When Competition Hinders Transparency: Evidence from the Pharmaceutical Industry.

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Abstract

I investigate how competition shapes the incentives for firms to acquire information on the quality of their products. I first develop a game of persuasion in which ex-ante identical firms can exert costly effort to discover the quality of their products. The level of effort that they choose determines their probability to be informed. This game involves asymmetric information on two dimensions: the product quality and the existence of information on quality. Informed firms can credibly transmit the gathered evidence on quality to consumers or withhold the evidence. When taste for quality is homogeneous, informed firms adopt a symmetric cutoff strategy consisting of disclosing only high enough quality. I show that the ex-ante value of information decreases with the number of competitors. Research efforts are strategic substitutes. Tougher competition, in the sense of more competitors in the market, reduces the incentives for firms to acquire information. I then test the empirical predictions of this model in the pharmaceutical industry. I use a newly constructed dataset describing the medical publications for all drugs that have been developed or marketed in the US. I measure the intensity of

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competition by the number of competitors in the market and the number of potential entrants. I find that firms facing intense competition disclose a lower amount of information through medical publications than firms selling their drugs in less competitive markets.

1 Introduction

In this paper, I develop a persuasion game that combines competition between multiple senders, costly acquisition of ex-post verifiable information, and uncertainty regarding whether senders are informed. In this framework, I show that increased competition leads to a lower level of research effort and more concealment of information. Using a panel data on publications of clinical trial results on drugs between 1990 and 2000 over 242 pharmaceutical markets, I find a significantly negative impact of competition on the number of publications, which confirms the predictions of my theoretical model.

Concealments of relevant information by privately informed agents are observed in many instances. CEOs sometimes withhold information about the performance of their firms to shareholders. Universities do not always display their ranking or the placement of their students on their websites. Pharmaceutical companies often withhold results of clinical trials showing adverse effects or lack of efficacy of their drugs.

Uncertainty regarding whether the sender possesses the information of interest is one of the factors which allow incomplete disclosure to arise at equilibrium. When information is costly for the sender to acquire, she might rationally decide to remain uninformed. The possibility for the sender to pretend to be uninformed allows her to withhold information without the receivers automatically inferring the worst.

If the disclosure strategic behavior of a single sender who can be of multiple types has been

extensively studied in the theoretical literature, nothing is known about the impact of competition on the incentives to disclose when information is costly to acquire. Understanding how competition shapes the incentives to acquire and disclose information is key to defining appropriate transparency policies. If tougher competition encourages firms to collect more information and engage in more systematic disclosure, then reinforcing antitrust effort, preventing firms from merging and fighting collusion will be an efficient way to make markets more transparent. However, if competition exacerbates the incentives for firms to conceal information and dissuades information acquisition, then pursuing the objective of providing more information to the consumers will require specific pro transparency policies such as funding independent testing or subsidizing the disclosure of unfavorable results.

Studying the disclosure behavior of firms that compete in oligopolies is particularly relevant in the pharmaceutical industry where several regulatory agencies have tried to implement transparency policies with little success.

In this paper, I investigate how competition shapes the incentives for firms to acquire information on the quality of their product. To address this question, I develop a persuasion game that combines competition and information acquisition. In this model, firms are ex-ante identical and choose simultaneously a level of effort that determines their probability to discover their quality. Once they have learned their quality, the informed firms make their disclosure decisions. Then, firms compete in price in a vertically differentiated market. In this setting, I find that an increase in the intensity of competition, in the sense of more firms in the market, discourages research effort and leads to more concealment.

The intuition behind this result is the following: A firm profit is the highest when it sells the highest quality among its rivals. The value of getting informed hinges on the possibility for a

firm to vertically differentiate its product by demonstrating that it is the highest quality seller. The likelihood of this event decreases with the number of competitors. This yields to less information acquisition. In turn, this makes the option of withholding information more appealing as a firm remaining silent will be more likely to be seen as uninformed rather than concealing unfavorable evidence about its quality.

Two crucial assumptions support those results. First, research efforts are unobserved, which allows concealing firms to pretend to be uninformed. Second, firms' profits depend only on their perceived qualities and not their actual quality, which implies that firms cannot signal their quality through their price.

The pharmaceutical industry offers a perfect setting to test the predictions of this model. Pharmaceutical firms need to run costly clinical trials in order to discover the quality of their drugs. Regulatory agencies (the Food and Drug Administration in the U.S., the European Medicine Agency in the E.U.) sets standards that drugs have to meet in order to be granted marketing approvals. But those standards should be seen as minimum requirements in terms of scientific evidence that firms have to provide to market their drugs. On top of the minimum required by the regulators, pharmaceutical firms have a large degree of freedom to choose how much they want to invest in drug testing. Even though regulatory agencies have adopted recent policies to mandate the registration of clinical trials, the lack of enforcement of these policies allows me to assume that the research efforts of firms are imperfectly observable. Moreover, firms have the legal obligation to disclose the results of all clinical trials to the agencies but they are free to select the clinical outcomes that they wish to disclose to potential consumers (i.e. physicians who prescribe drugs and patients) via medical publications.This implies that disclosure to the market is voluntary.

Pharmaceutical firms conducting clinical studies may remain genuinely uninformed about their

drugs' safety and efficacy. Trials testing the difference in drug efficacy against a placebo may fail to provide significant results due to a large variance with respect to the sample size rather than a real lack of efficacy. Trials can be discontinued due to high attrition rates despite the sponsor's effort to enroll a large number of patients.

Drug quality is not likely to be signaled by price as the marginal cost of a drug consists largely of manufacturing and detailing costs that are orthogonal to quality.

I use data on publication of randomized controlled trial results to measure the amount of information disclosed by firms on their drug quality. I exploit the evolution over time of the degree of competition within pharmaceutical markets created by drugs' transitions to successive phases of clinical development, drugs' discontinuation during development, drugs' entries to markets and drugs' withdrawal from markets to identify the impact of competition on provision of information through medical publications. I find that firms selling their drugs in more competitive markets are less likely to publish. I discuss the limitation of this estimation strategy and the possible endogeneity biases.

