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ABSTRACT

Competition for Listings*

We develop a model in which two profit-maximizing exchanges compete for IPO listings. They choose the listing fees paid by firms wishing to go public and control the trading costs incurred by investors. All firms prefer lower costs, however firms differ in how they value a decrease in trading costs. Hence, in equilibrium, competing exchanges obtain positive expected profits by charging different trading fees and different listing fees. As a result, firms that list on different exchanges have different characteristics. The model has testable implications for the cross-sectional characteristics of IPOs on different quality exchanges and the relationship between the level of trading costs and listing fees. We also find that competition does not guarantee that exchanges choose welfare-maximizing trading rules. In some cases, welfare is larger with a monopolist exchange than with oligopolist exchanges.

JEL Classification: G10, G32, L13
Keywords: exchanges, regulation, trading technology, listings, competition

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NON-TECHNICAL SUMMARY

Stock exchanges provide marketplaces. In such markets, investors buy and sell securities that have been listed by firms seeking to raise money through IPOs. The amount of money that a firm can raise, when it sells off claims to a cash flow, depends on the resale value of such claims and hence on the characteristics of the secondary market in which its shares will trade. As a well-functioning equity market is one of the most important ways in which firms raise money, we are interested in two distinct, but inter-related questions about the industrial organization of stock exchanges. First, given two different trading systems or technologies, how will competing equity markets set fees and how will firms trying to raise equity choose between such markets? Second, in the longer run, if exchanges can choose a trading technology, what will they choose and is this choice necessarily socially optimal? We wish to answer these questions both to understand cross-sectional differences of listed firms between exchanges and to provide a framework for regulators who are concerned with inter-exchange competition.

Stock exchanges compete for firms' listings. We view them as simple profit-maximizers whose revenues depend on the listings they attract in two ways. First, an exchange charges a listing (flat) fee to firms. Second, investors incur trading fees each time they trade listed shares. Both sources of revenue are in reality important to exchanges. In 1996, for North American stock exchanges, listing revenues accounted for 30.9% of total revenues whereas trading revenues accounted for 27.9% of total revenues (Source: FIBV Annual Report, 1997). Other revenue comes from additional services offered by Stock Exchanges such as market data dissemination, clearing and settlement services etc. The revenue generated by these ancillary services is also partly proportional to the number of listings.

Exchanges can compete for listings through a choice of listing policy, trading technology, listing fees or some combination of these. Casual empiricism suggests that competing exchanges do not follow the same listing policy, neither do they provide the same trading technology, nor do they charge the same listing fees. For example, the required minimum size of an IPO on the NYSE is larger than the required minimum size on the Nasdaq. Nasdaq is a celebrated broker/dealer market while the NYSE employs specialists. Further, listing fees on the NYSE are nearly an order of magnitude higher than those on the Nasdaq. Our Paper provides an explanation for this variety.

We view the choice of a trading technology as, effectively, a choice of trading cost incurred by investors. Much of the microstructure literature seeks to explain how differences in trading systems induce differences in transaction prices. Indeed, the microstructure literature suggests that costs incurred by investors vary across different market forms. For instance Huang and Stoll (1994), or Bessembinder and Kaufman (1997) conclude that trading costs on the NYSE are lower than trading costs on the Nasdaq. Affleck et al. (1994) ascribe these differences in execution costs to differences in the trading rules in the two markets.

The choice of a listing fee and trading cost are interdependent because both listing fees and trading costs influence a firm's listing choice. The effect of a trading cost is indirect, however. Amihud and Mendelson (1986) or more recently Brennan and Subrahamanyam (1996) find that the cost of capital increases with the trading costs incurred by investors in the secondary market. For this reason when deciding where to list, firms pay attention to trading costs. Empirical findings suggest that this is indeed the case. For instance, Cowan et al. (1992) show that firms with larger spreads are more likely to leave Nasdaq in order to be listed on the NYSE. Thus, trading rules have two effects on exchange revenue. A direct effect since trading volume, hence trading revenue, must increase when trading costs decrease. An indirect effect since the number of listings, that affects both listing revenue and trading revenue, depends on the trading costs. Most models of competing exchanges (Pagano (1989), Glosten (1994), Parlour and Seppi (1997)) have focused on the direct effect, taking as given trading rules in different exchanges. In the model considered in this Paper both the direct and indirect effects are present and influence the choice of their trading rules by exchanges.

In our model, investors' required rate of return for a given issue increases in the size of the expected trading cost in the exchange where the issue is listed. For this reason, all firms would prefer the exchanges to adopt trading technologies that minimize trading costs. Such technologies are also welfare-maximizing in our environment. We find, however that competition induces exchanges to differentiate themselves, through a choice of trading system or listing requirements to relax the competition for listings. In this way, exchanges can secure strictly positive profits. Thus we explain the co-existence of competing exchanges with different trading costs, listing requirements and listing fees as the outcome of imperfect competition between Exchanges. These differences translate into cross-sectional characteristics that are different for firms that list on different exchanges, even when listing requirements are identical. Some of our results are consistent with stylised facts. For instance, we find that, other things equal, firms that list on a low trading cost exchange have a larger size than firms that list on a high trading cost exchange. We also show that listing fees and trading costs should be inversely related.

1 Introduction

Stock exchanges provide marketplaces. In such markets, investors buy and sell securities which have been listed by ¯rms seeking to raise money through IPO's. The amount of money that a ¯rm can raise, when it sells o® claims to a cash °ow, depends on the resale value of such claims and hence on the characteristics of the secondary market in which its shares will trade. As a well{functioning equity market is one of the most important ways in which ¯rms raise money, we are interested in two distinct, but inter{related questions about the industrial organization of stock exchanges. First, given two di®erent trading systems or technologies, how will competing equity markets set fees and how will ¯rms trying to raise equity choose between such markets? Second, in the longer run, if exchanges can choose a trading technology what will they choose and is this choice necessarily socially optimal? We wish to answer these questions both to understand cross{sectional di®erences of listed ¯rms between exchanges and to provide a framework for regulators who are concerned with inter{exchange competition.

Stock exchanges compete for ¯rms' listings. We view them as simple pro¯t maximizers whose revenues depend on the listings they attract in two ways. First, an exchange charges a listing (°at) fee to ¯rms. Second, investors incur trading fees each time they trade listed shares. Both sources of revenue are important to exchanges. In 1996, for North American stock exchanges, listing revenues accounted for 30:9% of total revenues whereas trading revenues accounted for 27:9% of total revenues.[1]

Exchanges can compete for listings through a choice of listing policy, trading technology, listing fees or some combination of these. Casual empiricism suggests that competing exchanges do not follow the same listing policy, neither do they provide the same trading technology, nor do they charge the same listing fees. For example, the required minimum size of an IPO on the NYSE is larger than the required minimum size on the Nasdaq. Nasdaq is a celebrated broker/dealer market while the NYSE employs specialists. Further, listing fees on the NYSE are nearly an order of magnitude higher than those on the Nasdaq.[2]

[1] Source: FIBV Annual Report, 1997. Other revenue comes from additional services o®ered by Stock Exchanges such as market data dissemination, clearing and settlement services etc. Note that the revenue generated by these ancillary services is also partly proportional to the number of listings. It is interesting to note that the share of listing revenue and trading revenue in total revenue varies across exchanges. Angel and Aggarwal (1996) estimate that 41% of the NYSE annual revenue in 1996 came from listing fees. For Nasdaq, listing fees represented only 20% of total revenue in the same year.

[2] The maximum initial listing fee on Nasdaq is $50;000 versus $504;600 for the NYSE. Corwin and Harris (1998) estimate that for a ¯rm issuing 5 million shares at $5, the initial listing fee represents 0:0375% of market value on Nasdaq against 0:1058% on the NYSE.

We view the choice of a trading technology as, e®ectively, a choice of trading cost incurred by investors. Much of the microstructure literature seeks to explain how di®erences in trading systems induce di®erences in transaction prices. Indeed, the microstructure literature suggests that costs incurred by investors di®er across di®erent market forms. For instance Huang and Stoll (1994), or Bessembinder and Kaufman (1997) conclude that trading costs on the NYSE are lower than trading costs on the Nasdaq. A²eck et al. (1994) ascribe these di®erences in execution costs to di®erences in the trading rules in the two markets.[3]

The choice of a listing fee and trading cost are interdependent because both listing costs and trading costs in°uence a ¯rm's listing choice. The e®ect of a trading cost is indirect, however. Amihud and Mendelson (1986) or more recently Brennan and Subrahamanyam (1996) ¯nd that the cost of capital increases with the trading costs incurred by investors in the secondary market. For this reason when deciding where to list, ¯rms pay attention to trading costs.[4] Thus, trading rules have two e®ects on exchange revenue. A direct e®ect since trading volume, hence trading revenue, must increase when trading costs decrease. An indirect e®ect since the number of listings, that a®ects both listing revenue and trading revenue, depends on the trading costs. Most models of competing exchanges (Pagano (1989), Glosten (1994), Parlour and Seppi (1997)) have focused on the direct e®ect, taking as given trading rules in di®erent exchanges. In the model considered in this paper both the direct and indirect e®ects are present and in°uence the choice of their trading rules by exchanges.

In short, we present a model in which

- Pro¯t maximizing exchanges choose (i) the listing fee incurred by ¯rms and (ii) a per share trading cost (that we interpret as being determined by the trading rules) incurred by investors when they trade in the secondary market.

- Risk-neutral entrepreneurs, who own productive technologies, want to sell equity shares that are claims on the payo®s of these technologies. Entrepreneurs di®er in the size (value) of their companies. They choose (a) where to list, (b) how many shares to sell (what percentage ownership of their technology to cede) and (c) the price at which these shares are initially sold to the public.

[3] Market microstructure theory also shows that trading costs depend on trading rules. See Madhavan (1992) for instance.

[4] Empirical ¯ndings suggest that this is indeed the case. For instance, Cowan et al. (1992) show that ¯rms with larger spreads are more likely to leave Nasdaq in order to be listed on the NYSE.

- Risk neutral investors purchase shares in the Initial Public Offerings conducted by the entrepreneurs. These investors may be hit by liquidity shocks that force them to liquidate their stakes. For this reason, the trading costs in the different exchanges influence the prices at which IPOs' take place.

In our model, investors' required rate of return (gross of the expected trading cost) for a given issue increases with the per share trading cost associated with the exchange where the issue is listed. Thus, other things equal, all the entrepreneurs prefer to list on the exchange with the lowest trading cost (i.e. there is no exogenous "clientele effect"). We obtain the following results:

- Competing exchanges with different trading costs, listing requirements and listing fees can co-exist.
- Competing Exchanges may choose to differentiate themselves through a choice of trading system or listing requirements to soften the competition for listings.
- Entrepreneurs with different characteristics choose to list on different exchanges. Therefore, the cross-sectional characteristics of IPO's across different exchanges are different.
- Social welfare is maximized when both exchanges choose the lowest possible trading cost, but competition for listings is not sufficient to guarantee this. Thus, in some cases, welfare is higher when a monopolist exchange serves the market.

Several articles (Pagano (1993), Gehrig, Stahl and Vives (1996), Huddart et al. (1997), Angel and Aggarwal (1997)) have recently examined models in which firms can choose whether to go public or not and their listing location.[5] Pagano (1993) examines a model, with a single exchange, in which risk averse entrepreneurs trade off the possibility of risk diversification if they go public and listing fees. He shows that when listing fees are high, the number of firms that list is low relative to the efficient outcome. Gehrig et al. (1998) consider two exchanges, with identical listing fees, that are located in different countries. When investors have access to information of the same precision on domestic and foreign

[5]Most of the empirical literature on listing choice has focused on the price effects when firms delist from Nasdaq in order to list on the NYSE (Cowan et al.(1992), Grammatikos and Papaioannou (1986), Sanger and McConnell (1986), Baker (1996)). The findings in this empirical literature are not relevant for the present article that focuses on initial listing decisions by firms. Corwin and Harris (1998) study the factors that influence the initial listing choice.

¯rms, they show that, in general, ¯rms and traders concentrate on a single exchange. Conversely, when investors have access to higher precision information on domestic ¯rms, equilibria exist in which ¯rms list on the two exchanges. Angel and Aggarwal (1997) study competition for listings between the NYSE and the Nasdaq. They argue that Nasdaq attracts some listings, despite higher trading costs, because Nasdaq dealers have more incentive than NYSE specialists to advertise the stocks in which they make market. This sponsorship reduces the cost of capital for some ¯rms.

In these three papers, the analysis focuses on ¯rms' listing choices, taking as given the di®erence in the listing fees and/or the per share trading cost of the competing exchanges. In contrast, we study a model in which both ¯rms' listing choices and exchanges' decisions regarding listing requirements and the design of trading rules are endogenous. Huddart and Hughes (1997) consider a special type of listing requirement: disclosure requirements. In their model, two exchanges compete for listings and seek to maximize trading volume. To this end, they both end up choosing the highest possible level of disclosure. We, however, show that competing exchanges do not necessarily choose trading rules that minimize trading costs. A main reason for this di®erence is that, in our setting, exchanges have a di®erent objective function: they maximize their total expected pro¯t rather than their trading volume.

Finally, our model is tangentially related to models of the going public decision by ¯rms (e.g. Chemmanur and Fulghieri (1996), Pagano and Roell (1997), Titman and Subrahamanyam (1997)). It complements these models since the choice of a listing location is part of the going public decision. Furthermore, in some of these models (e.g. Pagano and Roell (1997)), listing fees play an important role but are taken as exogenous.

The next section describes the model. Section 3 describes and characterizes the outcome of the IPO mechanism. In Section 4 we characterize the equilibrium of the competition game between exchanges when exchanges compete in listings and we discuss some empirical implications. We then consider possible technology choices in Section 5. In Section 6, we derive the policy implications of the model. Section 7 concludes. All the proofs are in the Appendix.

