

# Licensing and Scale Economies in the Biotechnology Pharmaceutical Industry

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## Abstract

This article empirically quantifies how market structure influences returns for successful innovation in the biotechnology pharmaceutical industry. I find that pharmaceutical marketing firms' values for adding a new drug to their product portfolio depend on the distribution of the other products marketed in the same physician specialty as the drug, the size of the patient market the drug serves, and the number of physicians in the physician specialty that prescribes the drug. I also show how the level of competition in the bidding market for the marketing rights of a successful innovation varies with market structure. In particular, when the distribution of marketing rights for products in a physician specialty are concentrated in a single firm, the bargaining position of the innovator is weakened and this effect becomes more severe as the size of the physician specialty increases. The difference between the firm with the highest valuation and the firm with the second highest valuation increases by an average of 2% for every additional 10,000 physicians in a specialty.

## 1 Introduction

In many innovative industries the majority of innovation occurs in a large number of small firms while marketing and commercialization are done by fewer large firms. This is particularly true in biotechnology where less than one third of biotechnology pharmaceuticals are marketed by the firms who brought them into phase one FDA trials. Most marketing rights in this industry are transferred from the innovating firm either through a license or an acquisition to another firm that markets the product. The size distribution of innovators is shown in Figure 1 while the size distribution of

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marketers is show in Figure 2. In this article I develop and estimate an econometric model that quantifies the forces driving the consolidation of products across firms.

Consolidation of marketing impacts the level of competition in licensing markets and the return an innovator will receive from successful innovation. The structural model of licensors' profits I estimate allows me to quantify how the share of overall producer surplus an innovator receives varies with the characteristics of the product and the distribution of the domestic marketing rights for other pharmaceutical products across firms. When marketers' values for adding a given product to their portfolio vary widely, particularly at the top of the value distribution, the return an innovator receives upon successful innovation is depressed. The problem is more severe when the innovator does not have the capabilities to market their product themselves. This lack of competition for the marketing rights of a product allows large marketing firms to extract value leaving a smaller proportion of overall producer surplus for innovators.

My estimates use data on the current distribution of domestic marketing rights and assumptions about how this distribution relates to firms' underlying profit functions. Specifically I assume the distribution of products across firms is a pairwise stable allocation. An allocation is pairwise stable if there do not exist two firms that jointly benefit by trading some part of their product portfolios while allowing an accompanying monetary transfer between the two firms. Using the revealed preference inequalities implied by pairwise stability, I proceed with estimation using a matching estimator developed recently by Fox (2007).

Throughout the article, I refer to physician class/specialty and disease/indication class. Drugs in the same indication/disease class compete with one another to be prescribed by a physician when a patient has a particular disease or disorder. However, drugs in the same physician class/specialty (but not in the same indication class) do not compete with each other to be prescribed for a given patient. For example, if one drug treats Rheumatoid Arthritis and another drug treats Multiple Sclerosis, these drugs do not directly compete against each other to be prescribed for a particular patient (i.e. they are not in the same indication class), but they are in the same physician class - Rheumatology.

In my analysis I find that the economies of scale firms realize from marketing multiple drugs in the same physician specialty and the diseconomies of scale firms encounter when growing the overall

size of their product portfolio are important factors in explaining differences in firms' valuations for licensing a particular product. An incumbent firm's return from deterring entry of new firms into a product market and a physician specialty, is also important. Additionally, I find that innovators are more likely to keep products they innovate particularly when the innovator already has cash flow from another successful product.

Using my parameter estimates I calculate each potential marketing firm's value for adding a product to their portfolio. My estimates show that when the marketing rights of products in a physician specialty are concentrated in a single firm, the bargaining position of the innovator of a new drug in this physician specialty is weakened. This effect becomes more severe as the number of physicians practicing in the physician specialty increases. An increase of 10,000 physicians in a specialty increases the difference between the firm with the highest valuation and the firm with the second highest valuation by an average of 2%.

My results have important implications for merger analysis. Many times the firm which is best equipt to innovate a product is not the firm that would most efficiently commercialize the product. As the innovating firm and the marketing firm are not able to write efficient ex-ante contracts due to the presence of agency problems and informational asymmetries (Lerner, Malmendier 2008), preserving competition in the biotechnology licensing market is important to ensure innovation incentives. Therefore, when considering the effect of a merger, policy makers should consider the effects on competition in the licensing market in addition to traditional considerations about the effects of the merger on downstream consumer market. My results show this is a particularly important force to consider in large physician specialities where the concentration of marketing rights across firms is high. The effect of the merger on competition in licensing markets can still be substantial even when the merging firms have no products that compete in downstream markets.

