0.7646	12.7774
	2	**4**	**45**	**40**	**8**	**1**	11.7495	0.8274	12.5769
θ	**2**	**4**	**45**	**40**	**7.8**	**1**	11.2238	0.9602	12.1839
	2	**4**	**45**	**40**	**7.9**	**1**	11.4694	0.8927	12.3621
	2	**4**	**45**	**40**	**8**	**1**	11.7495	0.8274	12.5769
	2	**4**	**45**	**40**	**8.1**	**1**	12.0706	0.7656	12.8362
	2	**4**	**45**	**40**	**8.2**	**1**	12.4407	0.7093	13.1500
ϒ	**2**	**4**	**45**	**40**	**8**	**0.9**	13.5567	0.6159	14.1726
	2	**4**	**45**	**40**	**8**	**0.95**	12.4720	0.7052	13.1772
	2	**4**	**45**	**40**	**8**	**1**	11.7495	0.8274	12.5769
	2	**4**	**45**	**40**	**8**	**1.05**	11.2404	0.9553	12.1957
	2	**4**	**45**	**40**	**8**	**1.1**	10.8665	1.0788	11.9453

In Table 1 we conduct a numerical analysis to illustrate how changes in the values of the parameters affect the profitability of the platforms. We restrict the calculations to the case that $2b_1 - b_2 > 0$, implying that platform 1 is the bigger platform. The results further strengthen the intuition provided in the Propositions. The calculations illustrate that the smaller platform (platform 2) unambiguously benefits when startups appreciate more highly attaining a compatible match (a bigger value of the parameter α.) In contrast, the effect of a bigger value of α on the profitability of the bigger platform

(platform 1) is ambiguous. Industry profits, however, unambiguously increase when α attains a bigger value. Similarly, an increase in the magnitude of the network externality effect as measured by the parameter β unambiguously reduces the profits of the smaller platform but may increase or decrease the profits of the bigger platform. Its effect on industry profits is unambiguously negative. The profits of the bigger (smaller) platform increase (decrease) with b_1 and decrease (increase) with b_2, respectively. Industry profits unambiguously increase with b_1 and decrease with b_2 because the extent of asymmetry between the platforms intensifies when b_1 is bigger and weakens when b_2 is bigger, given that we restrict attention to the case that $2b_1 - b_2 > 0$. Greater appreciation of investors of the quality offered by the platforms (bigger values of θ) and lower cost to improve quality (smaller values of γ) hurt the profitability of the smaller platform and improves the profitability of the bigger platform because the advantage of the bigger platform intensifies in this case.

4. Only Investors Pay a Fee

In this section, we analyze the case where only investors are charged a fixed membership fee and startups can utilize the services offered by the platform for free. The payoff functions of the platforms take the following form:

$$\max_{q_1,p_1} V_1 = p_1 r^* - \gamma q_1^2 \tag{16}$$

$$\max_{q_2,p_2} V_2 = p_2(1 - r^*) - \gamma q_2^2,$$

where s^* is given by (8) upon the substitution $R_1 = R_2 = 0$, and r^* is given by (10).

When only investors are charged, the revenues of each platform accrue only from the population of investors they serve. In our case, platform 1 serves the lower tail of the distribution of investors (less than r^*) and platform 2 serves the upper tail of this distribution (more than r^*). Solving for the equilibrium of the two stage game requires, once again, the use of backward induction. The results of this two stage optimization process yields the results reported in Proposition 3.

Proposition 3

When only investors pay a fee to the platform:

(i) At the equilibrium the market shares of the platforms are determined as follows:

$$(2r^* - 1) = \frac{3\gamma(2b_1 - b_2)}{F} \; and \; (1 - 2s^*) = \frac{\gamma(6\beta - \alpha)(2b_1 - b_2)}{3\alpha F}, \tag{17}$$

where $F \equiv 9\gamma b_2 - 4\theta^2 > 0$ to ensure that the condition for stability of reaction functions is satisfied.