2 The Model

We consider an economy with three classes of agents: entrepreneurs, investors and exchanges. Each entrepreneur owns a productive technology and seeks to (partially) divest from his company by going public. Investors, who may have liquidity shocks, are willing to buy shares of this technology to transfer money across time. Pro¯t{maximizing exchanges o®er a listing venue to entrepreneurs and provide a trading technology for investors to rebalance their portfolios in case of liquidity needs.

The timing of the game that these agents play is described in Figure 1. At date 1, up to two exchanges choose trading rules which generate a per unit cost of trading. At date 2, they set listing fees. At date 3, each entrepreneur chooses the exchange on which to list his company and sells part of it to investors in an IPO. At date 4, some of the investors are hit by liquidity shocks and have to sell their shares. At date 5, the ¯rms' payo®s are realized. We solve the game using backward induction.

Entrepreneurs: There is a continuum of entrepreneurs of di®erent types. The cash °ows from the technology of each entrepreneur can be divided into N claims or shares. Entrepreneur i's type is denoted t_i and is the expected per share payo® from his productive technology. Therefore, $t_i N$ is the total size of his ¯rm. In the population, entrepreneur types are uniformly distributed on $[\underline{t}; \bar{t}]$. The average expected per share payo® in the population is m. We will sometimes refer to the dispersion of ¯rms' expected payo®s, denoted ¾. Hence, $\underline{t} = m$ ¡ $\frac{¾}{2}$ and $\bar{t} = m + \frac{¾}{2}$. As all cash °ows are positive, $m >$ ¾.

Each entrepreneur derives utility from consumption at time 3 and time 5. Date 3 is the IPO stage and on date 5 cash °ows are realized. For each entrepreneur,

$$U(c_3; c_5) = c_3 + \pm c_5; \tag{1}$$

where c_t denotes the consumption of an entrepreneur at date t and where ± is the intertemporal preference parameter of the entrepreneurs. To characterize the equilibrium, we assume that $\pm = \frac{1}{2}$. This assumption does not qualitatively a®ect results since parameter ± just determines the size of the gains from trade between investors and entrepreneurs (more on this below). In fact, all our results are robust for $\pm < 1$. In order to increase date 3 consumption, entrepreneurs go public and sell some of their shares or equivalently, a percentage of ownership of the future proceeds from their productive technology, to outside investors.[6] Thus, entrepreneurs in our model can be thought as venture capitalists or original owners who want to \cash in" by selling o® shares.[7] Entrepreneurs therefore

[6] We assume that entrepreneurs cannot borrow. This may be due to the agency problems of debt but the exact reason is left unmodeled.

[7] This is, indeed, one of the reason for which ¯rms go public. See, for instance, Ellingsen and Rydqvist (1997) or Pagano and Zingales (1998).

maximize utility by choosing (i) whether to go public, (ii) the listing location and (iii) the issue size and the IPO price.

Investors: A continuum of potential investors indexed by $s \in [0,1]$ bid for shares in the entrepreneurs' IPO's. At date 4 or 5, investors may be hit by liquidity shocks.[8] At time 0, the timing of these liquidity needs is unknown to each investor. If Φ_s is an indicator variable that is equal to 1 if investor s is hit by a liquidity shock at date 4 and 0 otherwise then the utility of investor s is:

$$U_s(c_3, c_4, c_5) = c_3 + \Phi_s c_4 + (1 - \Phi_s) c_5 \tag{2}$$

We assume that $Pr\{\Phi_s = 1\} = s$. Hence, investors are indexed by the probability that they will be hit by a liquidity shock at time 4. At time 3, the IPO stage, each investor knows his probability.

Each investor has sufficient wealth at the IPO stage (date 3) so that they are never wealth constrained.[9] They do not, however, have any endowment at date 4 or at date 5 (no productive technology). Therefore, they buy shares from the entrepreneurs to transfer wealth across periods. Investors can also invest in a riskless asset whose rate of return, per period, is normalized to zero.[10] Hence, at the IPO stage (date 3) gains from trade exist between investors and entrepreneurs because these two groups have different intertemporal preference parameters ($\delta = 1$ for investors and $\delta = \frac{1}{2}$ for entrepreneurs). At date 4, the investors that are hit by liquidity shocks sell the shares of the firms in which they have a stake. Such trades are executed on the exchange on which the shares are listed.

Exchanges: Exchanges are profit maximizers who derive profits from two sources: listing fees that they charge to entrepreneurs and trading fees that they charge to investors. There are at most two exchanges, Exchange 1 and Exchange 2. At date 1, the exchanges simultaneously choose a trading technology. A trading technology is a specific set of trading rules, the outcome of which is a trading cost. The market microstructure literature has shown that different trading rules are associated with different levels of trading costs. For simplicity, we do not explicitly model the relationship between trading rules and trading

[8] Our specification of investors' preferences is similar to Gorton and Pennacchi (1990) or Bolton and Von Thadden (1998).

[9] Introducing wealth constraints for investors or entrepreneurs creates technical complexities but it does not qualitatively change our results.

[10] We assume that the entrepreneurs cannot short sell the riskless asset. Otherwise, the difference in intertemporal preference parameters between entrepreneurs and investors precludes the existence of an equilibrium in the market for the riskless asset since all the agents are risk neutral.

costs. Rather, we directly assume that each trading technology is associated with a per share trading cost, c, in the secondary market. Exchanges can choose one of two trading technologies: (i) a low quality trading technology, with a high per share trading cost that we denote c_H or (ii) a high quality trading technology, with a low per share trading cost: $c_L < c_H$. We sometimes denote $c_H = \frac{1}{1-a}c_L$ with $a \in (0;1)$. Hence, a is the percentage difference in trade execution costs or $a = \frac{c_H - c_L}{c_L}$. We often refer to $q_j = 1/c_j$ as the "quality" of Exchange j.[11] Without affecting the results, we assume that trading costs are entirely borne by sellers in the secondary market.

It is worth stressing that the trading cost is not necessarily a trading fee that is paid to the exchange. That is, costs faced by investors are not necessarily completely recovered by the exchanges. The market microstructure literature is replete with examples in which there are other sources to execution costs that are partially controlled by the exchange (through the design of its trading rules) but that do not directly generate revenues for the exchange. For example, consider the minimum price variation (tick size). Tick size is chosen by an exchange and creates a wedge between the fair value of the asset and the price at which investors can buy or sell the asset. This wedge is a transaction cost but is not recovered by the exchange. Rather, it allows liquidity suppliers (e.g. limit order traders or dealers) to capture rents.[12] Thus, we denote by $\gamma \geq 0$ the fraction of the total trading cost c_j that is recovered by an exchange.

At date 2, exchanges simultaneously set their listing fees,[13] F_j, that must be paid by a firm if it lists on the exchange.[14] Listing requirements can also include a minimum size requirement. For the moment, we assume that there is no size requirement but we consider this possibility in Section 5.1 . In sum, an exchange, say j, is characterized by $(c_j; F_j)$, i.e a specific bundle of trading cost and listing fee.

[11] It is customary in the market microstructure literature to measure the quality of an exchange by the inverse of the per share trading cost in the exchange. For instance, Hasbrouck (1993) or Corwin and Harris (1998) use this terminology.

[12] Subrahmanyam and Chordia (1995) provide a model in which the minimum price variation enables dealers to capture strictly positive expected profits at the expense of liquidity demanders. Madhavan (1992) compares trading costs (due to asymmetric information) in two markets with different trading rules: an order-driven market and a quote-driven market. He shows that trading costs differ in these two trading mechanisms. This is another illustration of the fact that an exchange can control execution costs, even when these costs do not directly accrue to the exchange.

[13] Exchanges charge two types of listing fees. An entry fee that is paid up-front when the firm initially lists and a continuation fee that is paid annually. For our model, this distinction is not relevant.

[14] We assume that exchanges choose their listing fee after their trading technology for two reasons. First, in reality, it is difficult for an exchange to frequently rewrite its trading rules, whereas listing fees can easily be modified. Thus, it is natural to allow the listing fee of one exchange to depend on the trading technology of the other exchange. Second, the competition game in which exchanges choose simultaneously their listing fee and their trading technology is plagued with non-existence problems.

Let $\Pi_j(t)$ be the expected revenue that Exchange j derives from the listing of an entrepreneur with type t and let $Vol(t; q_j)$ be the expected trading volume in the secondary market for the shares issued by this entrepreneur. Then,

$$\Pi_j(t) = F_j + \gamma c_j Vol(t; q_j). \tag{3}$$

Observe that a listing contributes in two ways to the revenue of the exchange. First, the exchange obtains the listing fee. Second, the exchange obtains a revenue that is proportional to the trading volume in this listing. Let $T_j \subseteq [\underline{t}; \bar{t}]$ be the subset of entrepreneurs who list on Exchange j. We normalize the marginal cost of an additional listing to zero. Therefore, the total expected profit of Exchange j is:

$$\Pi_j = \Pr[t \in T_j] F_j + \gamma c_j E[Vol(t; q_j) \mid t \in T_j]. \tag{4}$$

Exchange j chooses $(c_j; F_j)$ to maximize its total expected profit.

3 The Initial Public Offering Mechanism

Consider an entrepreneur who has decided to go public on Exchange j. We derive the number of shares that are sold by the entrepreneur in the IPO (the "issue size") and the price at which he sells these shares ("the IPO price"). Then, we compute the utility benefit to the entrepreneur from going public and we relate it to the liquidity of the exchange.

Our model of price formation in the IPO is a stylized rendering of a book building. Alternatively, it can be viewed as a uniform price auction. For simplicity, we assume that there is complete information on firms' expected payoffs. Our purpose here is not to study the IPO process but to model the positive relationship that exists between investors' required rate of return and the size of trading cost in the secondary market.[15]

In the IPO, investors truthfully report their valuation for the issue. The entrepreneur announces an IPO price and all investors with a valuation greater than or equal to the IPO price get an equal number of shares. The entrepreneur retains the residual.

Investors' Valuations: We first derive the (per share) valuation, $V(s; t; c_j)$, of an investor with type s, for a firm with an expected payoff t that is listed on Exchange j. At

[15] Amihud and Mendelson (1986), Brennan and Subrahmanyam (1996) and Brennan, Chordia and Subrahmanyam (1998) find empirical evidences of a liquidity premium in risk-adjusted average returns.

date 4, investors that are not hit by liquidity shocks are willing to buy one share of this firm at a price equal to $p^{SEC}(t) = t$. Bertrand competition among the buyers insures that this price is indeed the equilibrium price in the secondary market.[16] Given this, we can determine the price that an investor is willing to pay at the IPO stage. If an investor of type s buys one share of the firm in the IPO at an IPO price of p^{IPO}, then her expected payoff is:

$$U^r - p^{IPO} + s[p^{SEC}(t) - c_j] + (1 - s)t;$$

where U^r is the expected utility of the investor if she does not buy shares in the firm. The previous equation can be written:

$$U^r + (t - sc_j - p^{IPO}):$$

It follows that the maximum price per share the investor is willing to pay for an IPO (her valuation) is:

$$V(s; t; c_j) = t - sc_j: \qquad (5)$$

Thus, the investor's valuation is equal to the expected payoff per share[17] minus the expected trading cost for the investor. Observe that $V(s; t; c_j)$ decreases with s. In what follows, we restrict attention to trading technologies so that the investor with the lowest valuation for any IPO would be willing to participate in the market place, or that the trading technologies satisfy individual rationality. Hence,

Condition 1 :Individual Rationality

$$\begin{aligned} \underline{t} &> c_H \\ = \left(m - \frac{\sigma}{2}\right)(1 - a) &> c_L: \end{aligned}$$

[16] Note that the entrepreneurs have no utility for consumption at date 4. Thus they do not sell or short-sell shares at this date. If the entrepreneurs could consume at date 4, the equilibrium in the secondary market would exist only if we assume that short sales are forbidden since agents are risk-neutral and have different utility discount factors (valuations). Assuming that the entrepreneurs do not consume at date 4 simplifies the presentation of the model without affecting the results.

[17] As investors are risk-neutral, their required return is independent of the size of their stake.

In the IPO, each investor who is willing to pay the IPO price[18] is allocated a small number, $N ds$, of the shares so that each investor eventually gets an equal fraction of all the shares that are sold.[19] The allocation rule is such that all the original shares could be sold to the public since $\int_0^1 N ds = N$.

Suppose that the entrepreneur decides to sell a fraction $(1 - \alpha)$ of his N shares. As all investors receive the same number of shares and since investors' bids decrease with s, the marginal investor, s^*, is such that:

$$\int_0^{s^*} N ds = [1 - \alpha]N. \tag{6}$$

Hence, $s^* = (1 - \alpha)$. To sell his $(1 - \alpha)N$ shares, the entrepreneur must therefore choose an IPO price[20] which is just equal to the valuation of the marginal investor of type $s^* = (1 - \alpha)$. Hence,

$$p^{IPO}(\alpha, t, c_j) = V(s^*, t, c_j) = t - (1 - \alpha)c_j. \tag{7}$$

This equation is the demand curve faced by the entrepreneur at the IPO stage. Figure 2 depicts this function for different levels of trading costs in the secondary market. Observe that the IPO price is decreasing in the number of shares, $(1 - \alpha)N$, that the entrepreneur sells. The larger the number of shares the entrepreneur sells, the larger the set of investors the entrepreneur must tap into. Hence, the marginal investor in the IPO has a higher probability of a liquidity shock and hence a lower valuation for the shares. Similarly, investors' required rate of return, gross of the expected trading cost, must increase with the size of the trading cost. For this reason, the larger the trading cost, the lower is the IPO price for a given proportion of shares sold to the public.