Historically, large traditional pharmaceutical firms were highly involved in the research and development of new pharmaceutical products.<sup>1</sup> Today the bulk of research occurs in small venture capital

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<sup>1</sup>Cockburn and Henderson (1996, 2001) study the effect of scale and scope economies on research (patent) and development (drug approval) productivity in pharmaceutical industry from 1960-1990. Their work demonstrates that during the discovery phase having a large and diverse set of projects increases firms' productivity. They also show that during the development phase only diversity seems to be important. There are several ways my project differs from theirs. In their analysis they examine, for example, the probability of success for a particular product whereas I endogenize the product portfolios firms have and use their choices of products to infer information about their profit

backed firms (Cockburn 2004). At the same time, the direction of drug development has shifted towards drugs treating niche diseases. These treatments are many times prescribed by specialists and are for diseases with few if any other treatments. Possible explanations for this shift include changes in the nature of research and an increase in capital available to support start-up firms. My article suggests a third contributing factor: as research has shifted towards niche markets, startup innovators no longer face the threat of hold up in the licensing markets. In niche markets large marketing firms are not able to extract value from new innovators and therefore these innovators receive a larger proportion of total producer surplus.

Several related studies analyze licensing, mergers and acquisitions in the biotechnology pharmaceutical industry (Danzon et al. 2004, Gans, Stern 2000, Lerner, Merges 1999). In Danzon, Epstein, and Nicholson (2004), the authors look at the predictors of merger activity and the subsequent impact of mergers on firm growth. Consistent with my results, they identify the importance of established distribution networks, and financial distress of small firms as important drivers for merger activity. My analysis also reveals how the importance of these forces may vary across different disease markets in this industry.

Gans, Hsu, and Stern (2002) examine a cross section of innovative industries and find that when complementary asset ownership is more important, innovators are more likely to either license or be acquired by larger incumbent firms. The authors use a survey in which firms report how important complementary assets are for commercializing their products. In this article, I identify the characteristics of the markets within the industry for which these complementary assets are important and to what extent these market characteristics drive the licensing patterns we observe in this industry.

Scott Morten (1999) examines the entry decisions of generic pharmaceutical firms. In this analysis she finds that firms are more likely to market products that are similar to their current portfolio. In this analysis she finds that technological and therapeutic similarities increase a firm's probability of entry into a particular market. While I examine a different area of the pharmaceutical industry, I also find that a firm's ability to leverage their experience in an area is an important driver of a firm's cost of

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functions. In addition, these articles study the research and development phases of the drug's life cycle whereas I study the marketing and distribution of products after they are approved. They also study traditional pharmaceutical firms in an earlier period when licensing and venture capital financing was less prevalent.

adding a product to their portfolio. Additionally I find that the value of this experience varies across markets and that competitive externalities also play an important role in driving product portfolio decisions.

In section 2, I describe the industry. In section 3, I present a basic empirical model and describe the stability assumption I make on market outcomes which I use for my later estimation. In section 4, I describe the data used in my analysis. In section 5, I present descriptive empirical results. In section 6, I present my estimation strategy, and my empirical results. I conclude in section 7.

## **2 Industry Description: Biotechnology Pharmaceuticals**

Beginning in 1980 there have been hundreds of firms founded that specialize in the field of biotechnology pharmaceuticals. Biotechnology pharmaceuticals treat a wide range of diseases; some biotechnology drugs treat common ailments such as diabetes whereas other drugs treat extremely rare disease such as Gaucher disease. Over one half of biotechnology drugs treat orphan diseases. Orphan diseases affect less than 200,000 people in the United States. In addition, some biotechnology drugs treat ailments for which they are the only available treatments while others treat conditions with many treatment options.

Biotechnology pharmaceuticals also differ from traditional small molecule drugs in their research processes. Biotechnology innovation relies heavily on the tools of molecular biology.<sup>2</sup> Biotechnology drugs are produced using living organisms, which makes process innovations an important part of biotechnology research. In addition, the biotechnology discovery process is more directed than small molecule research. For example, a particular protein may be known to be missing for a particular patient population. Research then focuses on finding ways to produce this protein. To a large extent, firms involved in small molecule research (traditional pharmaceutical firms) cannot use their research capabilities from that sector to help them develop biotechnology drugs. However, firms that have established relationships marketing traditional pharmaceuticals can leverage that experience to market biotechnology pharmaceuticals. Traditional pharmaceutical firms are involved more in the marketing of biotechnology drugs than in the innovation of these drugs as shown in Figure 3.

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<sup>2</sup>Robbins-Roth 2003, Chandler 2005, and Abate 2005 provide excellent industry overviews.

Direct to physician marketing is an important aspect of marketing products in the biotechnology pharmaceutical industry. In many cases, the diseases these drugs treat are life threatening and the importance of direct to consumer advertising is diminished. Direct to physician marketing includes making visits to doctors, creating events that doctors will attend and/or advertising in the publications doctors read. Creating contacts with physicians is both extremely important and costly. In addition, relationships with physicians can be leveraged across multiple drugs (Harris, Carey 2007). For example, pharmaceutical firms typically hire a sales force for a physician specialty, for example cardiology, and a sales team member can market multiple drugs to the same physicians.