(ii) The gap between the quality levels selected by the two platforms is given as:

$$q_1 - q_2 = \frac{(2b_1 - b_2)\theta}{F}. \quad (18)$$

(iii) The gap between the investor fees selected by the platforms is given as:

$$p_1 - p_2 = \frac{3b_2\gamma(2b_1 - b_2)}{2F}. \quad (19)$$

Similarly to the results we derived in the previous section, when only investors pay a fee, the identity of the dominant platform depends of the sign of the expression $(2b_1 - b_2)$. Platform 1 (platform 2) becomes the dominant platform if $(2b_1 - b_2) > 0$ (< 0), respectively.

We can now fully characterize the equilibrium quality levels, fees, and profits of the platforms when only investors pay a fee.

Proposition 4

When only investors pay a fee to the platforms, the equilibrium levels of quality, fees, and profits are:

$$q_1 = \frac{\theta}{6\gamma} + \frac{\theta(2b_1 - b_2)}{2F}, q_2 = \frac{\theta}{6\gamma} - \frac{\theta(2b_1 - b_2)}{2F}.$$

$$p_1 = \frac{b_2}{4}\left[1 + \frac{3\gamma(2b_1 - b_2)}{F}\right], p_2 = \frac{b_2}{4}\left[1 - \frac{3\gamma(2b_1 - b_2)}{F}\right].$$

$$\pi_1 = \frac{b_2}{2}r^{*2} - \gamma {q_1}^2 = \left[1 + \frac{3\gamma(2b_1 - b_2)}{F}\right]^2 \left[\frac{9\gamma b_2 - 2\theta^2}{72\gamma}\right],$$

$$\pi_2 = \frac{b_2}{2}(1 - r^*)^2 - \gamma {q_2}^2 = \left[1 - \frac{3\gamma(2b_1 - b_2)}{F}\right]^2 \left[\frac{9\gamma b_2 - 2\theta^2}{72\gamma}\right].$$

Note that the profit of both platforms is positive, given the requirements that ensure positive market shares to both platforms and the fact that $9\gamma b_2 - 2\theta^2 = F + 2\theta^2 > 0$.

In Corollary 3, we report how changes in the values of the parameters affect average investor fee and average quality when only investors pay a fee.

Corollary 3

When only investors pay a fee to the platforms the average investor fee and average quality are determined independent of the values of the parameters β and α. The average investor fee increases when the parameter b_2 increases. Average quality increases when θ increases and/or γ declines.

The comparative statics results reported in Corollary 4 are similar to those derived when both sides of the market pay a fee. However, as startups do not pay a fee, the additional ambiguity that arises in Corollary 2 because of the network externality effect disappears when only investors pay a fee. In particular, the values of the parameters β and α play no role in determining average investor fee or average quality. Appendix B includes, once again, conditions that ensure that the local segmented equilibrium is global. As in the regime when both sides of the market pay a fee, when only investors pay a fee, neither platform has an incentive to deviate from the local equilibrium if the platforms are considered sufficiently differentiated from the perspective of both investors and startups (i.e., when b_2 and α are sufficiently big[9]) and if the quality gap between the platforms that is established at the equilibrium is sufficiently big (when θ is sufficiently big and/or γ is sufficiently small.)

Next we use the expressions derived in Proposition 4 to obtain joint industry profits when only investors pay a fee, designated as π_I^J.

$$\pi_I^J = \underbrace{\frac{b_2}{4}}_{average\ fees} - \underbrace{\frac{\theta^2}{18\gamma}}_{investment\ cost\ in\ \bar{q}} + \underbrace{\frac{(2b_1-b_2)^2\gamma(F+2\theta^2)}{4F^2}}_{payoff\ from\ asymmetry} . \tag{20}$$

As in the previous pricing regime we break up the equilibrium joint industry profits into the same three components: average fees, cost of investment in improved average quality, and the payoff from asymmetry.

5. Only Startups Pay a Fee

In this section we characterize the equilibrium when only the startups are charged a fixed membership fee for using the platform. The payoff functions can be expressed as follows:

$$\max_{q_1,R_1} V_1 = (1-s^*)\,R_1 - \gamma q_1^2, \tag{21}$$

$$\max_{q_2,R_2} V_2 = s^* R_2 - \gamma q_2^2,$$

where s^* is given by (8) and r^* are given by (10), upon the substitution that $p_1 = p_2 = 0$.