2 Related Literature

The literature on disclosure has been initiated by Milgrom (1981) and Grossman(1981) who have developed the famous "unravelling result" which predicts that sellers should always disclose the quality of their products. The intuition behind this result is the following: The highest quality seller has incentives to reveal that its quality is the highest to maximize its profit. The second highest quality seller anticipates the disclosure decision of the highest quality seller and discloses to differentiate herself from the lower type sellers. The argument can be iterated backward, the quality

"unravels" until the lowest quality seller who is indifferent between disclosing and withholding. Consumers adopt an extreme skepticism strategy and regard all withholding sellers as the worst possible type. Since this seminal work, authors have worked on explaining why unravelling might not be an equilibrium outcome.

Various anti-unravelling mechanisms have been identified in the literature: communication of information is costly, Jovanovic (1982); buyers have limited rationality; buyers are unaware of the possibility of disclosure; information is endogenous and buyers cannot observe whether sellers are informed, Shavell (1994). Those papers consider either a unique seller who can be of different types or a multiplicity of sellers who sell a single unit product and face a large amount of buyers. In all cases, the disclosure behavior of sellers is driven by their incentives to appear as high quality types and competition plays not direct role on disclosure decisions since the presence of competitors do not affect the profit that the firm can derive from its disclosure decision.

Only recently have authors started investigating the impact of competition on the incentives to disclose.

One stream of this literature focuses on cases where information on quality is exogenous and exists with certainty. In this framework, competition is shown to prevent full disclosure when communication of quality is costless and to reduce the likelihood of disclosure when communication is costly.

Board (2009) shows that, in a duopoly setting with heterogeneous consumers, when facing a high quality opponent, a high quality firm may decide not to disclose in order to make its products appear more differentiated from its competitor's. The resulting perception of differentiation between the products decreases price elasticity of demand, softens price competition, and increases profit for both firms. Hotz and Jiao (2010) extend the setting of Board (2009) by adding an hor-

izontal dimension in products differentiation. Allowing consumers valuations for quality to be correlated with their horizontal location, they find that a high quality firm located in market where consumers have low willingness to pay for quality competing with a similar type firm located in a market where consumers have high valuation for quality can choose not to disclose in order to enjoy a monopoly position on its home market.

In both papers, high quality sellers trade off disclosing information on quality at the risk of toughening price competition and withholding at the risk of decreasing their perceived quality. Both papers assume that information on quality is common knowledge across firms and that disclosure is costless.

Levin et al. (2005) use a different information structure assuming that firms privately observe their quality and incur a cost to communicate their quality to consumers. They compare the disclosing behavior of firms competing in a duopoly to that of a monopolist selling two products (or cartel) when disclosure is costly, firms are privately informed about their quality, and products are horizontally differentiated. They find that competing firms are less likely to disclose than a cartel as their ability to raise their price after disclosing a high quality is limited by the presence of their opponent.

Another stream of this recent literature considers situations in which information remains exogenous but the existence of the information on quality is uncertain. Assuming that information about quality is either accessible to all firms or to none of them and that, when observable, qualities are common knowledge among firms, Stivers (2004) shows that competition acts as a pro transparency force. The mechanism is the following: The highest quality firm has incentives to disclose even when its quality is low in absolute value since its profit depends on its relative quality level; Competing firms anticipate the decision of the highest quality firm and disclose since they have

lost the option of concealing while pretending not to be informed.

Lastly, Gentzkow and Kamenica (2011) shows that competition cannot reduce the amount of information revealed at equilibrium when information is endogenous but costless to acquire.

3 Institutional Context

Selective reporting of clinical trials results have been of growing concern in the medical community. Turner et al. (2008) study publications of FDA-registered clinical trials for antidepressant drugs from 1987 to 2004. They find that clinical trials whose outcomes are judged as unfavorable by the FDA are much less likely to be published than those yielding outcomes deemed as favorable. Studying selective serotonin reuptake inhibitors, Melander et al.(2003) finds evidence of selection of publications, selective reporting of results and duplication of favorable publications. The authors express concerns that biased publications could lead to overestimations of drugs efficacy and risk-benefit ratio then leading to suboptimal prescription decisions by practitioners.

In 2005, in order to tackle the issue of selective publication, the International Committee of Medical Journal Editors (ICMJE) adopted a new policy requiring prospective registration of all interventional clinical studies to investigators in order to be eligible for publication. In September 2007, the Food and Drug Administration Amendment Act (FDAAA) imposed mandatory registration of all interventional clinical studies above stage I within a period of 21 days after enrollment of the first participant and mandatory disclosure of the results no later than 30 days after approval or within 12 months after completion of the study for drugs that were approved before the end of the trial.

By making research efforts perfectly observable these initiatives aim to increasing the incentives to disclose quality: if consumers adopt an extreme pessimism strategy they regard any unpub-

lished clinical outcome as the most unfavorable which gives incentives for firms to publish even negative results. The medical literature suggests that trials registered in clinicaltrial.org after the adoption of the FDAAA suffer from similar publication biases as previous trials. Andrew P Prayle et al. (2012) show that only 22 % of trials comply with the results disclosure requirement.

4 Model

Firms: I consider an oligopoly with n firms. Firms are not subject to any capacity constraint and can produce as many product units as consumers demand. Firms have the same marginal cost of production which does not depend on their quality. Without loss of generality, I set this cost to 0.

Quality: Ex ante identical firms produce a product whose quality, θ, is drawn from the common knowledge continuously differentiable distribution F, with positive density f(.) over the compact and convex support $[\underline{\theta}, \overline{\theta}]$. The product quality is exogenous and ex-ante unobservable. Firms need to perform costly research (testing the product) in order to discover their quality. They choose a level of research effort, e $\in \mathbb{R}_+$, that determines their probability to be informed, i.e. their probability to discover their quality, $\phi(e)$. I assume that the probability to be informed is increasing and concave: $\phi : \mathbb{R}_+ \rightarrow [0,1]$, $\phi'(e) > 0$, $\phi''(e) < 0$. Effort is costly and the cost function, $c(e)$ is assumed to be positive, increasing, and convex: $c : \mathbb{R}_+ \rightarrow \mathbb{R}_+$, $c'(e) > 0$, $c''(e) > 0$, . In order to guarantee the existence of an equilibrium where firms exert some positive effort, I assume further that the marginal cost of effort is nil in zero,$c'(0) = 0$, while the marginal return of effort in terms of probability to be informed is strictly positive,$\phi'(0) > 0$. The level of effort such that the firm is certain to be informed is denoted $\bar{e} : \phi(\bar{e}) = 1$. I assume that $c'(\bar{e}) > E(\theta)$ and $\phi'(\bar{e}) \leq 1$ so as to guarantee that firms never find it profitable to be fully informed. The level of effort chosen by each firm cannot be observed by its competitors or by consumers.