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[18] Note that the IPO price must be larger than the valuation (δt) of the entrepreneur for one share. As all the entrepreneurs have the same discount factor, it is never optimal for an entrepreneur of firm i' to buy shares in the IPO of firm i, $i' \neq i$.

[19] The specific allocation rule we consider enables us to get closed form solutions for the equilibrium. The crucial assumption is that no investor can buy more than a small fraction of all the shares in a given issue. This assumption has been made in other articles that model the going public decision (e.g. Chemmanur and Fulghieri (1996)). There are several reasons why this should be the case in practice. For instance, investors choose to be well diversified. Alternatively, entrepreneurs want to tap the wealth of different classes of investors (institutional investors, small investors) and want to avoid any large stake being assembled by a single investor (Brennan and Franks (1997)).

[20] The IPO can be seen as a uniform price auction in which (i) the entrepreneur announces the size of the issue, (ii) investors post bids for a fixed quantity, (ii) the IPO price is chosen so as to equate supply and demand and (iii) all the orders from investors with a bid larger than or equal to the IPO price are filled. As there is a continuum of investors, it is optimal for each investor to post a bid equal to her valuation.

Let $\Delta U(\alpha; t; c_j)$ be the increase in the expected utility (gross of the listing fee) of the entrepreneur who goes public on Exchange j and who retains a proportion α of all the shares. Then,

$$\Delta U(\alpha; t; c_j) = N(1 - \alpha)p^{IPO}(\alpha; t; c_j) - \frac{(1 - \alpha)Nt}{2}$$

which, given the IPO price, can be written:

$$\Delta U(\alpha; t; c_j) = \frac{N(1 - \alpha)t}{2} - (1 - \alpha)^2(Nc_j). \quad (8)$$

The entrepreneur chooses α to maximize ΔU. The solution to this problem determines the IPO price and the issue size. They are given in the following lemma.

Lemma 1 (IPO price and Issue Size): An entrepreneur with type t that lists on Exchange j sells $(1 - \alpha^*(t; q_j))N$ shares to the public at a price $p^{IPO} = \frac{3t}{4}$ where

$$\alpha^*(t; q_j) = 1 - \frac{tq_j}{4}. \quad (9)$$

Trade occurs at the IPO stage between entrepreneurs and investors because each entrepreneur has a smaller valuation for a unit of future consumption than each investor. The benefit from going public in our setting is captured by the first term of Equation (8). If the secondary market were perfectly liquid ($c_j = 0$), it would be optimal for the entrepreneur to divest entirely ($\alpha^* = 0$) because the difference in valuation for the shares between the entrepreneur and the public is independent of each investors' stake. When the secondary market is illiquid ($c_j > 0$), this is not the case. As the entrepreneur issues more shares, the valuation of the marginal buyer in the IPO decreases. This effect is captured by the second term of Equation (8). As a consequence, the entrepreneur optimally retains a stake in the firm, as stated in Lemma 1. So, the trading cost is a source of inefficiency since it prevents gains from trade between investors and entrepreneurs from being fully realized at the IPO stage. Note, finally, that the number of shares sold in the IPO increases with the size of the firm.

In what follows, we restrict our attention to the set of parameters that are such that the optimal number of retained shares, $\alpha^*(t; q_j)$, is strictly positive.[21] Thus, we assume that $(c_L; m; \sigma)$ satisfy a no-short selling constraint or:

[21] For the parameters such that this condition is not satisfied, some entrepreneurs do not retain any

Condition 2 :No short selling, $c_L > \frac{m+\frac{\sigma}{2}}{4}$:

It follows from Lemma 1 that the utility benefit from going public on Exchange j is:

$$\Delta U(\alpha^*(t;q_j);t) = \frac{N q_j t^2}{16}: \tag{10}$$

Clearly, $\Delta U(\alpha^*(t;q_j);t)$ is the maximum listing fee that a firm with type t is willing to pay in order to be listed on Exchange j. This willingness to pay has three properties that are crucial for our analysis of competition between exchanges:

Lemma 2 : An entrepreneur's willingness to pay to go public on Exchange j, $\Delta U(\alpha^*(t;q_j);t)$, increases with the size of his future cash flows and increases in the quality of the exchange, or

1. $\frac{d\Delta U}{dt} > 0$
2. $\frac{d\Delta U}{dq} > 0$.

   Further, larger firms are more willing to pay for increase in exchange quality than small firms or,

3. $\frac{d^2\Delta U}{dtdq} > 0$.

Observe, that all firms prefer lower trading costs, but larger firms are willing to incur a larger increase in the listing fee for a given improvement in exchange quality. The entrepreneurs of these firms are more sensitive to the size of the trading cost since they sell more shares to the public. For this reason, in equilibrium, firms that list on exchanges with different qualities will have different characteristics, as shown in Section 4.2.

Expected Trading Volume: The previous analysis shows that for a firm with type t that lists on Exchange j, investors' types are uniformly distributed on $[0; 1-\alpha^*(t;q_j)]$. It follows that the expected trading volume in the secondary market of the firm is:

$$Vol(t;q_j) = \int_0^{1-\alpha^*(t;q_j)} \frac{sN}{(1-\alpha^*(t;q_j))} ds \tag{11}$$

or,

---

stake in their firm ($\alpha^* = 0$). This "bunching" make the analysis of the optimization problems solved by the two exchanges more complex without any additional insights.

$$Vol(t;q_j) = \frac{Ntq_j}{8}. \tag{12}$$

Thus, the expected trading volume decreases with the per share trading cost paid by investors and increases with the size of the firm. Hence, given the IPO mechanism, the expected profit of Exchange j is just:

$$\Pi_j = \Pr[t \in T_j]F_j + \gamma E\left[\frac{Nt}{8} \mid t \in T_j\right]. \tag{13}$$

4 Competition for Listings with Given Trading Technologies.

Given the IPO mechanism, what are the listing fees charged by exchanges, taking trading technologies as given. Let $\Pi_j(F_j;F_{j'} \mid c_j;c_{j'})$ be the expected profit of Exchange j, for given listing fees in the two exchanges. We are interested in the Nash equilibrium of competition in listing fees given the technology choice.

As a benchmark, we first consider the case in which exchanges have the same trading technology. Then, we derive optimal listing fees when their trading technologies are different and we discuss the testable implications of the model. The analysis has relevance for situations where different exchanges compete for listings within the same country (as, for instance, in the U.S., in Canada or in the U.K.[22]). Throughout this section, we denote the difference in quality between the two exchanges by $\Delta q = q_1 - q_2$ and the difference in listing fee by $\Delta F = F_1 - F_2$. Since $c_H = \frac{c_L}{1-a}$, $\Delta q = \frac{a}{c_L}$. When the exchanges have different trading technologies, we assign index 1 to the low trading cost (high quality) exchange (i.e. $c_2 = c_H$ and $c_1 = c_L$).

4.1 A Benchmark: Competition for Listings with Identical Trading Technologies.

For given listing fees $(F_1;F_2)$ of the two exchanges, a firm of type t lists on Exchange j iff:

$$\Delta U(\alpha^*(t;q_j);t) - F_j > Max[\Delta U(\alpha^*(t;q_{j'});t) - F_{j'};0]. \tag{14}$$

[22] In the U.K., the London Stock Exchange compete with Tradepoint, a new trading system introduced in 1996.

If $q_j = q_{j'}$, the previous condition imposes $F_j < F_{j'}$. Consequently, listing location is entirely determined by the listing fee. If these fees are different, all the entrepreneurs list on the exchange with the lowest listing fee. If the fees are equal, we assume that they randomly choose the exchange on which to list, with equal probabilities. Consider a fee $F \leq \Delta U(\alpha^*(\underline{t}; q_j); \underline{t})$. For such a fee, all the entrepreneurs are willing to go public. Using Equation (13) and the randomization rule, the profit of Exchange j is just

$$\Pi_j(F_j; F_j') = \begin{cases} \frac{1}{2}F + \frac{N\gamma m}{16} & \text{if } F_j = F_j' = F \\ F + \frac{N\gamma m}{8} & \text{if } F_j = F < F_j' \\ 0 & \text{otherwise} \end{cases}$$

Undercutting is profitable as long as $F > -\frac{N\gamma m}{8}$. Thus, in equilibrium both exchanges choose a listing fee equal to $F^* = -\frac{N\gamma m}{8}$ and obtain zero expected profit, just as in the traditional model of Betrand price competition. Note, that the listing fee is in fact a subsidy if $\gamma > 0$. When exchanges derive revenues from trading in the secondary market, they are willing to subsidize firms that go public since listings are necessary to generate trading volume. This is, of course, never the case when $\gamma = 0$ since in this case an exchange cannot recover the subsidy. The next proposition summarizes the results of this section.

Proposition 1 If two exchanges in competition have the same trading technology so that $q_1 = q_2$, and if entrepreneurs, when indifferent, randomize with probability $1/2$ then:

1. Each exchange subsidizes listings with a subsidy equal to $\frac{N\gamma m}{8}$.
2. All the entrepreneurs go public.
3. Each exchange makes zero expected profits.

Observe that in this case, as firms randomize between the exchanges, the cross-sectional characteristics of firms on either exchange are the same. Further, the listing subsidy is increasing in γ, the proportion of the trading costs that the exchange recovers.

4.2 Competition for Listings With Different Trading Technologies.

Now, suppose that the two exchanges have different trading technologies, so that the trade quality differential is positive, or $\Delta q > 0$. For given listing fees $(F_1; F_2)$ on the two exchanges, a firm with type t lists on the low quality Exchange 2 iff:

$$\Delta U(\alpha^*(t; q_2); t) - F_2 \geq \max[\Delta U(\alpha^*(t; q_1); t) - F_1; 0]. \tag{15}$$

Or, if the net utility from going public on the low quality exchange is higher than the net utility of going public on the high quality exchange 1. The max reflects the fact that if $F_2 \geq \Delta U(\alpha^*(\underline{t}; q_2); \underline{t})$, some entrepreneurs might prefer not to go public. Using Equation (10), for a firm that does go public, this is equivalent to:

$$\frac{N t^2}{16} \leq \frac{\Delta F}{\Delta q}. \tag{16}$$

Note that if $F_2 > F_1$, or if the listing fees on the low quality exchange are higher than the listing fees on the high quality exchange, then $\Delta F < 0$ and the previous inequality cannot be satisfied. In this case, the low quality, Exchange 2, attracts no listings. It follows that for Exchange 2 to attract some listings, it must charge a lower listing fee than the high quality Exchange 1.

When $\Delta F > 0$, so that the listing fee on the high quality is higher than the listing fee on the low quality exchange, firms trade-off the larger utility benefit, gross of the listing fee, if they go public on the high quality exchange against the higher listing fee charged by the high quality exchange. If the difference in listing fees between the exchanges is sufficiently large relative to the difference in quality, some firms will choose to list on the low quality exchange.

Lemma 3 If $q_1 > q_2$ and $F_1 > F_2$, then there exists a firm type t_c, such that for $t > t_c$, the entrepreneur prefers to list on Exchange 1 and for $t \leq t_c$, the entrepreneur prefers to list on Exchange 2, where $t_c = \max[\underline{t}; t^*]$ and

$$t^*(F_1; F_2) = 4\sqrt{\frac{\Delta F}{N \Delta q}}. \tag{17}$$

Thus, $t^*(F_1; F_2)$ is the entrepreneur type who is indifferent between listing on the low quality exchange and the high quality exchange so that Equation (16) holds as an equality. It follows from Equation (16) that an entrepreneur with $t > t_c \equiv \max\{\underline{t}; t^*\}$ chooses to list on the high quality exchange whereas an entrepreneur with $t < t_c$ lists on the low quality exchange. Thus, if both exchanges attract listings (i.e. $t_c > \underline{t}$), the average firm size on Exchange 1 must be higher than the average firm size on Exchange 2. This is in contrast to the benchmark case in which, in equilibrium, there is no difference in the average firm size across exchanges. The sorting of ¯rms between exchanges according to their size re°ects the higher willingness to pay for an improvement in trading costs in large ¯rms. This is because larger ¯rms issue more shares. Hence, large ¯rms are more sensitive to the impact of trading cost on the required rate of return by investors. In an empirical paper, Corwin and Harris (1998) ¯nd that the size of a ¯rm[23] is, indeed, an important determinant of the choice of a listing location. Speci¯cally, controlling for the e®ect of listing requirements, their analysis reveals that smaller ¯rms are more likely to list on Nasdaq.

Equation (17) also shows that the listing fee of an exchange and its quality are important determinants of the choice of a listing location by a ¯rm. For instance, the probability that a ¯rm lists on Exchange 1, $Pr(t > t_c)$, is negatively related to the listing fee of Exchange 1 and positively related to its quality. This feature of our model is also consistent with Corwin and Harris (1998) who ¯nd that di®erences in listing costs and execution costs between the NYSE and Nasdaq are important factors in the initial listing decision of ¯rms.

We now have to establish that there is an equilibrium for which $t_c > \underline{t}$. That is, are there conditions under which both exchanges can exist in the market? Clearly, for a given listing fee of Exchange 2, there is a listing fee (e.g. $F_1 = F_2$) for Exchange 1 such that it captures all the listings (i.e. such that $t_c = \underline{t}$). This pricing policy, however, is not necessarily optimal for Exchange 1. In fact, the high quality exchange might be better o® charging a larger fee that only attracts the entrepreneurs with the highest willingness to pay. Such a policy leaves some room for the low quality Exchange 2, which can then charge a listing fee that attracts the remaining entrepreneurs.

The following proposition establishes that, depending on the dispersion of ¯rms size in the economy, two types of equilibria can exist when exchanges have di®erent trading technologies. The ¯rst type of equilibrium is such that there is a fragmentation of listings between the two exchanges. We refer to this equilibrium as the fragmented equilibrium. Conversely, in the second equilibrium, the low trading cost exchange chooses a su±ciently low listing fee so that (i) it captures all the listings and that (ii) it prevents Exchange 2 from pro¯tably lowering its listing fee. In this equilibrium there is a concentration of listings on a single exchange and we refer to it as the concentrated equilibrium. First, we de¯ne ¾c ´ $\frac{2m}{5}$.