The revenues that accrue to platform 1 (platform 2) accrue from the upper tail of the distribution of growth potential startups bigger than s^* (smaller than s^*), respectively. Solving the two stage optimization for each platform using backward induction, yields the results reported in Proposition 5.

[9] The restrictions imposed on α and b_2 are $\frac{\alpha}{\beta} > \frac{3}{14}$ and $b_2 > b_1\left[\frac{1}{2} + \frac{(6\beta-\alpha)}{18\alpha}\right]$.

Proposition 5

When only startups pay a fee to the platform:

(i) The market shares of the platforms among investors and startups are given by:

$(2r^* - 1) = \frac{81\gamma\alpha b_2(2b_1 - b_2)}{D}$, $(1 - 2s^*) = \frac{9\gamma b_2(6\beta - \alpha)(2b_1 - b_2)}{D}$,

where $D \equiv \left[81\gamma\alpha {b_2}^2 - 8\theta^2(6\beta - \alpha)^2\right] > 0$ for stability of reaction functions.

(ii) The gap in the quality levels offered by the platforms is:

$q_1 - q_2 = \frac{2\theta(6\beta - \alpha)^2(2b_1 - b_2)}{D}$.

(iii) The gap in the fees the platforms charge is:

$R_1 - R_2 = \frac{9\gamma\alpha b_2(6\beta - \alpha)(2b_1 - b_2)}{D}$.

We can now fully characterize the equilibrium quality levels and fees selected by the platforms when only startups pay a fee.

Proposition 6

When only startups pay a fee, the equilibrium level of qualities and listing fees are:

$$q_1 = \frac{\theta(6\beta - \alpha)}{9\gamma b_2}\left[1 + \frac{9\gamma b_2(6\beta - \alpha)(2b_1 - b_2)}{D}\right], q_2 = \frac{\theta(6\beta - \alpha)}{9\gamma b_2}\left[1 - \frac{9\gamma b_2(6\beta - \alpha)(2b_1 - b_2)}{D}\right].$$

$$R_1 = \alpha(1 - s^*) = \frac{\alpha}{2}\left[1 + \frac{9\gamma b_2(6\beta - \alpha)(2b_1 - b_2)}{D}\right], R_2 = \alpha s^* = \frac{\alpha}{2}\left[1 - \frac{9\gamma b_2(6\beta - \alpha)(2b_1 - b_2)}{D}\right].$$

$$\pi_1 = \alpha(1 - s^*)^2 - \gamma {q_1}^2 = \left[1 + \frac{9\gamma b_2(6\beta - \alpha)(2b_1 - b_2)}{D}\right]^2 \left[\frac{81\gamma\alpha {b_2}^2 - 4\theta^2(6\beta - \alpha)^2}{324\gamma {b_2}^2}\right],$$

$$\pi_2 = \alpha {s^*}^2 - \gamma {q_2}^2 = \left[1 - \frac{9\gamma b_2(6\beta - \alpha)(2b_1 - b_2)}{D}\right]^2 \left[\frac{81\gamma\alpha {b_2}^2 - 4\theta^2(6\beta - \alpha)^2}{324\gamma {b_2}^2}\right].$$

Note that the profit of both platforms is positive, given the requirements that ensure positive market shares to both platforms and the fact that $\left[81\gamma\alpha {b_2}^2 - 4\theta^2(6\beta - \alpha)^2\right] = D + 4\theta^2(6\beta - \alpha)^2 > 0$. In Corollary 4 we conduct a comparative statics analysis to investigate how changes in the parameters affect the average startup fee and average quality.

Corollary 4

The average startup fee is an increasing function of α. Average quality increases with θ, and $(6\beta - \alpha)$ and decreases with γ and b_2.

When the strength of network externality $(6\beta - \alpha)$ increases or when investors view the platforms as being less differentiated because b_2 is smaller, platforms are forced to compete more aggressively for investors. This forces them to raise quality. Average quality is higher also when investors value quality to a larger extent and when improving quality is less costly.