Disclosure: When informed, firms can choose to disclose their quality to consumers in a credible and verifiable way. I assume that firms cannot manipulate the evidence to misrepresent their quality but can conceal the information that they have acquired. Moreover, nobody but the firm itself observes whether or not it has discovered its quality. Communication of information on quality is assumed to be costless. Uninformed firms have no choice but to remain silent. We denote by d_i the disclosure decision of firm i, $d_i = 1$ if firm i discloses, $d_i = 0$ if firm i withholds.

Consumers: There is a mass one of identical consumers who can buy at most one unit of good. Their utility from buying the product from firm i can be written as follows :

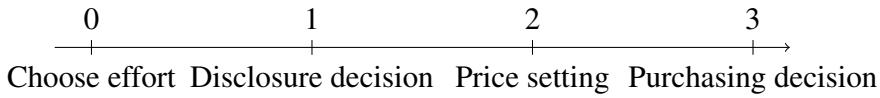
$$U_i = \theta_i - p_i$$

Where θ_i is the quality of the product sold by firm i and p_i is the price charged by firm i.
When they make their purchasing decisions, consumers maximize their expected utility which depends on the perceived quality:

$$E(U_i) = \tilde{\theta}_i - p_i$$

When firm i discloses, $\tilde{\theta}_i$ corresponds to the true quality product i. When firm i is informed but decides to withhold or when firm i is uninformed and cannot communicate any evidence on quality, $\tilde{\theta}_i$ is the perceived quality of silent firms $\tilde{\theta}_s$.

Timing of the game:



To see how an increase in competition, in the sense of more firms in the market, affects the

equilibrium level of effort and the disclosure decisions, I study the equilibrium disclosure behavior in monopoly and oligopoly.

4.1 Monopoly

The game consists of four stages: the research stage, the disclosure stage, the pricing stage, and the purchasing stage. I use the concept of perfect Bayesian equilibrium. The game is solved by backward induction.

Equilibrium: A pure strategy equilibrium of the game is characterized by the following conditions:

- *Purchasing subgame:* Consumers are willing to pay no more than their perceived quality of the product. They purchase the product as long as $p_i \leq \tilde{\theta}$.
- *Pricing subgame* The monopolist chooses the price that maximizes its profit. $p = \tilde{\theta}$, its downstream profit (profit absent of research cost) is $\pi = \tilde{\theta}$.
- *Disclosure subgame* The informed monopolist discloses if and only if its quality is above its expected quality conditional on remaining silent.

$$d = \begin{cases} 1 & \text{if } \theta > \tilde{\theta}_s \\ 0 & \text{otherwise.} \end{cases}$$

- *Disclosure threshold* The disclosure threshold corresponds the expectation of Bayesian consumers on the quality of the monopolist that do not disclose its quality.

$$\tilde{\theta}_s = (1 - \phi(\tilde{e}_M))E(\theta) + \phi(\tilde{e}_M)E(\theta|\theta < \tilde{\theta}_s) \tag{4.1}$$

Where $\tilde{e}_M$ is the conjecture of the consumers about the level of effort exerted by the monopolist.

- *Research subgame:* The monopolist chooses a level of effort, e^*_M, that maximizes its expected value of getting informed, $V^M(e)$.

$$V^M(e) = \phi(e) \int_{\tilde{\theta}_s}^{\overline{\theta}} (\theta - \tilde{\theta}_s) f(\theta) d\,\theta - c(e)$$

$$e^*_M = \arg\max_e \; V^M(e)$$

- Consumers forecast correctly the chosen level of effort:

$$\tilde{e}_M = e^*_M \tag{4.2}$$

Proposition 1. *At equilibrium, the monopolist chooses a level of effort* $e^*_M \in [0, \bar{e}]$ *associated with the probability to be informed* $\phi(e^*_M) \in (0, 1)$. *When informed it discloses if and only if its quality is above the equilibrium threshold* θ^*_M. *We show that* θ^*_M *is necessarily lower than* $E(\theta)$.

4.2 Oligopoly

I consider an oligopoly with N firms. Since firms are ex ante identical, I focus on symmetric equilibrium where all firms choose the same disclosure threshold and the same level of effort. A pure strategy symmetric equilibrium of the oligopoly disclosure game is characterized by the following conditions:

- *Purchasing subgame:* Consumers buy the product i so that: $u_i \geq u_j\,, \forall j \neq i$

- *Pricing subgame* After observing the vector of disclosed qualities, firms compete in price in

a vertically differentiated market. The subscript i indexes the sellers in order of perceived quality from high to low: $\tilde{\theta}_1 \geq \tilde{\theta}_2 \geq ... \geq \tilde{\theta}_N$. The equilibrium pricing strategy of the firm with the highest perceived quality, firm 1, is the following:

$$p_1 = \tilde{\theta}_1 - \tilde{\theta}_2$$

Lower perceived quality firms price at their marginal cost:

$$p_i = 0\,, \forall i > 1$$

The highest quality firm serves the entire market. It is easy to see that there is no profitable deviations. Firm 1 cannot set a higher price without losing all its consumers and the lower quality firms already charge the lowest possible price without attracting any consumer. Firm 1's profit is:

$$\pi_1 = \tilde{\theta}_1 - \tilde{\theta}_2$$

For $i > 1$, firm i's profit is:

$$\pi_i = 0$$

- *Disclosure subgame* The informed firm discloses if and only if its quality is above its expected quality conditional on remaining silent, $\tilde{\theta}_s^N$.

$$d = \begin{cases} 1 & \text{if } \theta > \tilde{\theta}_s^N \\ 0 & \text{otherwise.} \end{cases}$$

- *Disclosure threshold* The disclosure threshold corresponds the expectation of Bayesian con-

sumers on the quality of the oligopolist that does not disclose its quality.

$$\tilde{\theta}_s^N = (1 - \phi(\tilde{e}_N))E(\theta) + \phi(\tilde{e}_N)E(\theta|\theta < \tilde{\theta}_s^N) \tag{4.3}$$

Where $\tilde{e}_N$ is the conjecture of the consumers about the level of effort exerted by each firm.