Proposition 2 : (equilibrium listing fees) Suppose that all entrepreneurs go public

[23] They measure the size of a ¯rm by its total market value after the IPO.

and there is a pure strategy Nash equilibrium or that $\frac{5\gamma C_L}{8m} \le a \le \frac{1}{3}$. Then, there are two types of Nash equilibria:

1. **Fragmented Equilibrium.** If the dispersion of entrepreneur types is sufficiently large so that $\sigma \ge \sigma^c$ then the equilibrium listing fees are:

$$F_1^* = [b_1(\sigma) \cdot q - b_0(\gamma)]N;$$
$$F_2^* = [b_1'(\sigma) \cdot q - b_0(\gamma)]N;$$

   where $b_1(\sigma) = (\frac{m}{5} + \frac{\sigma}{2})\frac{m}{10}$, $b_1'(\sigma) = (\frac{\sigma}{2} - \frac{m}{5})\frac{m}{10}$ and $b_0(\gamma) = \frac{\gamma m}{10}$:

   Further, both exchange obtain strictly positive expected profits and all the firms go public. The market shares of Exchange 1 and Exchange 2 are respectively: $\frac{1}{2} + \frac{m}{5\sigma}$ and $\frac{1}{2} - \frac{m}{5\sigma}$.

2. **Concentrated Equilibrium.** If $\sigma < \sigma^c$ then

$$F_1^* = \left[\frac{\underline{t}^2 \cdot q}{16} - \frac{\gamma m}{8}\right] N$$
$$F_2^* = -\frac{\gamma m N}{8}:$$

   All the entrepreneurs go public and list on Exchange 1 which obtains a strictly positive expected profit.

Thus, a fragmented equilibrium is obtained if the dispersion of firm size is sufficiently large. In this case, the low trading cost exchange is better off specializing in relatively large firms rather than choosing a very low fee that would prevent Exchange 2 from attracting any listings. Note, that the proposition holds even if $\gamma = 0$, i.e. if exchanges do not capture any revenue from trading in the secondary market.

It is natural to relate the dispersion of firm types to the size of the economy. If the economy is sufficiently large, that is if $\sigma \ge \sigma^c$, then two different exchanges serving the listing market is the natural outcome of competition in listings. If, by contrast, σ is sufficiently small, then the exchange with the highest quality serves as a natural monopoly. This suggests that as economies grow, we should expect more exchanges with different trading technologies.

Alternatively, one can interpret the dispersion of entrepreneur types as a function of the outside opportunities for raising capital and diversifying holdings. If there are few opportunities outside equity markets for raising capital, that is if σ is large, then we predict differentiated equity markets. If, however, there are many and well–developed avenues for raising funds, so that σ is small in the economy, then we predict a concentrated equilibrium.

Note that Proposition 2 holds for $\frac{5\gamma c_L}{8m} \le a \le \frac{1}{3}$. Recall that $\Delta q = \frac{a}{c_L}$. When a increases, the quality differential, Δq, increases. This means that in the fragmented equilibrium, the listing fees of Exchange 1 and Exchange 2 increase with a. If $a > \frac{1}{3}$, then the listing fee of Exchange 2 is larger than the utility benefit from going public of a firm with the smallest size, $\underline{t}$. Thus, when $a > \frac{1}{3}$, some firms do not go public and the closed form solutions for the listing fees of each exchange are different. But, even in this case, the main result established in Proposition 2 is unchanged: if $\sigma > \sigma^c$, the equilibrium features a fragmentation of listings between the two exchanges. (We have chosen to focus only on the case in which $a < 1/3$ for brevity.) When $a < \frac{5\gamma c_L}{8m}$, then the difference in quality between the two markets is small. It is possible to show that in this case, there is no pure strategy equilibrium in which the two exchanges are active. For this reason we have assumed that $a \ge \frac{5\gamma c_L}{8m}$. Intuitively, if the quality differential is small, exchanges cannot differentiate and revert to Bertrand like competition.

The following corollaries analyze the impact of a change in exogenous parameters on the listing fees in the fragmented equilibrium.

Corollary 1 If $\sigma \ge \sigma^c$, then differences in trade execution quality soften price competition so that the listing fee of each exchange increases with the difference in quality between the two exchanges. Or,

$$\frac{dF_1^*}{d\Delta q} > 0;$$
$$\frac{dF_2^*}{d\Delta q} > 0.$$

Consider an exogenous increase in the quality of Exchange 1. Such an increase results in a larger proportion of entrepreneurs that wish to list on this exchange (Equation (17)), ceteris paribus. But entrepreneurs' willingness to pay, for being listed on Exchange 1, increases. Exchange 1 reacts by increasing its listing fee. As a result, the proportion of entrepreneurs that wish to list on Exchange 2 increases, allowing this exchange to increase its own listing fee. Ultimately, in equilibrium, the cutoff type remains unchanged ($t^* = \frac{4m}{5}$). This corollary suggests that if exchanges compete by changing their trading system so that the quality differential of two exchanges competing in the same market decreases, then there should be a corresponding decrease in listing fees.

Corollary 2 If $\sigma \geq \sigma^c$, then, the larger the dispersion of entrepreneur's types, the higher the listing fees of each exchange. Or,

$$\frac{dF_1^*}{d\sigma} > 0;$$
$$\frac{dF_2^*}{d\sigma} > 0.$$

The higher the dispersion of types, the higher the market share of Exchange 2 , ceteris paribus (see the first part of Proposition 2). Exchange 2 reacts by increasing its listing fee. But this in turn allows Exchange 1 to increase its listing fee as well. Effectively, the larger distribution of types, the more local monopoly power each exchange exerts.

Corollary 3 If $\sigma \geq \sigma^c$, then the higher the revenues from trading volume, the lower the listing fee of each exchange. Or,

$$\frac{dF_1^*}{d\gamma} < 0;$$
$$\frac{dF_2^*}{d\gamma} < 0.$$

For each exchange, the opportunity cost of losing one listing, which includes the loss of trading fees generated by this listing, increases as γ increases. It follows that exchanges compete more aggressively for listings. As in the benchmark case, the two exchanges can even offer subsidies (negative listing fees) if $\gamma > 0$. Thus, the model is consistent with listing fees being small in some exchanges (as it is the case in Nasdaq for instance). Interestingly, this corollary suggests that the existence of third parties that contribute to trade execution costs of investors may be a way for exchanges to credibly commit to charging high listing fees. Whereas, a movement to recover trading costs for an exchange signals a willingness to compete aggressively on listing fees.

4.3 Testable Implications.

Our model has testable implications both for the listing choices of firms and the listing fee policies of exchanges.

One important implication of our analysis is that when two exchanges with different trading technologies coexist, they should attract listings from firms with different characteristics. This suggests that the characteristics (issue size, proceeds, market value) of

IPOs' on two exchanges with different execution costs under the same jurisdiction should differ in a systematic way. In particular:

Corollary 4 In any economy in which two exchanges with different trading technologies compete for listings, the proportion of original shares offered to the public is larger for an IPO taking place on the high quality exchange (Exchange 1) than for an IPO taking place on the low quality exchange (Exchange 2), or

$$E[(1-\alpha^*) \mid \text{Lists on Exchange 1}] > E[(1-\alpha^*) \mid \text{Lists on Exchange 2}].$$

This suggests that the post IPO ownership structure of firms who list on the low cost exchange should be less concentrated than those that list on the high cost exchange.

Corollary 5 In any economy in which two exchanges with different trading technologies compete for listings:

1. The expected proceeds for an IPO taking place on the high quality exchange (Exchange 1) are larger than for an IPO taking place on the low quality exchange (Exchange 2), or

   $$E[(1-\alpha^*)Np^{IPO} \mid \text{Lists on Exchange 1}] > E[(1-\alpha^*)Np^{IPO} \mid \text{Lists on Exchange 2}].$$

2. The expected market value of a firm listing on the high quality exchange (Exchange 1) is larger than for a firm with an IPO on the low quality exchange (Exchange 2), or

   $$E[(1-\alpha^*)Np^{SEC} \mid \text{Lists on Exchange 1}] > E[(1-\alpha^*)Np^{SEC} \mid \text{Lists on Exchange 2}].$$

Of course, if both exchanges have the same trading technology, then there should be no cross-sectional differences. In the U.S. it is, however, well-documented that execution costs are larger on Nasdaq (see for instance Huang and Stoll (1996)). Corwin and Harris (1998) study initial listing choices for a sample of firms that conducted Initial Public Offerings of equity between 1991 and 1996, either on the NYSE and the Nasdaq. They restrict their attention to firms that are eligible to list on both exchanges. They document substantial differences between the IPOs' that take place on the NYSE and Nasdaq. In particular they find (Table 3, page 30) that the number of offered shares, the offer proceeds and the post IPO market value of firms that list on the NYSE are significantly larger than on Nasdaq. These findings are consistent with our corollaries.

Corwin and Harris (1998) also analyze the factors that influence the choice of a listing location. Our model suggests that factors (t in our setting) affecting the number of shares sold to investors should also affect the choice of the listing location. Specifically, the model suggests that the larger the issue size, the more likely a firm is to list on the low trading cost exchange. For instance, other things equal, firms that elect to have a more concentrated ownership structure (that sell less shares to the public) are more likely to list on the low quality exchange. This suggests that there should be systematic differences in the (post IPO) ownership structure of firms that list on exchanges with different qualities (after controlling for the effect of listing requirement).

Regarding the listing fee policy of exchanges, our model has two specific implications. First, recall that in any equilibrium in which the two exchanges are active, there is an inverse relationship between listing fees and execution costs.[24] This property is consistent with stylized facts. In the U.S., empirical studies find that Nasdaq has higher execution costs than the NYSE. At the same time, listing fees (as a percentage of market capitalization) are much higher on the NYSE than on the Nasdaq (See Corwin and Harris (1998)). Second, using Proposition 2, we obtain that when the two exchanges are active:

Corollary 6 In any economy in which two exchanges with different trading systems compete for listings, the difference in listing fees is proportional to the percentage difference in execution costs. Or,

$$F_1^* - F_2^* = \left(\frac{m^2}{25}\right)\frac{a}{c_L}. \tag{18}$$

To our knowledge, this implication has not been tested.

[24] Execution costs depend both on trading organization and on firms' characteristics. Our model and its implications focus on the component of execution cost, which is exchange specific. One way to estimate this component is to measure total trading costs for matched samples of firms listed on different exchanges. The difference between the average trading costs for these samples can be ascribed to structural differences in the organization of the exchanges and can be used as a proxy for $c_H - c_L$ in our model. This is the method used in Huang and Stoll (1996) or Affleck-Graves et al. (1994) for instance.

5 Long Term Competition in Technology choice

Given the previous sections, it is natural to ask: if firms choose their trading technology, what technologies will they choose. That is, will exchanges choose to differentiate? To answer this, consider the stage in which the exchanges choose their trading technology (date 1). If they make different choices, we denote by Π_H the expected profit of the exchange with the high trading cost level and we denote by Π_L the expected profit of the exchange with the low trading cost level. Using Proposition 2, it is readily shown that $0 \le \Pi_H < \Pi_L$ and that $\Pi_H = 0$ iff $\sigma \le \sigma^c$. When the exchanges choose the same trading technology, they get a zero expected profit (Proposition 1). Table 1 below is the matrix of exchanges' expected profits as a function of their trading technology choices at date 1. Exchange j is the row player and j' is the column player. Payoffs are recorded as $(\pi_j; \pi_{j'})$.

	c_H	c_L
c_H	$(0; 0)$	$(\Pi_H; \Pi_L)$
c_L	$(\Pi_H; \Pi_L)$	$(0; 0)$

Table 1

Clearly, there are two Nash equilibria in pure strategies, if $\sigma \ge \sigma^c$. Either Exchange j chooses the low trading cost technology and Exchange j' chooses the high trading cost technology or vice versa. There also exists a mixed strategy equilibrium in which each exchange chooses the high trading cost technology with probability $\beta = \frac{\Pi_H}{\Pi_L + \Pi_H}$. If, however, $\sigma < \sigma^c$, it is a weakly dominant strategy for the two exchanges to choose the low trading cost technology. The next proposition summarizes this discussion.

Proposition 3 : In an economy in which two exchanges choose trading technology:

1. If $\sigma \ge \sigma^c$ then the outcome of the pure strategy Nash equilibrium is that each exchange chooses a different technology.

2. If $\sigma < \sigma^c$ then there is a unique weakly dominant Nash equilibrium in which exchanges choose the low trading cost technology.

This proposition establishes that it can be optimal for an exchange not to provide the socially optimal low cost trading technology.[25] The intuition is simple. When the

[25] We discuss social optimality in Section 6.

exchanges choose the same trading technology, the listing cost is the only dimension along which exchanges di®er. This results in a cut-throat competition that leaves no room for pro¯ts. In contrast, if one exchange chooses the high trading cost technology, competition in listing fees is softened. In fact, the low trading cost exchange can charge a high listing fee without fear of losing all the listings to the other exchange. As the listing fee of the low trading cost exchange is large, some entrepreneurs are better o® listing on the high trading cost exchange. In this way, both exchanges can capture strictly positive expected pro¯ts. It is worth stressing that Proposition 3 holds even if ° = 0. This emphasizes that the bene¯t for an exchange of having a large execution cost is indirect in our model. This is a way to soften the competition for listings between the two exchanges. Note that, interestingly, Proposition 3 suggests that the diversity of trading rules could re°ect the diversity of ¯rms' sizes in the economy.