In Appendix B we derive the conditions necessary to ensure that the local equilibrium is global. To support segmentation it is necessary, once again, that the quality gap established at the equilibrium is sufficiently large. However, in contrast to regimes B and I, under regime S, when only startups pay a fee the network externality has to be sufficiently strong (instead of weak) in order to ensure that no platform has an incentive to deviate from segmentation. Specifically, the ratio $\frac{\alpha}{\beta}$ has to be sufficiently small to ensure that segmentation survives. Because of this different range of parameter values it follows that regime S can never support segmentation over the same range of parameter values as regimes I or B. While regimes B and I require that $\frac{\alpha}{\beta} > \frac{6}{37}$ and $\frac{\alpha}{\beta} > \frac{3}{14}$, respectively, Regime S requires that $\frac{\alpha}{\beta} < \frac{6}{19+\sqrt{405}}$. This last range of values for the ratio $\frac{\alpha}{\beta}$ is inconsistent with the requirements necessary to support segmentation under regimes B or I. In contrast, regimes I and B can concurrently support segmentation when $\frac{\alpha}{\beta} > \frac{3}{14}$.

Next we use the expressions derived in Proposition 6 to obtain the joint industry profits when only startups pay a fee, designated as π_S^J.

$$\pi_S^J = \underbrace{\frac{\alpha}{2}}_{average\ fees} - \underbrace{\frac{2\theta^2(6\beta-\alpha)^2}{81\gamma {b_2}^2}}_{nvestment\ cost\ in\ \bar{q}} + \underbrace{\frac{(2b_1-b_2)^2\gamma(6\beta-\alpha)^2\left(D+4\theta^2(6\beta-\alpha)^2\right)}{2D^2}}_{payoff\ from\ asymmetry}. \tag{22}$$

6. Comparison of the three Pricing Regimes

We have demonstrated that under all three pricing regimes, to support segmentation the parameter b_2 has to be relatively big, namely investors have to consider the platforms to be sufficiently differentiated. In addition, under all three pricing regimes segmentation is supported only if the quality gap established at the equilibrium is sufficiently large, namely if θ is sufficiently big and/or γ is sufficiently small. As far as the ratio $\frac{\alpha}{\beta}$ is concerned, the results we derive in Appendix B indicate that the three pricing models impose constraints of different nature to ensure that the local equilibrium is global. When only investors pay a fee or when both sides of the market pay a fee this ratio has to be sufficiently big. In contrast, when only startups pay a fee the ratio $\frac{\alpha}{\beta}$ has to be sufficiently small. Hence, to support segmentation

when only startups pay a fee, it is necessary that network externality is relatively strong. To understand this result, note that the incentive of each platform to take over the entire market is especially strong when only startups pay a fee because of the one-sided network externality that we assume. By taking over the market in this case the platform can offer significantly higher value to the side of the market that is being exclusively charged under this pricing model, namely the startups. However, when the network externality is relatively strong, the extent of asymmetry between the two platforms that arises at the segmented equilibrium is relatively big. As a result, the smaller platform has to cut fees to a very large extent in order to take over the market and the larger platform cannot offer significantly higher value to startups by taking over the market in comparison to its position at the segmented equilibrium, given that it already commands a significant market share at this equilibrium. Deviation from segmentation to domination of the market is unprofitable, therefore, for either one of the platforms.

It is noteworthy that our results indicate that the only pricing model that supports segmentation when the extent of network externality effect is relatively strong is the one that charges only startups, namely the side of the market that cares about the externality in our model. The earlier literature on platform competition has demonstrated that when the size of the opposite market is of great importance to one of the sides served by the platform, it may be optimal to charge only this side (startups in our case.) Our analysis indicates that a similar result is true regarding the ability of platforms to segment the markets. With significant network externality segmentation can be supported only if startups and not investors are paying a fee.

The different constraints imposed on the size of the network externality under the three pricing models imply that the regions of the parameters that support segmentation under regime I or regime B can never coincide with the region of the parameters that supports segmentation under regime S. However, regimes I and B can concurrently support segmentation when $\frac{\alpha}{\beta} > \frac{3}{14}$. In the comparison we conduct we restrict attention, therefore, to comparing the characteristics of the segmented equilibrium under regimes I and B only. We start by comparing the extent of asymmetry between the platforms in terms of the quality levels they offer to investors under these two pricing models.