- *Research subgame* Let $W(n)$ be the expected value of being informed in an oligopoly when n competitors have discovered their quality. The quantity $W(n)$ can be decomposed as the expected profit of the firm when the highest quality among the n informed competitors is disclosed, which happens with probability $1 - (F(\theta_s^N))^n$, and its expected profit when none of its competitors disclose, which happens with probability $(F(\theta_s^N))^n$.

$$W(n) = \int_{\tilde{\theta}_s^N}^{\overline{\theta}} \int_{\theta_2}^{\overline{\theta}} (\theta - \theta_2) f(\theta) n f(\theta_2) (F(\theta_2))^{n-1} d\theta d\theta_2 + (F(\theta_s^N))^n \int_{\tilde{\theta}_s^N}^{\overline{\theta}} (\theta - \tilde{\theta}_s^N) f(\theta) d\theta$$

With N firm, the expected profit of the informed firm, when its competitors extort an effort e, is:

$$B(N) = \sum_{k=1}^{N} \phi(e)^{k-1} (1 - \phi(e))^{N-k} W(k-1)$$

The expected value for firm of exerting a level of effort, e_i, when its competitors choose a level of effort, e, writes as:

$$V^N(e_i) = \phi(e_i) B(N) - c(e_i)$$

Firm i chooses the optimal level of effort e_i^* so that $e_i^* = \arg\max_{e_i} V^N(e_i)$.

- Consumers forecast correctly the chosen level of effort:

$$\tilde{e}_N = e_N^* \tag{4.4}$$

Lemma 1.

$$B(N+1) = (1-\phi(e))B(N) + \phi(e)^N W(N)$$

Lemma 2.

$$B(N+1) \leq B(N)$$

Proposition 2. *Research efforts are strategic substitutes.*

Proposition 3. *The equilibrium level of effort decreases with N. The disclosure threshold increases with N.*

Increasing the intensity of competition decreases the incentives to acquire information and induces firms to choose a higher disclosure threshold. When applied to the pharmaceutical industry, this model offers three testable predictions. An increase in the number of drugs in the market should: (1) decrease the number of clinical trials run by each firm (fall in research effort), (2) decrease the probability for each trial to be published (higher disclosure threshold), (3) overall yield to less publication of clinical results.

5 Data

I have constructed a new dataset describing clinical trials, medical publications for 35050 drugs distributed over 242 three digit Anatomical Therapeutic Classes (ATC). I have collected information from three sources: the IMS drugs development focused database, the clinical trials registry maintained by the US National Institutes of Health (NIH) , and publications on drugs registered in PubMed.

The IMS database contains information on the characteristics and the timing of development and commercialization of 35,050 drugs developed from the early 50s to 2012 distributed over 42

three digit Anatomical Therapeutic Classes (ATC). An ATC is a set of drugs that treat the same conditions and that can be viewed as substitutable. The characteristics of the drugs that I observe are molecule names, brand names, ATCs, and companies developing and marketing the drugs. Following the literature on pharmaceutical industry, I define a market as an ATC. I measure the intensity of competition by the number of drugs on the market and the number of potential entrants which are drugs that have reached at least the first phase of clinical development. Figure 3 shows the distribution of drugs marketed in the U.S. across markets.

The clinical trials registry provides precise information on trials including titles, the lists of drugs under clinical investigation, sponsors (firms or public institutions funding the trial), the phases of the clinical development, enrollment (number of patients in the trial), masking (open label, single blind or double blind), and endpoints (safety, efficacy, bio-equivalence, or pharmacokinetics). I match data on clinical trials with the IMS sample of drugs to measure both the total quantity of clinical testing on each drug (this encompasses trials run by the drug sponsor and trials run by its opponents) and the research effort exerted by the drug seller. Registration of clinical trials was voluntary until the FDAAA of 2007. Moreover, firms had little incentives to register their trials before the policy adopted by the ICMJE in 2005 to impose prospective registration of clinical trials. Figure 1 shows that the total number of registered clinical trials is multiplied by five between 1994 and 2014 where the number of drugs in development decreases over the same period as shown in Figure 2. This indicates that registration of clinical trials was partial and probably strategic during most of the period under study.

I retrieve all medical publications registered in PubMed on clinical trials mentioning the name (generic name, brand name or lab code) in the list of chemicals involved in the study for the 1,201 drugs, defined as New Molecular Entities, that have been marketed or that have reached the second

phase of clinical development in the US from 1990 to 2012. I find matching publications for 811 of those drugs. collect 194,091 publications. From those publications I extract the date of publication, the name of the journal, the list of chemicals tested in the study, the type of the sponsor of the study (National Institute of Health, U.S. government, and Industry). As shown in table **??**, 10% of those studies are funded by either the U.S. government or the N.I.H.. Publications that are not funded by those two sources are likely to be funded by pharmaceutical companies, universities, or non U.S. governmental agencies. I parsed all the publications In order to retrieve the identity of the sponsor when this information is disclosed. The disclosure rate of the sponsor's identity is very low, round 10% , albeit increasing over time as medical journals make more effort to enforce transparency rules. For the empirical analysis, I assume that all studies that are not funded by a U.S. agency received financial support by the sponsor of the drug. This approach is certainly not ideal and I plan to use imputation technics in order to infer the identity of the sponsor in a future version of this paper.