The argument that di®erent trading costs can soften price competition, applies to other forms of di®erentiation, for example minimum size requirements.

5.1 Minimum Size Requirements and Competition.

To quickly convey the intuition, we consider the following simple game that we call the listing requirements game. In this game, exchanges have the same trading cost, however each exchange can require a minimum size for listed ¯rms. Our purpose is to show that exchanges have an incentive to choose di®erent size requirements in order to soften competition.

To formalize the notion of a minimum size requirement, let t_j^{min} be the minimum size requirement of Exchange j, meaning that only ¯rms with an expected payo® larger than t_j^{min} can list on Exchange j. Suppose that the two exchanges have the same trading technology and suppose that at date 1, they can choose between two minimum size requirements: soft in which case $t_j^{min} = \underline{t}$ or tough in which case $t_j^{min} = t_T > \underline{t}$. We call Exchange 1, the exchange with a tough listing policy. Suppose that Exchange 1 chooses its listing fee ¯rst.[26] If the two exchanges have the same listing policy, one exchange is randomly selected to choose its listing fee ¯rst. We obtain the following result.

Proposition 4 Consider the listing requirements game at date 2. In equilibrium:

[26] When the two exchanges have di®erent minimum size requirements, there is no equilibrium in pure strategy, in the listing fee stage, if the exchanges determine their fees simultaneously. Thus, for simplicity, we assume that exchanges choose their fees in sequence. The results in this section do not qualitatively depend on the sequence of moves.

- If the two exchanges have different minimum size requirements, Exchange 1 and Exchange 2 charge listing fees so that they attract respectively firms with sizes in $[t_T; \bar{t}]$ and $[\underline{t}; t_T]$. Both exchanges get strictly positive expected profits.
- If the two exchanges have the same minimum size requirement, both exchanges charge zero expected profit listing fees.

The intuition is straightforward. If the two exchanges have the same minimum size requirement, they end up competing à la Bertrand for listings which leaves no room for profits. By contrast, if they have a different minimum size requirements, Exchange 2 (with the low listing requirement) has monopoly power on all the entrepreneurs with an expected payoff in $[\underline{t}; t_T]$. This exchange can attract all the firms with a fee that is sufficiently low but is better off charging the monopoly fee for the entrepreneurs that are not eligible to list on Exchange 1. Exchange 1 chooses a listing fee sufficiently small so (i) that it attracts all the entrepreneurs with type larger than t_T and (ii) that Exchange 2 has no incentive to attract some of these entrepreneurs by decreasing its fee. Exchange 1's fee is (see the proof of Proposition 4):

$$F_1^* = \Pi_2^m - \frac{\gamma N m}{8}; \tag{19}$$

where Π_2^m is the expected profit of Exchange 2 when it chooses to charge the monopoly fee for the firms with a size in $[\underline{t}; t_T]$. Using the reasoning of Proposition 3, we can show that the stage in which exchanges choose their minimum size requirement has two Nash equilibria in pure strategies. In both equilibria, exchanges choose different size requirements. As is true for trading technologies, a difference in minimum size requirements is a way for competing exchanges to soften competition for listings and to sustain strictly positive expected profits.

We have considered t_T as given. Note that if Exchange 1 could optimally pick t_T, it would not choose it too close to $\underline{t}$. Π_2^m increases with t_T. It follows (using Equation (19)) that F_1^* also increases with t_T. Using this remark, it is straightforward to show that Exchange 1's expected profit is strictly increasing with t_T, for values of this minimum size requirement close to $\underline{t}$.

6 Policy Implications and Regulation.

Should Stock Exchanges be allowed to choose their own trading rules or not? Recently this issue has attracted considerable attention in the Law and Economics literature (see, for instance, Mahoney (1997), Kahan (1997) or Macey and O'Hara (1997)). One argument in favor of self regulation is that competition for listings should lead exchanges to choose trading rules that are socially desirable. For instance, Mahoney (1997) claims that:

> The necessity of attracting investors who have ample alternatives should lead exchanges to choose rules and listing standards that produce benefits to investors [...]. Self-interested Stock Exchange members will produce rules that investors want for the same reasons that self-interested bakers produce the kind of bread that consumers want.[Mahoney (1997), p1459]

Recall, that the larger is the proportion of shares sold to the public, the larger are the gains from trade that are realized in the IPO stage in the model. The proportion of shares sold to the public increases when the quality of the exchange increases, other things equal. This suggests that welfare is larger when both exchanges choose the low trading cost technology. We first establish this result by comparing social welfare in equilibrium when exchanges have different trading technologies and when exchanges have both the low trading cost technology.

Our measure of social welfare is the total surplus, $\Lambda(q_1, q_2)$, that is made up of the sum of total investors' surplus, $\Lambda^I(q_1, q_2)$, total entrepreneurs' surplus, $\Lambda^E(q_1, q_2)$, and total exchange surplus, $\Pi_1 + \Pi_2$). First, we study whether competition for listings induces exchanges to choose the trading technology that maximizes social welfare. Second, we show that, for some parameters values, social welfare is maximized with a monopolist exchange. In order to simplify the analysis, when computing the total surplus, we assume that $\gamma = 1$ but our results do not depend on this assumption. Furthermore, we restrict attention to parameter values so that the possible equilibria of the stage in which exchanges choose their listing fees are described by Proposition 2.

6.1 Exchange Quality and Welfare

First, consider the case in which exchanges have different trading technologies. After some algebra, we obtain that the total surplus to entrepreneurs that list on Exchange 1 and Exchange 2 is:

$$\Lambda^E(q_1;q_2) = \left[\frac{Nq_1(\bar{t}^3 - t_c^3)}{48\sigma} - \Pr(t \geq t_c)F_1^*\right] + \left[\frac{Nq_2(t_c^3 - \underline{t}^3)}{48\sigma} - \Pr(t \leq t_c)F_2^*\right]. \quad (20)$$

The total surplus to investors from buying shares of firms that list on the two exchanges is:

$$\Lambda^I(q_1;q_2) = \left\{\left[\frac{\bar{t}^2 - t_c^2}{8} - c_1\int_{t_c}^{\bar{t}} Vol(t;q_1)dt\right] + \left[\frac{t_c^2 - \underline{t}^2}{8} - c_2\int_{\underline{t}}^{t_c} Vol(t;q_2)dt\right]\right\}\frac{N}{\sigma}. \quad (21)$$

Finally, the total surplus (including exchanges' expected profits) is[27]:

$$\Lambda(q_1;q_2) = \left[\frac{\bar{t}^2 - \underline{t}^2}{8\sigma} + \frac{q_1(\bar{t}^3 - \underline{t}^3)}{48\sigma} - \frac{(t_c^3 - \underline{t}^3)\Delta q}{48\sigma}\right]N. \quad (22)$$

Recall, that in equilibrium, $t_c = t^* > \underline{t}$ if $\sigma \geq \sigma^c$ and that $t_c = \underline{t}$ if $\sigma < \sigma^c$. Similar computations show that when the two exchanges operate with the low trading cost technology then:

$$\Lambda(q_1;q_2) = \left[\frac{\bar{t}^2 - \underline{t}^2}{8\sigma} + \frac{q_1(\bar{t}^3 - \underline{t}^3)}{48\sigma}\right]N. \quad (23)$$

Let $\Delta\Lambda$ be the difference between Equation (23) and (22). That is, $\Delta\Lambda$ is the difference in social surplus between a market in which both firms choose the low cost technology and one in which both choose different technologies. We obtain:

$$\Delta\Lambda = \begin{cases} (t_c^3 - \underline{t}^3)\frac{N\Delta q}{(48\sigma)} & \text{if } \sigma \geq \sigma^c \\ 0 & \text{otherwise} \end{cases}$$

This implies,

Lemma 4 : Social welfare is maximized if the exchanges choose the low trading cost technology. This maximum is not reached if $\sigma \geq \sigma^c$ because in this case one exchange optimally chooses the high trading cost technology and attracts some listings.

Our last result shows that it should not be taken for granted that competition between exchanges leads them to choose socially efficient trading rules. It is interesting to compare

[27] Note that the sum of the terms that include the Fs and the cs in the expressions for the total entrepreneurs' surplus and the total investors' surplus are respectively the total listing fees that are paid by firms and the total expected trading cost borne by investors. As $\gamma = 1$, the sum of these listing fees and these expected trading costs is just equal to the total expected profits of the two exchanges.

this result to the results obtained by Huddart et al. (1998). They consider the choice of disclosure requirements, in a Kyle (1985) model, by two Stock Exchanges competing for trading volume. The choice of a disclosure requirement in their model is similar to the choice of a trading technology in our model. Information disclosures by firms affect the level of asymmetric information in the secondary market and in this way affect the trading costs borne by uninformed investors. Huddart et al.(1998) show that competition between exchanges results in a "race for the top" in the sense that both exchanges choose the highest possible disclosure requirement. Their analysis offers some support for the view that the choice of trading rules should be delegated to exchanges. We obtain a different conclusion. This is mainly[28] because exchanges' objective functions are different in our model. To see this point, suppose that instead of maximizing the total expected profit, each exchange chooses its listing fee and its trading technology in order to maximize the expected trading volume, under the constraint that they obtain a positive expected profit.

Proposition 5 *If the exchanges seek to maximize expected trading volume (instead of profit maximization), they both choose the low trading cost technology ("race for the top") and their listing fees are as described in Proposition 1 .*

To sum up, the results of this section show that self-regulation for a profit maximizing exchange does not necessarily yield the socially efficient trading organization, even in a competitive environment.

6.2 Industrial Organization of Exchanges and Welfare.

In some countries (e.g. in France or in the Netherlands), there is a single Stock Exchange. In this section, we show that this situation can indeed be socially optimal.

Let F_m and q_m be respectively the listing fee and the quality chosen by a monopolist exchange. An entrepreneur goes public iff $\Delta U(\alpha^*(t; q_m); t) - F_m \geq 0$. Let t' be the entrepreneur's type such that:

$$\Delta U(\alpha^*(t'; q_m); t') - F_m = 0: \tag{24}$$

This is the lowest type who would list on a monopolist exchange. Using Equation (10), we obtain that:

[28] Comparison between Hudddart et al. (1998)'s model and our model is not straightforward because the assumptions are very different.

$$t'(F_m) = 4\sqrt{\frac{F_m}{Nq_m}}. \tag{25}$$

Let $t_m \equiv \max\{t'(F_m); \underline{t}\}$. As the utility from going public increases with t, only the entrepreneurs with type $t \geq t_m$ go public. Using Equation (13), the expected profit of the monopolist exchange can be written:

$$\Pi_m(F_m) = \left(\frac{\bar{t} - t_m(F_m)}{\sigma} F_m + \frac{\gamma N}{16\sigma}(\bar{t}^2 - t_m^2(F_m))\right) \tag{26}$$

For a given trading technology, the monopolist exchange chooses the listing fee that maximizes expected profit. The exchange faces the traditional price-quantity trade-off for a monopolist. An increase in the listing fee translates into higher listing revenues from the firms that go public. However, such an increase reduces the proportion of entrepreneurs that find it worthwhile to go public (t_m increases with F^m). This second effect tends to decrease both the revenue from listing fees and the revenue from trading fees for the monopolist. The optimal solution to this problem is given in the next lemma.

Lemma 5 (Listing fee of the monopolist exchange):

1. If $\sigma \leq \sigma^m$ then the monopolist exchange charges a listing fee of $F^m = \frac{N\underline{t}^2 q_m}{16}$ and all the entrepreneurs go public ($t_m = \underline{t}$).
2. If $\sigma > \sigma^m$ then the monopolist exchange charges a listing fee of $F^m = \frac{Nq_m}{36}(\bar{t} - \frac{\gamma}{q_m})^2$ and the proportion of entrepreneurs that do not list is $\frac{5}{6}(1 - \frac{\sigma^m}{\sigma})$.

with $\sigma^m = \frac{2m}{5} + \frac{4\gamma}{5q^m}$.

Note, that if the dispersion of firms' sizes is sufficiently high, the optimal pricing policy of the exchange prevents some entrepreneurs from going public, although this would be socially optimal (recall that the marginal cost of an additional listing has been normalized to zero). This is the usual distortion introduced by monopolist pricing. This distortion does not exist when the dispersion of firms' sizes is small ($\sigma \leq \sigma^m$). We use the previous lemma to prove the following result.

Proposition 6 (Trading technology of a monopolist exchange):

1. The listing fee of the monopolist exchange (weakly) increases with the quality of the exchange, so that $\frac{dF^m}{dq^m} \geq 0$ whereas the proportion of firms that go public decreases with the quality of the monopolist exchange.

2. It is always optimal for the monopolist exchange to choose the trading technology with the lowest trading cost: $c_m = c_L$.

A change in the quality of the monopolist exchange affects both its revenue from listings and its revenue from trading fees. When the quality increases, the willingness to pay of entrepreneurs for going public increases. This effect allows the exchange to increase its listing fee. In equilibrium, this ultimately results in a lower proportion of entrepreneurs that decide to go public but in a larger revenue from listings for the exchange. An increase in the quality of the monopolist exchange affects its revenue from trading as well. Indeed, (i) the expected trading volume per listed firm increases but (ii) the per share trading fee decreases and (iii) the number of listed firms decreases. Finally, the effect of the increase in quality on trading revenue is negative. Hence, an increase in quality increases the revenue from listing fees but it decreases the revenue from trading fees for the monopolist exchange. The net effect on the exchanges' total expected profit is always positive, which explains the second part of the proposition.