Proposition 7

$|q_1 - q_2|_B > |q_1 - q_2|_I$. As a result, the market shares of the dominant platform among investors and startups are bigger under regime B than under regime I.

To understand the result reported in Proposition 7, note that when the platforms move from charging only investors to also charging the startups, price and quality competition on the investor side of the market intensifies because of the network externality effect. Because the dominant platform has larger shares in both markets it has stronger incentives to defend its dominance in the investor market by raising its investment in quality, and the extent of asymmetry between the platforms intensifies both in terms of quality investment and market shares.

Next, we investigate the average fees and average quality that arise at the segmented equilibrium under the different pricing models ($\bar{R}, \bar{p}$, and $\bar{q}$). From Proposition 2, 4, and 6 we obtain that:

$$\bar{R}_B = \frac{\alpha}{2}, \bar{p}_B = \frac{b_2}{4} - \frac{(6\beta-\alpha)}{6}, and\ \bar{q}_B = \frac{\theta[27\alpha b_2 - 2(6\beta-\alpha)(3\beta+\alpha)]}{2\gamma T}. \quad (23a)$$

$$\bar{p}_I = \frac{b_2}{4}, and\ \ \bar{q}_I = \frac{\theta}{6\gamma}. \quad (23b)$$

$$\bar{R}_S = \frac{\alpha}{2}, and\ \bar{q}_S = \frac{\theta(6\beta-\alpha)}{9\gamma b_2}. \quad (23c)$$

In Proposition 8 we compare average fees and average quality between the two pricing models that can concurrently support segmentation (i.e., regimes I and B).

Proposition 8

(i) $\begin{cases} \bar{R}_B + \bar{p}_B > \bar{p}_I & if\ \frac{\alpha}{\beta} > \frac{3}{2} \\ \bar{R}_B + \bar{p}_B < \bar{p}_I & if\ \frac{\alpha}{\beta} < \frac{3}{2} \end{cases}$

(ii) $\begin{cases} \bar{q}_I > \bar{q}_B & if\ \frac{\alpha}{\beta} > \frac{3}{5} \\ \bar{q}_I < \bar{q}_B & if\ \frac{\alpha}{\beta} < \frac{3}{5} \end{cases}$.

According to part (i) of the Proposition, total average fees collected from both startups and investors are higher under regime B than the average fees collected from investors only under regime I when the network externality effect is relatively weak (i.e., $\frac{\alpha}{\beta} > \frac{3}{2}$). From (23a) and (23b) we observe that when both sides of the market are charged, investors pay, on average, a lower fee than if only investors pay a fee. The reduction in the average investor fee in the former case is proportional to the strength of the network externality effect as measured by $(6\beta - \alpha)$. Hence, this reduction is moderate when the network externality effect is relatively weak. Because regime B provides platforms with an additional

source of revenues from startups (which from 23a is equal[10] to $\frac{\alpha}{2}$) and regime I does not, the total fees collected under regime B are higher when network externality is relatively weak. However, when the effect of the externality is strong, the reduction in the investor fee is so significant that total fees actually decline in spite of the additional source of revenues from startups that is available under regime B.

As far as average quality is concerned, in part (ii) of the Proposition we demonstrate that average quality is lower under regime B when the network externality effect is relatively weak. When moving from a regime where only investors pay to a regime where startups pay as well, competition in the investor market intensifies both in terms of fees and qualities because of the additional forces to defend share in the investor market that are created by the network externality. Such intensified competition creates stronger incentives to improve quality. However, the lower investor fee that can be charged when both sides of the market pay implies that the reward to defending share in the investor market is smaller, thus creating weaker incentives to invest in quality. Part (ii) states that the latter weaker incentives dominate when the network externality effect is relatively weak (i.e., when β is relatively small in comparison to α, specifically $\frac{\alpha}{\beta} > \frac{3}{5}$). When the network externality effect is relatively strong, average quality improves when moving from a pricing regime that charges only investors to a regime that charges both sides of the market.