6 Estimation

6.1 Model

I investigate how changes in market structure in the form of entries of new drugs in the market and variation in the number of drugs in clinical development affect the flow of information released by sellers of marketed drugs through medical publication. To do so, I estimate the following negative

binomial model:

$$
\begin{aligned}
Pub_{i,j,t} = & f(\beta_0 + \alpha_j + \alpha_i + \beta_1 Drugage_{i,t} + \beta_2 Drugage_{i,t}^2 + \beta_4 CompPubst_{i,t-1} \\
& \beta_5 comp < 5years_{j,t} + \beta_6 comp[5-10]years_{i,t} + \beta_7, comp > 10years_{i,t} \\
& \beta_6 scomp < 5years_{j,t} + \beta_7 scomp[5-10]years_{i,t} + \beta_8, scomp > 10years_{i,t} \\
& + \beta_9 Phase1nb\_comp_{j,t} + \beta_10 Phase2nb\_comp_{j,t} + \beta_11 Phase3nb\_comp_{j,t} \\
& + \beta_12 Phase1nb\_scomp_{j,t} + \beta_13 Phase2nb\_scomp_{j,t} + \beta_14 Phase2nb\_scomp_{j,t} \\
& \beta_15 ICMJE)
\end{aligned}
$$

The dependent variables $Pub_{i,j,t}$ denotes the number of publications by drug i in ATC (i.e. market) j and at year j. It is a count variable presenting a large degree of over dispersion which motivates the choice of a negative binomial model.

Table 1: Summary statistics on $Pub_{i,j,t}$

Variable	**Mean**	**Std. Dev.**
$Pub_{i,j,t}$	514.781	1087.39
N	21,689	

Where:

- α_j is the ATC j fixed effect.
- α_i is the drug i fixed effect.
- $Drugage_{i,t}$ denotes the number of years since the drug has entered the market.
- $CompPubst_{j,t-1}$ is the total stock of publication on drugs that compete against drug i in market j at the end of the year $t-1$.

- $comp < 5years_{j,t}$ is the number of drugs aged of less than 5 years that are commercialized by competing firms.
- $comp[5-10]years_{i,t}$ is the number of drugs between the age of 5 and 10 years that are commercialized by competing firms.
- $comp > 10years_{i,t}$ is the number of drugs aged of more than 5 years that are commercialized by competing firms.
- $scomp < 5years_{j,t}$ is the number of drugs aged of less than 5 years that are commercialized by the same firm (the sponsor of drug i).
- $scomp[5-10]years_{i,t}$ is the number of drugs between the age of 5 and 10 years that are commercialized by the same firm (the sponsor of drug i).
- $scomp > 10years_{i,t}$ is the number of drugs aged of more than 5 years that are commercialized by the same firm .
- $Phaseknb\_comp_{j,t}$ is the number of drugs developed by firms that compete with drug i and that are on phase k of development at year t in market j.
- $Phaseknb\_scomp_{j,t}$ is the number of drugs developed by the firm that commercializes drug i and that are on phase k of development at year t in market j.
- *ICMJE* is a dummy variable that takes value one for years following the adoption of the mandatory disclosure of clinical trials by the ICMJE.

My theoretical model predicts that when facing tougher competition, firms should react by disclosing less information on quality. I measure the intensity of competition by counting the number

of marketed drugs and the number of potential entrants which are the drugs in clinical development. I allow for the number of marketed drugs to impact differently the disclosure behavior of firms depending on their age and on whether or not they are commercialized by the same company.

Identification arises from time-series variation in the intensity of competition. Within a market the intensity of competition changes due to entry, discontinuation, and withdrawal of drugs.

I include the following set of control variables. I use a ATC fixed effect to control for the market size and the market profitability assuming that they remain constant over time. I add a drug fixed effect to capture the quality of the drug. I control for the age of the drug as it indicates how much profit the drug seller can expect to make while its drug is still under patent protection and is also a proxy for the quantity of information already disclosed about the drug. I include a time dummy corresponding to the adoption of mandatary disclosure of clinical trials by the ICMJE. Finally I include the stock of publication by competing drugs which indicate both the quality of the competitors as well as the research effort they exerted.

I should find that an increase in the number of drugs competing in the market diminishes the flow of medical publications. The number of potential entrants, measured by the number of drugs in phase I, II , and III, can affect the publication flow through two channels: (1) firms anticipating an increase in the intensity of competition in the future could lower their research effort and subsequently engage in less publication; (2) facing higher threat of entry, firms might react in publishing more to deter entry.

6.2 Results

I find that only the number of older drugs marketed by competitors affect significantly the flow of publications (with a 10% significance level). The coefficients associated to the number of younger

Table 2: Negative binomial regression with ATC and drug fixed effect, Dependent variable: number of publications

Variable	Coefficient	(Std. Err.)
$CompPubst_{j,t-1}$	-1.51e-10	(1.24e-10)
drugage	0.020	(0.022)
drugage2	-0.001	(0.000)
$comp < 5years_{j,t}$	-0.002	(0.008)
$comp[5-10]years_{i,t}$	-0.005	(0.014)
$comp > 10years_{i,t}$	-0.006	(0.004)
$scomp < 5years_{j,t}$	0.005	(0.106)
$scomp[5-10]years_{i,t}$	0.010	(0.040)
$scomp > 10years_{i,t}$	0.010	(0.013)
$Phase1nb\_comp_{j,t}$	0.002	(0.001)
$Phase2nb\_comp_{j,t}$	-0.002	(0.004)
$Phase3nb\_comp_{j,t}$	0.005	(0.004)
$Phase1nb\_scomp_{j,t}$	0.007	(0.013)
$Phase2nb\_scomp_{j,t}$	0.037	(0.002)
$Phase3nb\_scomp_{j,t}$	0.021	(0.005)
ICMJE	-0.115	(0.087)
Intercept	4.924	(0.000)
Log likelihood	-786739.19	
Number of observations	16,483	
Number of groups	794	

marketed competitors have the negative signs predicted by the model by are not significant.

The number of drugs at any age marketed by the same company does not impact the flow of publications.

For potential entrants, the disclosure decisions of firms does not appear to be affected by the pipeline of their competitors. The positive coefficients associated with the number of drugs in the latest phases of development (phase II and phase III) by the same company could indicate that firms publish more when they sell numerous drugs in the same market to differentiate horizontally their products and thereby increase their profits.