Using the results derived in Lemma 5 and Proposition 6, we obtain that the total surplus with a monopolist exchange is:

$$\Lambda(q_m) = N\left[\frac{\bar{t}^2 - t_{mc}^2}{8\sigma} + \frac{q_1(\bar{t}^3 - t_{mc})^3}{48\sigma}\right]; \tag{27}$$

where $t_{mc} = \underline{t}$ if $\sigma \leq \sigma^m$ and $t_{mc} > \underline{t}$ if $\sigma > \sigma^m$. Now consider the case in which $\sigma \geq \sigma^c$. Using Equations (22) and (27), we deduce that the difference between the total surplus obtained with oligopolist exchanges and a monopolist exchange, $\Delta\Lambda^{om}$ is:

$$\Delta\Lambda^{om} = \left[\frac{t_{mc}^2 - \underline{t}^2}{8\sigma} + \frac{q_1(t_{mc}^3 - \underline{t}^3)}{48\sigma} - \frac{(\Delta q)(t_c^3 - \underline{t}^3)}{48\sigma}\right]N. \tag{28}$$

The two first terms in Equation (28) are always positive because $t_{mc} \geq \underline{t}$. This reflects the fact that the monopolist exchange chooses a listing fee that can deter some firms from going public which is detrimental to welfare in our model. This source of inefficiency does not arise with oligopolist exchanges since the high trading cost exchange offers a listing venue to ¯rms that ¯nd it too expensive to list on the low trading cost exchange.[29] For these ¯rms, however, gains from trade at the IPO stage are lower than if they were to list on the low trading cost exchange. This e±ciency loss associated with oligopolist exchanges is re°ected in the last term of Equation (28). It does not exist with a monopolist exchange since the latter always chooses the low trading cost technology. Thus both types of market structure (monopolistic, oligopolistic) are associated with an ine±ciency but the ine±ciency is of a di®erent nature in the two cases.

It follows that a monopolistic exchange maximizes welfare if ¾ · $¾^m$. To see this point, note that $¾^c$ < $¾^m$ if ° > 0. Now, when ¾ < $¾^m$, $t_{mc} = \underline{t}$ (i.e. there is no ine±ciency with the monopolist exchange). It follows that:

$$¢¤^{om} = ¡\left[\frac{(¢q)(t_c^3\ ¡\ \underline{t}^3)}{48¾}\right]N \quad \text{if} \quad ¾\ 2\ [¾^c; ¾^m];$$

which means that total surplus is strictly larger when there is a single exchange than when there are two exchanges competing for listings. Furthermore, when ¾ < $¾^c$, $t_c = \underline{t}$ and total surplus is identical with a monopolist exchange or with oligopolist exchanges. Consequently we have proved the following result.

Proposition 7 : If ¾ · $¾^m$, total surplus is larger with a monopolist exchange than with oligopolist exchanges.

This result holds true for values of ¾ larger than $¾^m$ as well. To see this, note that F_m increases with ¾ when ¾ > $¾^m$. It follows that t_{mc} also increases with ¾ for ¾ > $¾^m$. The negative term in Equation (28) does not depend on ¾. Using this, it is possible to show that $¢¤^{om}$ increases with ¾ for ¾ > $¾^m$. Furthermore $¢¤^{om}$ < 0 for ¾ = $¾^m$. Consequently, there exists an interval [¾; $¾^¤$] such that $¢¤^{om}$ < 0 for values of ¾ in this interval. For these values, welfare is larger with a monopolist exchange. If the dispersion of ¯rms' sizes is larger than $¾^¤$ then welfare is larger with oligopolist exchanges. As an illustration, consider Figure 3. In this numerical example, $¾^m$ = 3:6 but for all values of ¾ in [3:6; 4], welfare is larger when there is a monopolist exchange than when there are two competing exchanges. Hence, even with unbridled competition, oligolopists may provide lower social welfare than a monopolist.

[29] If a > 1=3, there are parameters values such that even in the oligopoly case, some entrepreneurs do not go public. Taking into account this possibility would reinforce our main result in this section which is that total surplus can be larger with a monopolist exchange.

7 Conclusion.

This paper provides a model of competition for listings in which exchanges can choose their trading rules and their listing requirements (which include listing fees). We ¯nd that this competition results in a variety of trading rules and listing requirements in equilibrium. This variety is a way for exchanges to soften competition. The general point that a choice of trading technology allows ¯rms to di®erentiate themselves and so soften price competition applies to any of the screening rules promulgated by exchanges. Further, the fact that trading rules can soften price competition implies that exchanges may take decisions with respect to trading rules that are not optimal for social welfare.

One of the implications of the exchange di®erentiation, and hence ¯rm sorting at the IPO stage, is that ¯rms that list on di®erent exchanges have di®erent characteristics. It follows that IPOs' characteristics on competing exchanges with di®erent trading rules are di®erent. Whether such di®erences automatically persist over time is a question for future research.

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9 Appendix.

Proof of Lemma 1

Given t and $c_j = \frac{1}{q_j}$, an entrepreneur maximizes

$$\Delta U(\alpha; t; c_j) = \frac{N(1-\alpha)t}{2} - (1-\alpha)^2(Nc_j)$$

by choosing α. $\Delta U(\alpha; t; c_j)$ is concave in α. The result follows.

Proof of Lemma 2

Immediate from inspection of Equation (10)

Proof of Proposition 1

Immediate from arguments in the text.

Proof of Lemma 3

Immediate from lemma 2

Proof of Proposition 2:

Part 1

Using Equation (13), we obtain that for given listing fees $(F_1; F_2)$ of the two exchanges, the expected profits of Exchange 1 and Exchange 2 can be written:

$$\Pi_1(F_1; F_2) = \frac{(\bar{t} - t_c)F_1}{\sigma} + \frac{(\gamma N)(\bar{t}^2 - t_c^2)}{16\sigma}$$

$$\Pi_2(F_1; F_2) = \frac{(t_c - \underline{t})F_2}{\sigma} + \frac{(\gamma N)(t_c^2 - \underline{t}^2)}{16\sigma}$$

where $t_c = Max\{t^*; \underline{t}\}$ (where t^* is defined in equation (17)). We are searching for a Nash equilibrium in which all firms go public, so that $F_2^* < \frac{q_2 \underline{t}^2}{16}N$, and both exchanges are active, $t_c = t^*$. Consider $(F_1^*; F_2^*)$ a candidate Nash equilibrium. F_1^* must be a best response to F_2^*. Writing the first order condition for profit maximization for Exchange 1, we obtain the following necessary condition for F_1^* to be a best response:

$$(\bar{t} - t^*) - \frac{\partial t^*}{\partial F_1}F_1^* - \frac{N\gamma t^*}{8}\frac{\partial t^*}{\partial F_1} = 0 \tag{29}$$

Proceeding in the same way with Exchange 2, we obtain that a necessary condition for F_2^* to be a best response to F_1^* is:

$$(t^* - \underline{t}) + \frac{\partial t^*}{\partial F_2}F_2^* + \frac{N\gamma t^*}{8}\frac{\partial t^*}{\partial F_2} = 0 \tag{30}$$

Using Equation (17), we obtain:

$$\frac{\partial t^*}{\partial F_1} = -\frac{\partial t^*}{\partial F_2} = -\frac{2}{\sqrt{N\Delta q(F_1 - F_2)}} \tag{31}$$

Subtracting Equation (30) from Equation (29), we get that:

$$(\bar{t} + \underline{t} - 2t^*) = \left(\frac{\partial t^*}{\partial F_1}\right)(F_1^* - F_2^*)$$

Using Equation (31) at the point $(F_1^*; F_2^*)$ and the definition of t^*, this is just:

$$(\bar{t} + \underline{t} - 2t^*) = \frac{t^*}{2}$$

Solving for t^* and using the condition that $t^* > \underline{t}$ implies that

$$\frac{4m}{5} > m - \frac{\sigma}{2}$$

which is satisfied if and only if $\sigma \geq \sigma^c$.

Using Equation (17), we obtain that $(F_1^*; F_2^*)$ must be such that:

$$\sqrt{(F_1^* - F_2^*)} = \frac{m\sqrt{N\Delta q}}{5} \tag{32}$$

Replacing $\sqrt{F_1^* - F_2^*}$ by this expression in Equation (31), we can easily solve Equations (29) and (30) for F_1^* and F_2^*. Using the fact that $\Delta q = \frac{a}{1-a}q_2$, it is readily shown that $a \leq \frac{1}{3}$ is a sufficient and necessary condition for $F_2^* < \frac{q_2 N \underline{t}^2}{16}$, for all values of the other parameters.

Now, we need to establish that F_1^* and F_2^* dominate any other listing fees that the two exchanges could choose. As the profits are not strictly concave we need to check that the solutions to equations (29) and (30) are, in fact, best responses. To do so, we establish that F_1^* and F_2^* are local maxima. Then, we show that these local maxima are indeed global maxima. Consider Exchange 1 first.

$$\frac{\partial^2 \Pi_1(F_1;F_2^*)}{\partial^2 F_1} = -\left[2\frac{\partial t^*}{\partial F_1} - \frac{\gamma N}{8}\left(\frac{\partial t^*}{\partial F_1}\right)^2 - \frac{\partial^2 t^*}{\partial^2 F_1}\left(\frac{\gamma t^* N}{8} + F_1\right)\right]\sigma^{-1}$$

with $\frac{\partial^2 t^*}{\partial^2 F_1} = -(F_1 - F_2)^{-\frac{3}{2}}(N\cdot q)^{-\frac{1}{2}}$. Using Equation (31), algebra yields:

$$\frac{\partial^2 \Pi_1(F_1;F_2^*)}{\partial^2 F_1} = -[3F_1 - 4F_2^*]\left(\frac{\sqrt{\Delta F}}{\sqrt{N\cdot q}\,\sigma}\right) \tag{33}$$

Using the characterization of F_1^* and F_2^* in Proposition 2, we obtain:

$$\frac{\partial^2 \Pi_1(F_1^*;F_2^*)}{\partial^2 F_1} < 0.$$

Hence, F_1^* is a local maximum. For a given F_2^*, Equation (29) is quadratic in F_1. Thus, this equation has another solution. But this solution is a local minimum since F_1^* is a local maximum.[30]

Now, let F_1^{min} and F_1^{max} be the listing fees of Exchange 1 such that $t^*(F_1^{min};F_2^*) = \underline{t}$ and $t^*(F_1^{max};F_2^*) = \bar{t}$. Clearly, Exchange 1 must choose its fee in the interval $[F_1^{min};F_1^{max}]$. We have already established that F_1^* is the unique local maximum of $\Pi_1(\cdot;F_2^*)$ in this interval. We still, have to check that $\Pi_1(F_1^*;F_2^*) > \Pi_1(F_1^{min};F_2^*)$ and that $\Pi_1(F_1^*;F_2^*) > \Pi_1(F_1^{max};F_2^*)$. Consider F_1^{min}

Using Equation (16), we get $F_1^{min} = F_2^* + \frac{N\underline{t}^2\cdot q}{16}$. Tedious computations yield:

$$\Pi_1(F_1^*;F_2^*) - \Pi_1(F_1^{min};F_2^*) = \left[\frac{(\frac{\sigma}{2} - \frac{m}{5})}{\sigma}\right]\left\{\left(\frac{N\sigma\cdot q + \gamma}{16}\right)\left(\underline{t} + \frac{4m}{5}\right) - F_1^*\right\}$$

The first term in bracket is positive since $\sigma \geq \sigma^c$. The second term in bracket can be shown to be positive as well because $m \geq \sigma$. Hence, $\Pi_1(F_1^*;F_2^*) - \Pi_1(F_1^{min};F_2^*) > 0$. Note that $\Pi_1(F_1^{min};F_2^*) > \Pi_2(F_1^*;F_2^*) > 0$. The first inequality is straightforward and the second inequality is proved below when we show that F_2^* is a global maximum. This implies $\Pi_1(F_1^*;F_2^*) > 0$. With a listing fee equal to F_1^{max}, Exchange 1's market share is zero which implies $\Pi_1(F_1^{max};F_2^*) = 0$. Thus F_1^* is preferred to F_1^{max}. This proves that F_1^* is a global maximum.

[30] If $\Pi_1(\cdot;F_2^*)$ had two local maxima then it would necessary have a local minimum as well. But this would imply that the first order condition has 3 solutions, which is impossible since this condition is a quadratic equation.

For Exchange 2, we obtain:

$$\frac{\partial^2 \pi_2(F_1^*; F_2)}{\partial^2 F_2} = -[4F_1 - 3F_2^*]\left(\frac{\sqrt{\Delta F}}{\sqrt{N \Delta q \sigma}}\right). \tag{34}$$

Since $F_1^* > F_2^*$, we obtain $\frac{\partial^2 \pi_2(F_1^*; F_2^*)}{\partial^2 F_2} < 0$, which proves that F_2^* is a local maximum. Following the same reasoning as for Exchange 1, we can show that this local maximum is unique. It remains to show that $\pi_2(F_1^*; F_2^*) > \pi_2(F_1^*; F_2^{min})$ and $\pi_2(F_1^*; F_2^*) > \pi_2(F_1^*; F_2^{max})$ where F_2^{max} and F_2^{min} are the listing fees such that $t^*(F_1^*; F_2^{min}) = \bar{t}$ and $t^*(F_1^*; F_2^{max}) = \underline{t}$. With F_2^{max}, Exchange 2 attracts no listings and gets a zero profit. We have $\pi_2(F_1^*; F_2^*) = (\frac{t^* - \underline{t}}{\sigma})[F_2^* + \frac{\gamma N}{16}(\underline{t} + t^*)]$. Thus, for Exchange 2 to get a positive expected profit with a listing fee equal to F_2^*, we need:

$$F_2^* \geq -\frac{\gamma N(\underline{t} + t^*)}{16}.$$

Algebra shows that this inequality is satisfied iff $\Delta q \geq \frac{5\gamma}{8m}$, i.e. $a \geq \frac{5\gamma c_L}{8m}$. This proves that under this condition $\pi_2(F_1^*; F_2^*) > \pi_2(F_1^*; F_2^{max})$. Under the same condition, it is also possible to show that $\pi_2(F_1^*; F_2^{min}) < 0$. It follows that $\pi_2(F_1^*; F_2^*) > \pi_2(F_1^*; F_2^{min})$. Consequently F_2^* is a global maximum.