Combining the results reported in Propositions 7 and 8 implies that the regime where both sides of the market pay fees has the potential to generate higher industry profits than the regime that charges investors only if the extent of network externality is relatively small. In particular, from Proposition 8 when $\frac{\alpha}{\beta} > \frac{3}{2}$ both the total revenues of the platforms are higher and the investment cost in average quality is lower, implying that the first two components of industry profits derived in (15) and (20) are higher under regime B than under regime I. In addition, from Proposition 7 the extent of asymmetry between the platforms is always more significant under regime B than under regime I. As a result, the third component of industry profits is always higher under regime B. However, when the network

[10] Armstrong (2007) considers an environment in which imposing the constraint that fees are non-negative may become binding. In such an environment, the side of the market that benefits less from the externality (investors in our case) pays a fee of zero and platforms are forced to reduce the fee they charge from the other side of the market (startups in our case) by an amount that is a function of the size of the externalities. We impose conditions to ensure that the investor fee is always strictly positive when both sides of the market are charged. In such an environment, the equilibrium expected fee of startups depends only on the degree of differentiation between the platforms from the perspective of startups (α), and not on any externality benefits.

externality effect is relatively strong, the comparison of industry profits between these two regimes may reverse as the total fees collected may be lower and the investment cost in average quality higher under regime B than under regime I.

In Table 2 we conduct numerical calculations to compare the profits of the platforms under regimes B and I when they can concurrently support segmentation (i.e., in the region $\frac{\alpha}{\beta} > \frac{3}{14}$). Varying the value of this ratio in this region while incorporating the remaining restrictions necessary for segmentation under these two pricing models, we obtain results that are consistent with our analytical derivations.

Table 2: Comparison of profits between regimes B ana I

Parameters							Regime B			Regime I		
β	**α**	**α/β**	**b_2**	**b_1**	**θ**	**ϒ**	profit P1	profit P2	Joint Profit	profit P1	profit P2	Joint Profit
2	**1.100**	**0.55**	**20**	**10.5**	**10**	**3.12**	3.0569	0.0471	3.1040	1.8016	1.4286	3.2302
2	**1.200**	**0.6**	**20**	**10.5**	**10**	**3.00**	3.3894	0.0177	3.4071	1.7830	1.3782	3.1612
2	**1.300**	**0.65**	**20**	**10.5**	**10**	**2.91**	3.5264	0.0147	3.5412	1.7711	1.3352	3.1062
2	**3.800**	**1.9**	**20**	**10.5**	**10**	**2.40**	3.3668	0.7586	4.1254	2.0147	0.8064	2.8211
2	**3.900**	**1.95**	**20**	**10.5**	**10**	**2.40**	3.2730	0.8265	4.0995	2.0147	0.8064	2.8211
2	**4.000**	**2**	**20**	**10.5**	**10**	**2.40**	3.2031	0.8906	4.0938	2.0147	0.8064	2.8211

Consistent with the results reported in Propositions 7 and 8, joint industry profits are unambiguously higher under regime B than under regime I when the extent of network externality is relatively small, namely when α/β is relatively big. However, when this ratio is relatively small ($\alpha/\beta = 0.55$ in the Table) the opposite may be the case. From the entries in the Table it appears that the bigger platform (platform 1 because $2b_1 - b_2 = 1 > 0$ for the entries in the Table) has a preference for regime B, whereas the smaller platform may prefer regime I when the extent of network externality is relatively big ($\alpha/\beta < 1.9$ in the Table). Because regime B generates greater asymmetry between the platforms than regime I the smaller platform may earn higher profits under regime I where its market share among investors and startups is bigger. However, when the extent of network externality is relatively small ($\alpha/\beta \geq 1.95$ in the Table) both platforms prefer regime B over regime I. Because of cumbersome derivations we do not allow platforms to utilize different pricing models in our analysis. However, the entries of the Table indicate that platforms may actually find it optimal to use different models at the equilibrium, with the smaller platform choosing to charge only investors and the bigger platform choosing to charge both investors and startups.