As expected, the stock of publications by competitors affects negatively $Pub_{i,j,t}$: firms publish less when they face higher quality competitors, and research efforts are strategic substitutes.

The flow of publication increases at a decreasing rate with the seniority of the drug on the market.

Finally, I find that firms publish mush less since the adoption by the ICMJE of the new policy requiring registration of clinical trials. The coefficient of -0.115 associated to the dummy ICMJE means that, within the same market and everything equal regarding the competitive environment, firms publish one less study per year since 2005. This indicates either that firms run less clinical trials or that they keep not disclosing a sizable portion of them which limits their possibility to publish.

7 Conclusion

This paper shows how competition can act as an anti transparency force when firms, ex-ante unaware of their quality, have to exert an unobservable research effort to discover their quality and disclose it to the market. The predictions of this model are tested with data on pharmaceutical

publications. I find empirical evidence that competition does weaken the provision of information in the pharmaceutical industry.

It is worth mentioning that the empirical analysis is still very preliminary and suffers from at least two major shortcomings.

The first caveat concerns the identification strategy. I use the variation over time of the number of competitors to identify the impact of competition on the quantity of information disclosed. But, as mentioned by Jin (2005) the entry and exit decisions made by firms are likely to be affected by the same time varying unobservable cost and demand factors. So rather than the causal impact of competition, I establish in this paper the existence of a negative correlation between competition and information provision.

The second caveat is related to the way I measure information provision. I count the number of articles published without taking into account the quality of those publications. The quantity of information conveyed in a publication varies presumably with the size and the design of the trial whose results are disclosed. Some firms may choose to publish less but more informative articles in more prestigious journals and those choices may not be independent of the competitive environment.

References

[1] Board, Oliver. "COMPETITION AND DISCLOSURE*." The Journal of Industrial Economics 57, no. 1 (2009): 197-213.

[2] Gentzkow, Matthew, and Emir Kamenica. Competition in persuasion. No. w17436. National Bureau of Economic Research, 2011.

[3] Grossman, Sanford J. ”The informational role of warranties and private disclosure about product quality.” Journal of law and economics 24, no. 3 (1981): 461-483.

[4] Hotz, Strategic Information Disclosure: The Case of Mult-Attribute Products with Heterogeneous Consumers, (with Mo Xiao), Economic Inquiry, 51(1), January 2013, 865-881.

[5] Jin, Ginger Zhe. ”Competition and disclosure incentives: an empirical study of HMOs.” RAND Journal of Economics (2005): 93-112.

[6] Levin, Dan, James Peck, and Lixin Ye. ”QUALITY DISCLOSURE AND COMPETITION*.” The Journal of Industrial Economics 57.1 (2009): 167-196.

[7] Melander, Hans, Jane Ahlqvist-Rastad, Gertie Meijer, and Bjrn Beermann. ”Evidence b (i) ased medicineselective reporting from studies sponsored by pharmaceutical industry: review of studies in new drug applications.” Bmj 326, no. 7400 (2003): 1171-1173.

[8] Meyerhoefer, Chad D., and Samuel H. Zuvekas. ”The Shape of Demand: What Does It Tell Us about Direct-to-Consumer Marketing of Antidepressants?.” The BE Journal of Economic Analysis & Policy 8, no. 2 (2008): 4.

[9] Milgrom, Paul R. ”Good news and bad news: Representation theorems and applications.” The Bell Journal of Economics (1981): 380-391.

[10] Prayle, Andrew P., Matthew N. Hurley, and Alan R. Smyth. ”Compliance with mandatory reporting of clinical trial results on ClinicalTrials. gov: cross sectional study.” BMJ 344 (2012).

[11] Rizzo, John A. ”Advertising and Competition in the Ethical Pharmaceutical Industry: The Case of Antihypertensive Drugs*.” The Journal of Law and Economics 42, no. 1 (1999): 89-116.

[12] Shavell, Steven. ”Acquisition and disclosure of information prior to sale.” The RAND Journal of Economics (1994): 20-36.

[13] Stivers, Andrew. ”Unraveling of information: Competition and Uncertainty.” The BE Journals: Topics in Theoretical Economics 4.1 (2004).

[14] Turner, Erick H., Annette M. Matthews, Eftihia Linardatos, Robert A. Tell, and Robert Rosenthal. ”Selective publication of antidepressant trials and its influence on apparent efficacy.” New England Journal of Medicine 358, no. 3 (2008): 252-260.