To sum up we have proved that when $\sigma \geq \sigma^c$, F_1^* and F_2^* (as given in the proposition) form a Nash equilibrium iff $\frac{5\gamma c_L}{8m} \leq a \leq \frac{1}{3}$.

Part 2

Now consider the case in which $\sigma < \sigma^c$. The previous analysis implies that there is no equilibrium in which the two exchanges are active. Assume that Exchange 1 chooses a listing fee equal to $F_1^* = [\frac{\underline{t}^2 \Delta q}{16} - \frac{\gamma m}{8}]N$. The best response of Exchange 2 is a fee equal to $F_2^* = -\frac{N\gamma m}{8}$. With such a fee, Exchange 2 gets a zero market share because $t^*(F_1^*; F_2^*) = \underline{t}$. A higher fee cannot increase its market share. A lower fee would increase its market share ($t^* > \underline{t}$) but would result in a negative profit for Exchange 2. To see this point, we note that for $F_2 \leq F_2^*$:

$$\pi_2(F_1^*; F_2) = \frac{(t^* - \underline{t})}{\sigma}[F_2 + \frac{\gamma N}{16}(\underline{t} + t^*)]$$

Thus the sign of $\pi_2(F_1^*; F_2)$ is the same as the sign of $F_2 + \frac{\gamma}{16}(\underline{t} + t^*)$. Since $F_2 \leq F_2^*$ and $t^* \leq \bar{t}$, we have:

$$F_2 + \frac{\gamma N}{16}(\underline{t} + t^*) \leq F_2^* + \frac{\gamma N}{16}(\underline{t} + \bar{t})$$

The R.H.S of this inequality is equal to 0 which proves that F_2^* is a best response to F_1^*. Now we show that F_1^* is a best response. We proceed in two steps. First we show that $\Pi_1(.;F_2^*)$ is concave for all $F_1 \geq F_1^*$. Then we show that $\frac{\partial \Pi_1(F_1^*;F_2^*)}{\partial F_1} < 0$. It follows that F_1^* is a corner solution to the maximization problem of Exchange 1. Using Equation (33), we get:

$$\text{Sign}\{\frac{\partial^2 \Pi_1}{\partial^2 F_1}\} = \text{Sign}\{-(3F_1 - 4F_2^*)\}$$

The term in parenthesis in this equation increases with F_1. Now $3F_1^* - 4F_2^* = \frac{3N\cdot q\underline{t}^2}{16} - F_2^*$, which is positive. This proves that $\frac{\partial^2 \Pi_1}{\partial^2 F_1} < 0 \quad \forall F_1 \geq F_1^*$. After some algebra, we get:

$$\frac{\partial \Pi_1}{\partial F_1}|_{\{F_1=F_1^*\}} = \frac{[\sigma - \frac{\gamma}{\cdot q} - \frac{8F_1^*}{\underline{t}\cdot qN}]}{\sigma}$$

As $F_1^* = \frac{\underline{t}^2\cdot q}{16} - \frac{\gamma\underline{t}}{8}$, this equation can be rewritten:

$$\frac{\partial \Pi_1}{\partial F_1}|_{\{F_1=F_1^*\}} = \frac{5(\sigma - \frac{2m}{5})}{4\sigma}$$

It follows that $\frac{\partial \Pi_1}{\partial F_1}|_{\{F_1=F_1^*\}} < 0$ since $\sigma \leq \sigma^c$. Thus F_1^* is a best response to F_2^*. Q.E.D.

Proof of Corollaries 1 — 3:

Immediate from inspection of Proposition 2

Proof of Corollary 4:

Let I be an indicator variable that is equal to 1 conditional on a firm listing on Exchange 1. The proportion of shares sold to investors in the IPO of a firm with type t that lists on Exchange j is $(1 - \alpha^*(t;q_j))$. Thus the expected proportion of original shares sold to the public conditional on the IPO taking place on Exchange 1 is:

$$E((1-\alpha^*(t;q_1))\,|\,I=1) = \frac{q_1}{4}E(\tilde{t}\,|\,t > t^*)$$

In the same way:

$$E((1-\alpha^*(t;q_2))\,|\,I=0) = \frac{q_2}{4}E(\tilde{t}\,|\,t \leq t^*)$$

As $q_1 > q_2$, we obtain $E((1-\alpha^*(t;q_1)\,|\,I=1) > E((1-\alpha^*(t;q_2))\,|\,I=0)$.

Proof of Corollary 5

We use the indicator function defined in the previous corollary. The post IPO market value of a firm t that lists on Exchange j is $Np^{IPO}(\alpha^*(t, q_j), t, c_j) = \frac{3Nt}{4}$. Consequently,

$$E(Np^{IPO}(\alpha^*(t, q_1), t, c_1) \mid I = 1) > E(Np^{IPO}(\alpha^*(t, q_2), t, c_2) \mid I = 0);$$

which proves the last part of the proposition. Finally, the IPO proceeds of a firm with type t that list on Exchange j are equal to

$$N(1 - \alpha^*(t, q_j))p^{IPO}(\alpha^*, t, c_j) = \frac{3Nt^2 q_j}{16}.$$

Consequently,

$$E(N(1 - \alpha^*(t, q_1))p^{IPO}(\alpha^*, t, c_1) \mid I = 1) > E(N(1 - \alpha^*(t, q_2))p^{IPO}(\alpha^*, t, c_2) \mid I = 1);$$

which proves the second part of the corollary. When the two exchanges have the same trading technologies, entrepreneurs randomly choose their listing location in equilibrium. This implies

$$E((1 - \alpha^*(t, q_1) \mid I = 1) = E((1 - \alpha^*(t, q_2)) \mid I = 0);$$

$$E(Np^{IPO}(\alpha^*(t, q_1), t, c_1) \mid I = 1) = E(Np^{IPO}(\alpha^*(t, q_2), t, c_2) \mid I = 0)$$

and

$$E(N(1 - \alpha^*(t, q_1))p^{IPO}(\alpha^*, t, c_1) \mid I = 1) = E(N(1 - \alpha^*(t, q_2))p^{IPO}(\alpha^*, t, c_2) \mid I = 1)$$

Q.E.D

Proof of Corollary 6

Immediate from Proposition 2

Proof of Proposition 3

Immediate from arguments in the text.

Proof of Proposition 4

First suppose that the two exchanges have different size requirements. We first derive the optimal reaction of Exchange 2 to the listing fee F_1^* chosen by Exchange 1. Let $F_m(\underline{t}, t_T)$

be the listing fee that is charged by an exchange who is in a monopoly situation and who faces a population of entrepreneurs with types in $[\underline{t}; t_T]$. Suppose that the listing fee of Exchange 1 is lower than $F_m(\underline{t}; t_T)$. Exchange 2 can choose between two strategies. First it can undercut slightly Exchange 1. In this way it captures all the listings since the two exchanges have the same trading technology. It obtains a profit equal to:

$$F_1 + \frac{\gamma N(\bar{t} + \underline{t})}{16}$$

Alternatively Exchange 2 can exploit its monopoly power on the entrepreneurs with a type in $[\underline{t}; t_T]$ since these entrepreneurs are not eligible to list on Exchange 1. In this case, it charges a fee $F_2^* = F_m(\underline{t}; t_T)$ and gets an expected profit:

$$\Pi_2^m = \frac{(t_T - t_m)}{\sigma}\left(F_m(\underline{t}; t_T) + \frac{\gamma N}{16}(t_T + t_m)\right)$$

where $t_m \in [\underline{t}; t_T]$ is the type of the entrepreneur who is just indifferent between listing on Exchange 2 or not going public. In order to be active Exchange 1 must choose its listing fee so that Exchange 2 is better off charging a fee equal to $F_m(\underline{t}; t_T)$. Thus, Exchange 1 chooses a fee equal to:

$$F_1^* = \Pi_2^m - \frac{\gamma N(\underline{t} + \bar{t})}{16}$$

Clearly Exchange 2 gets a strictly positive expected profit since $F_m(\underline{t}; t_T) \geq \frac{N\underline{t}^2 q_2}{16}$. Note that $F_1^* < F_m(\underline{t}; t_T)$ as it was assumed initially since:

$$F_1^* - F_m(\underline{t}; t_T) = \frac{(t_T - t_m)F_m - \sigma F_m}{\sigma} + \frac{\gamma N[(t_T^2 - t_m^2) - (\bar{t}^2 - \underline{t}^2)]}{16\sigma} < 0$$

Exchange 1 's expected profit is

$$\Pi_1 = \frac{(\bar{t} - t_T)}{\sigma}\left(F_1^* + \frac{\gamma N}{16}(\bar{t} + t_T)\right)$$

It is strictly positive iff:

$$F_1^* > \frac{-\gamma N(\bar{t} + t_T)}{16}$$

This is equivalent to:

$$\Pi_2^m > -\frac{\gamma N}{16}(t_T - \underline{t})$$

which is satisfied since $\Pi_2^m > 0$. This proves Part 1 of the lemma. If the two exchanges have the same minimum size requirement, the exchange with the lowest listing fee get all the listings. It is then direct that fees are chosen such that it cannot be optimal for the exchange that moves in second to undercut the first exchange. The only fee with this property is such that both exchanges get zero expected profits, which proves the second part.Q.E.D.

Proof of Lemma 4

Immediate from arguments in the text.

Proof of Proposition 5.

Suppose first that the two exchanges have different trading technologies and assume that Exchange 2 's listing fee is F_2^*. Let $E^T Vol(q_j)$ be the total expected trading volume in Exchange j. Consider the objective function of Exchange 1:

$$Max_{F_1} E^T Vol(q_1)) = \int_{t_c}^{\bar{t}} \frac{N t q_1}{8\sigma} dt = \frac{N q_1(\bar{t}^2 - t_c^2)}{16\sigma}$$

$$s.t. \quad \Pi_1(F_1; F_2^*) \geq 0$$

with $t_c = \max\{\underline{t}; 4\sqrt{\frac{F_1 - F_2^*}{N \cdot q}}\}$. Clearly, Exchange 1 maximizes its expected trading volume by choosing its fee so that $t_c = \underline{t}$. This is achieved by choosing a fee equal to $F_1^* = F_2^* + \frac{N\underline{t}^2 \cdot q}{16}$. Now consider the following listing policy for Exchange 1 and Exchange 2: $F_1^* = N[\frac{\underline{t}^2 \cdot q}{16} - \frac{\gamma m}{8}]$ and $F_2^* = -\frac{N\gamma m}{8}$. Following the same reasoning as in Part 2 of Proposition 2, one can show that the smallest fee that Exchange 2 can charge without losing money is F_2^* given the fee of Exchange 1. Thus F_2^* is a best response for Exchange 2. Furthermore $t^*(F_1^*; F_2^*) = \underline{t}$ which implies that if Exchange 1 chooses F_1^* then $t_c = \underline{t}$. As $\Pi_1(F_1^*; F_2^*)$ is strictly positive, it is clear that F_1^* is a solution of the previous maximization program. The expected trading volume in the two exchanges in this case are respectively:

$$E^T Vol(q_1)) = \frac{N q_1(\bar{t}^2 - \underline{t}^2)}{16\sigma}$$

$$E^T Vol(q_2) = 0$$

If the two exchanges choose the same trading technology, they compete à la Bertrand in order to attract the maximum number of listings since this maximizes the total expected trading volume. The equilibrium outcome is identical to the Nash equilibrium described in Proposition 1 and each exchange attracts half of the listings. In this case the expected trading volume of each exchange is:

$$E^T Vol(q) = \frac{Nq(\bar{t}^2 - \underline{t}^2)}{32\sigma}$$

where q is the quality of the trading technology chosen by both exchanges.

Now consider the stage (date 1) in which exchanges choose their trading technology with a view at maximizing their expected trading volume. The following table gives the expected trading volume of each exchange according to their trading technology choice, where c_H denotes the high trading cost trading technology and c_L the low trading cost technology.

	c_H	c_L
c_H	$\left(\frac{N(\bar{t}^2 - \underline{t}^2)}{32c_H\sigma}; \frac{N(\bar{t}^2 - \underline{t}^2)}{32c_H\sigma}\right)$	$\left(0; \frac{N(\bar{t}^2 - \underline{t}^2)}{16c_L\sigma}\right)$
c_L	$\left(\frac{Nq(\bar{t}^2 - t_0^2)}{16c_L\sigma}; 0\right)$	$\left(\frac{Nq(\bar{t}^2 - \underline{t}^2)}{32c_L\sigma}; \frac{Nq(\bar{t}^2 - \underline{t}^2)}{32c_L\sigma}\right)$

As $c_H > c_L$, it is a strictly dominant strategy for an exchange to choose the low trading cost technology. Q.E.D.