7. Welfare Implication of Segmentation

Next we wish to investigate the welfare implications of the segmented equilibrium we characterized so

far. In order to conduct the welfare analysis, we consider the case of two undifferentiated platforms that randomly match startups with investors. In the absence of differentiation each platform offers the minimum acceptable quality, namely $q_1 = q_2 = 0$, and investors choose randomly whether to rely on the evaluation of platforms 1 or 2 in making their investment choice. The payoffs of startups and investors can be expressed, therefore, as:

$$E\pi = K_S + \frac{\beta}{2} + \frac{\alpha}{2}\int_0^1\int_0^1 (s-r)^2 drds = K_S + \frac{\beta}{2} + \frac{\alpha}{12}, \tag{24}$$

$$EU = K_I + \left(b_1 - \frac{b_2}{2}\right)\frac{1}{2}. \tag{25}$$

As a startup chooses its platform at random, it attracts 50% of the investors; those relying on the assessment of this platform in making their investment choice. Hence, the market share of each startup among investors is $\frac{1}{2}$, which from (4), therefore, we obtain the component $\frac{\beta}{2}$ in $E\pi$. Similarly, a startup of type s is matched with probability $\frac{1}{2}$ with an investor of type r (this investor also chooses randomly which platform to follow). The compatibility component of $E\pi$ in (24) then follows. Because platforms are undifferentiated price competition between platforms yields the Bertrand outcome of $p_1 = p_2 = R_1 = R_2 = 0$, and listing fees are the lowest possible. The expected utility of investors from (3) can be calculated as $EU = K_I + (b_1 - b_2 Er)Es$ because $q_1 = q_2 = 0$. Given that $Er = Es = \frac{1}{2}$, the expression for EU in (25) follows. In Proposition 9 we report the welfare implication of the segmented equilibrium.

Proposition 9

In comparison to random matching, the segmented equilibrium unambiguously enhances the expected profits of the platforms. The effect of segmentation on the welfare of investors and startups is unclear.

According to Proposition 9, platforms unambiguously benefit from segmentation. Startups and investors might be worse off because of the higher fees that platforms can charge with segmentation. These higher fees may exceed the benefit that segmentation might potentially facilitate. This ambiguity regarding the welfare of investors and startups arises in spite of the fact that segmentation leads to improved matches between startups and investors and to higher quality that is offered by the platforms.

It is noteworthy that random matching with two competing platforms could never arise as equilibrium because one of the platforms would always have an incentive to deviate by offering higher quality, raising fees, and earning positive profits. As we argue in the paper and as was demonstrated in previous papers (Damiano and Li 2008, for instance), when segmentation fails, equilibrium with only one

platform dominating the market will arise. In this case the monopoly platform will offer the lowest quality, and assuming that it still wishes to cover the entire market, it will set fees to extract the payoff of the investor and startup that benefit from the matching the least. Because domination still yields random matching the investor (startup) that benefit the least are of type $r = 1$ ($s = \frac{1}{2}$), thus yielding the fees to investors (startups) equal to $p = K_I + \frac{b_1}{2} - \frac{b_2}{2}$ ($R = K_S + \beta + \frac{\alpha}{12}$), respectively. As a result, the expected welfare of the parties at the monopoly outcome is $\frac{b_2}{4}$ and $\frac{\alpha}{12}$ for investors and startups, respectively. Direct welfare comparison of the segmented equilibrium and the monopoly outcome is unclear. However, when the basic benefit the two sides of the market derive from any kind of match increases (namely when the constants K_I and K_S are sufficiently big), the welfare of both startups and investors is higher with segmentation because a monopoly platform can more successfully extract this basic benefit via the fees it sets.