8 Appendix

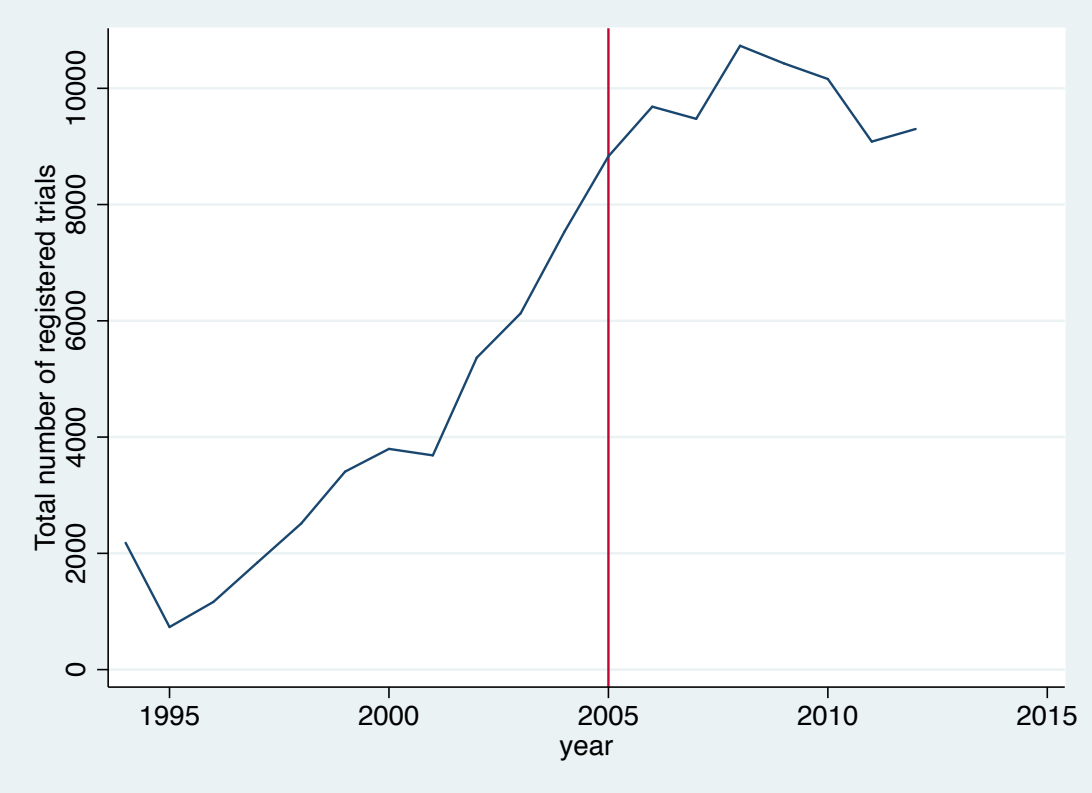


Figure 1: Number of registered trials over time

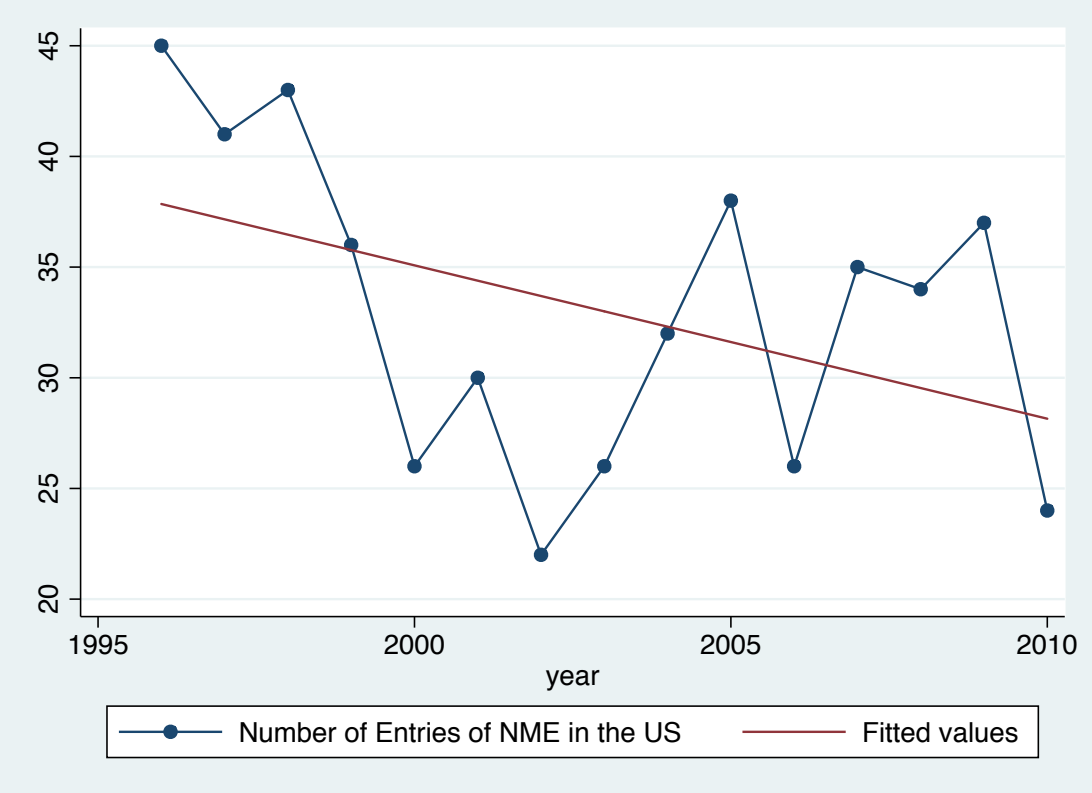


Figure 2: Number of NME over time

marketed.pdf

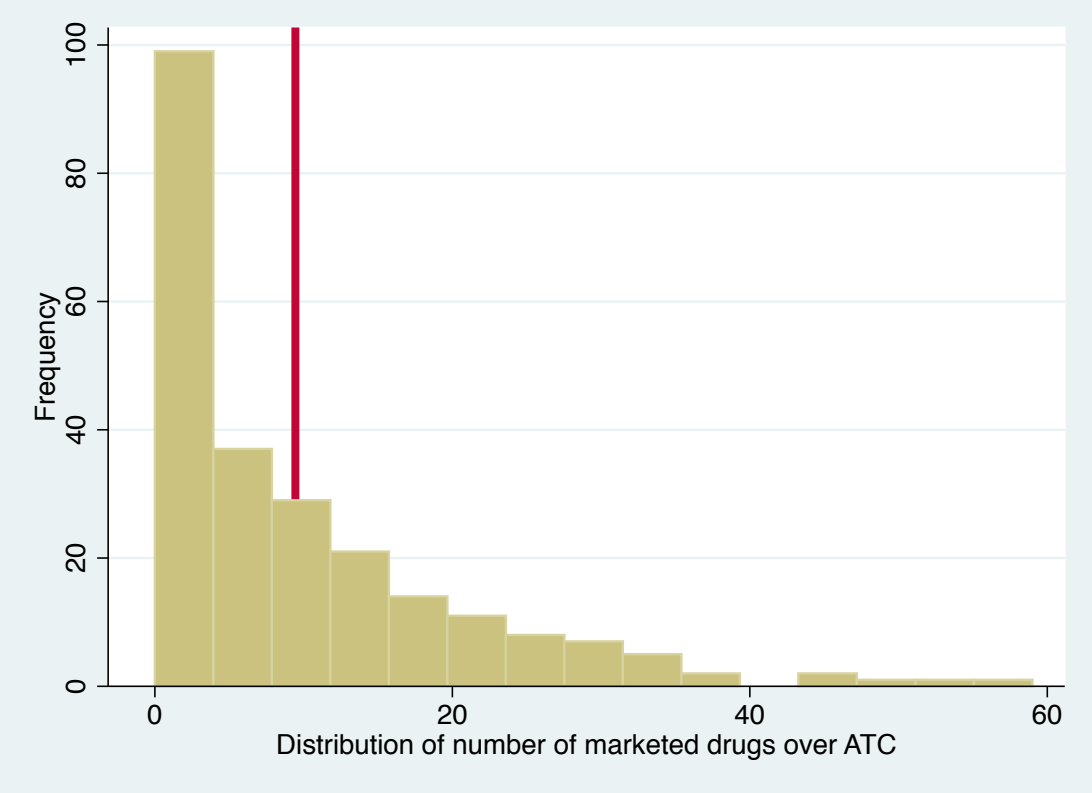


Figure 3: Distribution of drugs across markets

Table 3: Some descriptive statistics on publications for drugs marketed in the U.S. between 1990 and 2012

	Clinical Trial, Phase I	Clinical Trial, Phase II	Clinical Trial, Phase III	Clinical Trial, Phase IV	Total Clinical Trials
# obs.	12,171	18,948	7,811	701	79,600
# Funding: N.I.H.	442 (10.21%)	662 (9.16%)	238 (7.35%)	5 (1.30%)	2,746 (3.45%)
# Funding: U.S. govt	532 (12.29%)	690 (9.54%)	169 (5.22%)	9 (2.34%)	5,700 (7.16%)
# Funding: non U.S. govt	2,389 (55.19%)	3,592 (49.68%)	2,062 (63.64%)	257 (66.93%)	34,012 (42.73%)
# Funding: missing	1,535 (35.46%)	2,955 (40.87%)	1,008 (31.11%)	126 (32.81%)	41,832 (52.55%)
mean year publication	2004	2004	2006	2007	2000

Proof of proposition 1 The game is solved by backward induction. In the pricing subgame, the monopolist charges a price $p = \tilde{\theta}$ so as to capture completely the consumer surplus. Its profit is equal to its perceived quality, $\pi = \tilde{\theta}$. In the research subgame, the value of getting informed $V^M(e)$ corresponds to the extra profit that the monopolist can expect to make when it discloses a quality higher θ_s net of the research cost: this is the product of its probability to be informed $\phi(e)$ and the expected positive difference between the "sup threshold" quality and the threshold quality θ_s. The monopolist chooses the level of effort that equals the marginal value of getting informed to the marginal research cost. For any given $\tilde{\theta}_s \in [0, \overline{\theta}]$, the solution of the maximization of $V^M(e)$ is given by the FOC:

$$\phi'(e_M) \int_{\tilde{\theta}_s}^{\overline{\theta}} (\theta - \tilde{\theta}_s) f(\theta) d\,\theta = c'(e_M) \tag{8.1}$$

The concavity of $\phi(.)$ and the convexity of $c(.)$ guarantees that the level of effort that maximizes $V^M(E)$ exists and is unique. The equilibrium level of effort e_M^* is obtained by substituting **??** and **??** into **??**:

$$\underbrace{\phi'(e_M) \int_{\theta_s}^{\overline{\theta}} (\theta - \theta_s) f(\theta) d\,\theta - c'(e_M)}_{g(e_M)} = 0 \tag{8.2}$$