Proof of Lemma 5

Using Equation (25), we obtain that $t^0(F_m) \leq \underline{t} - \alpha F_m \leq \frac{N\underline{t}^2 q_m}{16}$. It follows that the listing fee chosen by the monopolist exchange solves:

$$\text{Max}_{F_m} \Pi_m = \left(\frac{\bar{t} - t_m(F_m)}{\sigma}\right) F_m + \left(\frac{\gamma N}{16\sigma}\right)\left(\bar{t}^2 - (t_m^2(F_m)\right) \tag{35}$$

with

$$t_m(F_m) = \begin{cases} \underline{t} & \text{if } F_m \leq \frac{N\underline{t}^2 q_m}{16} \\ 4\sqrt{\frac{F_m}{Nq_m}} & \text{if } F_m > \frac{N\underline{t}^2 q_m}{16} \end{cases}$$

Note that it is not optimal for the exchange to choose a fee strictly lower than $\frac{N\underline{t}^2 q_m}{16}$ since Π_m increases with F_m; $\forall F_m \leq \frac{N\underline{t}^2 q_m}{16}$. Now suppose that the optimal listing fee F_m^* is such that $F_m^* > \frac{N\underline{t}^2 q_m}{16}$. Then the first order condition of the optimization problem implies:

$$F_m^* = \frac{Nq_m}{36}\left(\bar{t} - \frac{\gamma}{q_m}\right)^2 = \frac{Nq_m}{36}\left(\mu + \frac{\sigma}{2} - \frac{\gamma}{q_m}\right)^2 \tag{36}$$

It is immediate that (i) F_m^* increases with σ and that (ii) $F_m^*(\sigma^m) = \frac{N\underline{t}^2 q_m}{16}$ (where σ^m is defined in Lemma 5). It follows that the optimal listing policy is:

$$F_m^* = \begin{cases} \frac{Nq_m}{36}\left(\bar{t} - \frac{\gamma}{q_m}\right)^2 & \text{if } \sigma^m \geq \sigma \\ \frac{(N\underline{t})^2 q_m}{16} & \text{if } \sigma^m \leq \sigma \end{cases}$$

In the first case some entrepreneurs do not list since $t_m > \underline{t}$. Using Equations (25), we obtain:

$$t_m(F_m^*) = \frac{2\left(\bar{t} - \frac{\gamma}{q_m}\right)}{3} \tag{37}$$

The proportion of entrepreneurs that do not list is given by

$$\Pr(t \in [\underline{t}; t_m(F_m)]) = \frac{t_m(F_m) - \underline{t}}{\sigma};$$

which can be written as in Lemma 5, using the previous equation.Q.E.D

Proof of Proposition 6.

Part 1

Using Equation (37) we find that t^m increases with q^m. This implies that the proportion of firms that go public decreases with the quality of the monopolist exchange if $\sigma > \sigma^m$. Furthermore, recall that:

$$t_m(F_m^*) = 4\sqrt{\frac{F_m^*}{Nq_m}}$$

Since t_m increases with q_m, the previous equation implies that F_m^* also increases with q_m. If $\sigma \leq \sigma^m$, then it is direct that F_m^* increases with q_m (See Lemma 5). Moreover t_m does not depend on q_m since $t_m = \underline{t}$ in this case.

Part 2. Suppose $\sigma > \sigma^m$. Let $\Pi_m(F_m^*; q_m)$ be the maximum profit of the monopolist exchange for a given level of quality. Using Equation (25):

$$\Pi_m(F_m^*; q_m) = \left(\frac{\bar{t} - 4\sqrt{\frac{F_m^*}{Nq_m}}}{\sigma}\right) F_m^* + \frac{\gamma N}{16\sigma}\left(\bar{t}^2 - \frac{16F_m^*}{Nq_m}\right) \tag{38}$$

We can write:

$$\frac{d\Pi_m}{dq_m} = \frac{\partial \Pi_m}{\partial F_m^*}\frac{\partial F_m^*}{\partial q_m} + \frac{\partial \Pi_m}{\partial q_m}$$

As $\frac{\partial \Pi_m}{\partial F_m^*} = 0$, we get:

$$\frac{d\Pi_m}{dq_m} = \frac{\partial \Pi_m}{\partial q_m} > 0$$

If $\sigma \leq \sigma^m$, $t_m = \underline{t}$. Thus:

$$\Pi_m(F_m^*; q_m) = F_m^* + \frac{\gamma N}{16}(\bar{t}^2 + \underline{t}^2) \tag{39}$$

In this case, $\frac{\partial \Pi_m}{\partial q_m} = 0$. Furthermore $\frac{\partial \Pi_m}{\partial F_m^*} > 0$ and $\frac{\partial F_m^*}{\partial q_m} > 0$ (Part 1). It follows that $\frac{d\Pi_m}{dq_m} = \frac{\partial \Pi_m}{\partial F_m^*}\frac{\partial F_m^*}{\partial q_m} > 0$. Q.E.D

Proof of Proposition 7

Immediate from arguments in the text.

Figure 1: Timing of the Model

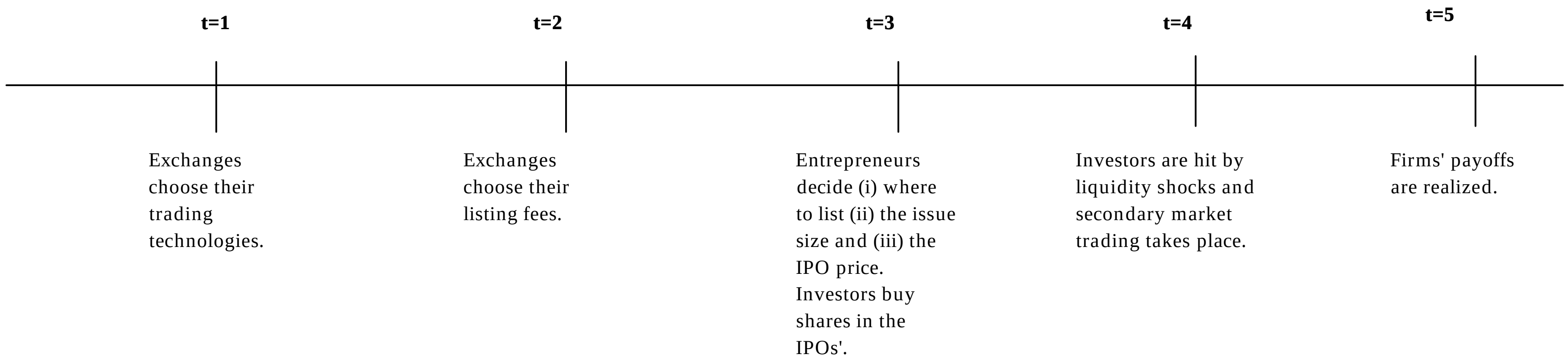


Figure 2

Demand for Shares in the IPO

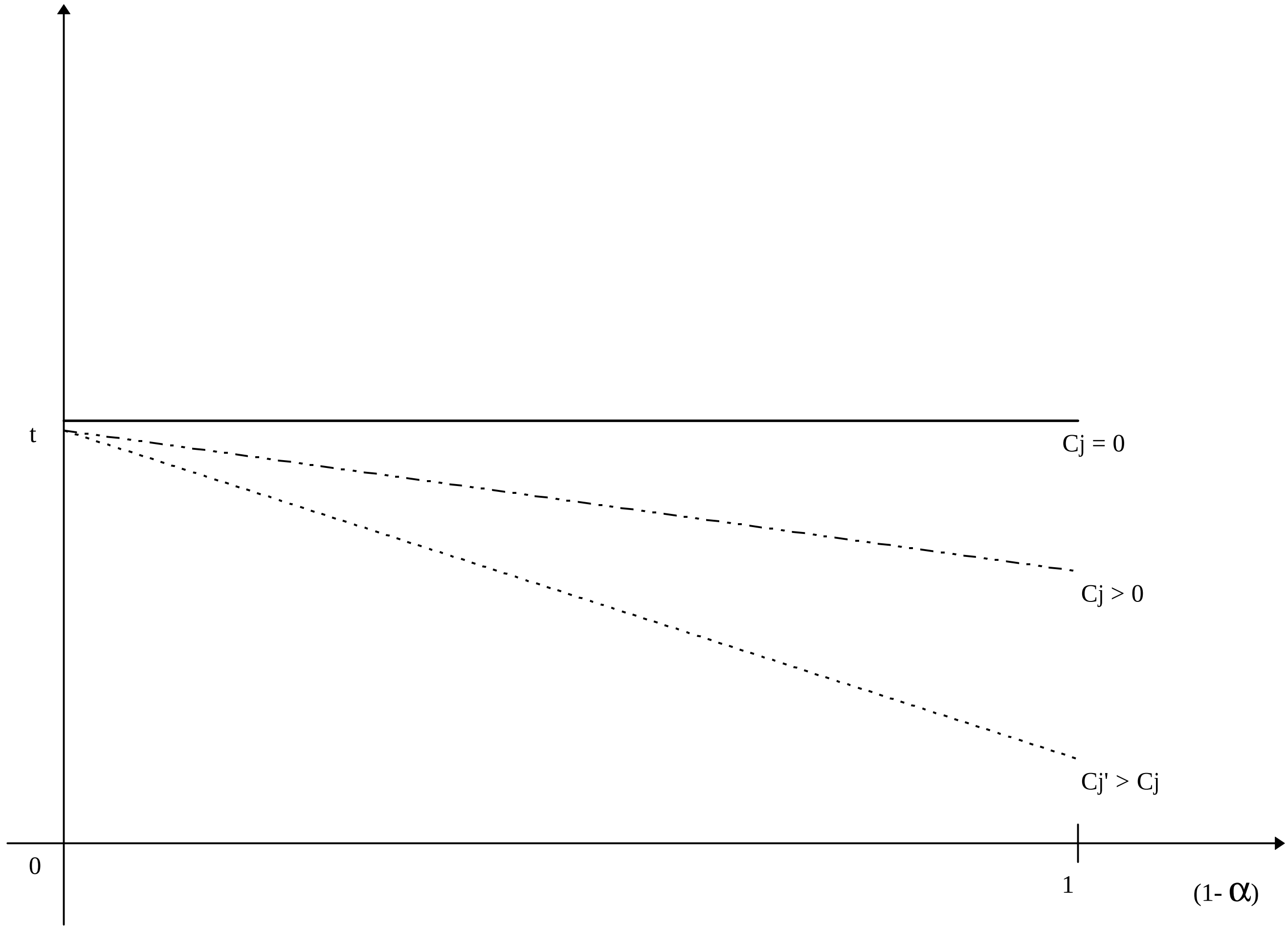
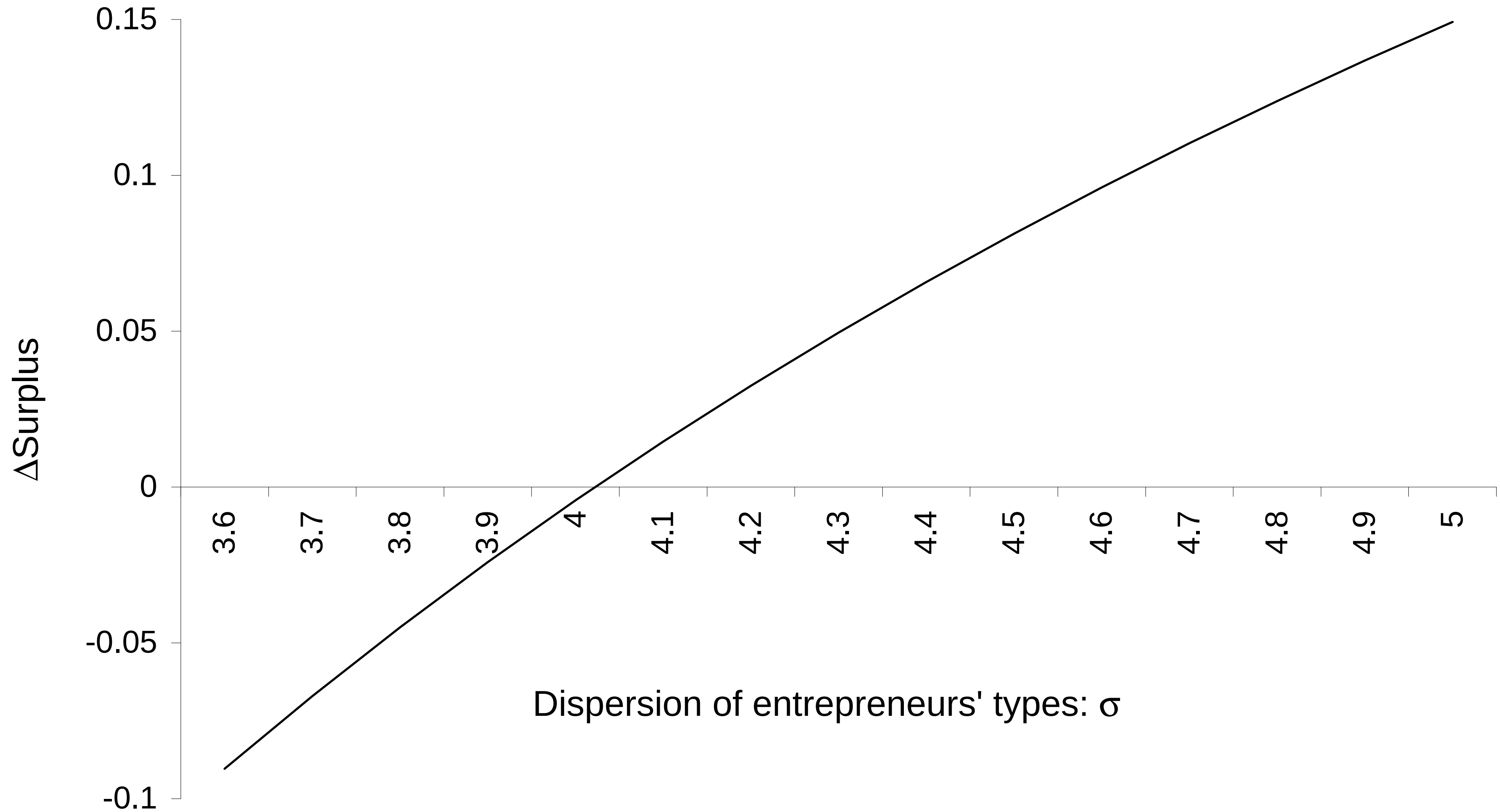


Figure 3



Numerical Example: $a=0.3, \gamma=1, m=5, N=1, C_L=2$