8. Managerial Implications and Concluding Remarks

Our model yields recommendations for managers of platforms that compete to attract two separate and heterogeneous populations on the two sides of the market they serve. Even though our investigation focuses primarily on equity crowdfunding platforms, our recommendations apply more generally whenever by achieving improved compatibility between two populations platforms can enhance the value of their intermediation services. Hence, our results are equally applicable for platforms providing matchmaking services or for platforms matching people seeking employment with potential employers. Our results indicate that managers should adopt strategies that lead to segmentation of the two populations, so that the profile of the segment of the population served by each platform on one side is compatible with the profile of the segment this platform serves on the other side of the market. In the case of crowdfunding, the two populations are startups and investors and compatibility of the match relates to the risk profiles of the two populations. If managers can implement such segmentation platforms are viewed as being differentiated, and as a result, can avoid fierce price competition and enhance their profits in comparison to random matching of the two populations. In particular, by carefully choosing different levels of investment in quality and different prices platforms can ensure that the two populations self- select between them in a manner that supports improved compatibility of the match. The exact equilibrium levels of quality and prices depend upon which side of the market is being charged, the size of the network externality considered by each population, and the importance of compatibility to each side of the market. Our results indicate that while segmentation enhances profitability it also generates great asymmetry between the competing platforms, with one of them

gaining a bigger share of the two populations and earning higher profits. Segmentation may be difficult to attain, however, when the size of the opposing market served by the platform (i.e., size of network externality) is much more important to the population than achieving compatibility with the opposing side. In this case segmentation fails and one platform may end up dominating the entire market.

Because the expectations of the populations served by the platforms play a crucial role in determining the outcome of the competition, multiple equilibria normally arise in such two sided markets. In particular, in our crowdfunding setting, for instance, riskier startups self-select between the platforms based upon their expectations of which of the two platforms attracts investors who are more tolerant to risk. Our analysis does not predict the identity of the platform that ends up serving this type of investors (we arbitrarily designate it to be platform 1 but it could easily have been platform 2, instead.) Hence, some degree of coordination between the platforms may be necessary in order to support segmentation. Because the segmenting equilibrium yields asymmetry in the profits of the platforms, achieving such coordination is complicated by the fact that each platform has an incentive to serve the same, more profitable segments of the startup and investor populations[11]. However, coordination may naturally arise because some platforms enter the market earlier than others. Early entrants benefit from a first mover advantage, as they are likely to capture the more profitable segments and establish reputation for the type of startups and investors they serve. When a segmenting equilibrium exists, late entrants would find it optimal to accept their inferior position of having to serve the less profitable segments of the populations.

We have made several simplifying assumptions in our model that are unlikely to change our qualitative results. This is, for instance, the case regarding the assumption that only startups and not investors care about the size of the opposing side of the market. Segmentation is likely to arise even with two sided network externalities, as long as investors care about the size of the opposing market less than startups do. However, given that the size of the network externality in our one sided setting plays an important role in determining whether segmentation is feasible, we expect that the existence of two sided externalities would require even greater appreciation for compatibility by both startups and investors in order to support segmentation. For simplicity, we also assume that all investors invest the same amount, which is exogenously given, in the startups they select. Relaxing this assumption would require investigating how the degree of risk aversion affects the level of investment. The platform serving riskier startups and more risk tolerant investors is likely to gain an extra edge in this case because investors

[11] The more profitable segments depend upon the sign of $(2b_1 - b_2)$ in our setting.

more tolerant to risk tend to make bigger investments. We assume that both the investor and startup markets are fully covered. This assumption implies that when one platform cuts prices or raises its quality of service it steals market share from its competitor without expanding the overall size of the population served. Relaxing the assumption that the investor market is fully covered is likely to lead the platform that offers lower quality at the equilibrium to raise its investment in quality in order expand the overall size of the investor population that is interested in crowdfunding. As a result, the extent of quality differentiation between the platforms might diminish. While we consider three different regimes of pricing in the model, in all three cases prices are set in the form of fixed membership fees rather than in the form of variable transaction fees. A welcome extension of our model would be to consider a pricing model that charges investors a percentage of the return on the investment instead of a fixed membership fee. It would be interesting to investigate, in particular, whether such pricing extends the region that supports segmentation, given that the earlier literature on platforms illustrated that variable costs may mitigate the adverse consequences of network externalities on pricing. With regard to the pricing mechanism, we restrict the derivations to an environment where both platforms choose the same mechanism. Specifically, either the platforms charge both sides of the market or they charge exclusively the same, one side of the market. It may be interesting to investigate the equilibrium when each platform chooses independently its pricing mechanism. We leave it for future research to consider this different environment.

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