With:

$$\theta_s = (1 - \phi(e_M))E(\theta) + \phi(e_M)E(\theta|\theta < \theta_s)$$

When $e_M = \bar{e}$ such that $\phi(\bar{e}) = 1$, $\theta_s = 0$. This result is intuitive: when consumers correctly anticipate that the monopolist exerts a level of effort so that it is always informed, the setting is equivalent to one in which the research effort is observed and the unravelling result holds. $\phi'(\bar{e}) \leq 1$, $\int_0^{\overline{\theta}} (\theta - 0) f(\theta) d\,\theta = E(\theta)$, $c'(\bar{e}) > E(\theta) \Rightarrow g(\bar{e}) < 0$. The assumptions on the cost function and the probability function guarantee that it is never profitable for the firm to choose to be informed for sure.

When $e_M = 0$, $\phi(0) = 0$ and $\theta_s = E(\theta)$. When consumers correctly forecast that the monopolist chooses a zero level of effort and is always uninformed, they regard the silent monopolist as an average quality firm. $\phi'(0) > 0$, $c'(0) = 0 \Rightarrow\ g(0) > 0$. The monopolist has an incentive to deviate and exert some effort to get the option to disclose if it discovers its quality is above the unconditional mean.

Since, g is continuous, $g(0) > 0$, and $g(\bar{e}) < 0$, by the intermediate value theorem, there exists an equilibrium level of effort $e_M^* \in (0, \bar{e})$ such that $g(e_M^*) = 0$.

Proof of lemma 1

$$\int_{\tilde{\theta}_s^N}^{\overline{\theta}} \int_{\theta_2}^{\overline{\theta}} (\theta - \theta_2) f(\theta)(n+1) f(\theta_2)(F(\theta_2))^n d\theta d\theta_2 \leq \int_{\tilde{\theta}_s^N}^{\overline{\theta}} \int_{\theta_2}^{\overline{\theta}} (\theta - \theta_2) f(\theta) n f(\theta_2)(F(\theta_2))^{n-1} d\theta d\theta_2$$

It follows that $W(n+1) \leq W(n)$.

Proof of lemma 2

$$B(N+1) = (1 - \phi(e))B(N) + \phi(e)^N W(N)$$

$$W(N) \leq B(N) \rightarrow B(N+1) \leq B(N)$$

Proof of proposition 2 The FOC of the maximization problem: $\max_{e_i}$ is:

$$\phi'(e_i)B(N) = c'(e_i)$$

From $W(n) < W(n-1)\ \forall n$, it follows that $B(N)$ is a decreasing function of e. Research efforts are strategic substitutes.

Proof of proposition 3

As $B(N)$ is a decreasing function of N, the marginal benefit of effort decreases with N and so does the optimal level of effort e_N^*. $\tilde{\theta}_s^N$ increases with N since it is a decreasing function of e_N^*.