Marketing rights are sold either for a lump sum, or more commonly for a lump sum plus a royalty. In addition, many innovating firms are acquired by larger firms. Table 1 describes the operating status of 73 of the 100 innovators in my sample as of July 2007. Thirty-one of these firms were still operating autonomously. The other firms were either acquired, merged with another firm or filed for bankruptcy. Table 2 shows the product portfolio size for the firms that were acquired or merged at the time of acquisition or merger. Fourteen of these firms had control over no currently approved products at the time of merger or acquisition while 17 had control over only one product. From these figures we see that most firms acquire marketing rights not through an acquisition or merger but through the licensing market. These figures also show that even when firms acquire marketing rights through other means, they typically only acquire the rights of a single approved drug.

Licensing decisions are made for a variety of reasons. A marketing firm may be looking to fill a place in their portfolio, and therefore they may actively seek out licensing partners who can fill that need. Also an inventor often looks for partners for drugs they can not profitably market themselves. For example, consider a small innovative firm that is developing both a treatment for a rare form of cancer and a drug for over active bladder (OAB) syndrome. The small firm knows that they must license the OAB drug because it serves a large market and it is prescribed by primary care physicians. The small firm will not be able to develop a large enough sales force to bring this drug to market and therefore it will actively look for partners. However, the firm might consider bringing the Oncology drug to market on its own. My estimation quantifies the impact of the variation in the size of the physician specialty that prescribes a drug as well as variation in the overall size of the

patient population with the disease a drug treats on the return different firms receive from bringing a product to market.

Innovators may receive special benefits from keeping the marketing rights of the products they have innovated. In particular, innovators may have developed relationships with physicians during the development process that they can later leverage when commercializing the drug. Additionally, they may have private information about the true quality of the drug or the potential for future drug development within a disease class. However, many firms in my sample were venture capital backed when they were founded. Most of these firms had an initial public offering before their first successful drug was approved. Anecdotal evidence suggests that cash flow pressures often force young firms into licensing agreements. Consistent with these stories, we will later see empirically that new innovators are more likely to license their first approved product than subsequent products, however for subsequent products all other things equal innovators are more likely to keep the product market rights for their own innovations.

An appendix provides several excerpts from the 10-K and annual reports of firms specializing in the discovery and development of pharmaceutical drugs. It includes and excerpts from small pharmaceutical firm, AntheroGenics Inc.(\$21.3M Market Cap, as of July 2008 not marketing any products), and two biotechnology firms Celgene (\$30.2B Market Cap, as of July 2008 marketing three products), and MedImmune (was marketing three products when acquired in 2007 by AstraZeneca, one of the world's largest pharmaceutical companies). These passages describe some of the licensing strategies and concerns of firms in this industry. These excerpts suggest small innovating firms look to license any products they develop in "broad", "competitive" markets and keep those drugs treating "narrow" markets. These firms cite the expertise of potential acquirers' salesforces in a particular specialty (for example Oncology) as an important factor driving a licensing agreement. In addition, several of these firms suggest that marketing multiple products in the same physician specialty (Oncology, Immunology) allows them to leverage the experience their sales force has gained when marketing other similar drugs.

Next I will present several specific examples of how the marketing rights of some approved biotech drugs have moved across firms. In May 2005 Naglazyme, an orphan drug, was approved by the FDA

to treat a rare lysosomal storage disorder, mucopolysaccharidosis VI (MPS VI). There are no other effective pharmaceutical treatments for MPS VI. The only other treatment for MPS VI, which has had only limited success, is bone marrow transplantation while the affected patient is under the age of two. Naglazyme is typically prescribed by genetic and metabolic specialists and there are around 2,000 physicians in the US that are genetic or metabolic specialists. Naglazyme was developed and is currently marketed by BioMarin Pharmaceuticals.

A firm with a sales force specializing in marketing to genetic and metabolic specialists may have been able to more cost effectively market Naglazyme, but the advantage this firm would have had would have been small as the overall sales force needed to market Naglazyme is small. In addition, as there were no incumbent firms with products already treating MPS VI, there were no firms with reasons to acquire Naglazyme to decrease competition in the disease market. BioMarin by marketing the product themselves was able to leverage their knowledge and expertise about Naglazyme as well as any relationships they developed during the development of Naglazyme.

Some drugs change hands many times before they are approved. Bexxar was approved in June 2003 to treat patients with a form of non-Hodgkins lymphoma. Non-Hodgkins Lymphoma (NHL) is the fifth most common cancer affecting an estimated 63,000 new patients according to the American Cancer Society. There are few other treatments that directly compete with Bexxar. Bexxar is prescribed mainly by Oncologists and Hematologists. There are over 11,000 board certified Oncologists and Hematologists in the US. To successfully market Bexxar the marketing firm must have a substantial sales force, and therefore an innovator marketing no other products, while having special knowledge and expertise on Bexxar would face high costs to develop a sales force to market Bexxar.

Bexxar was brought into phase 1 FDA trials by Coulter Pharmaceutical, a small biotech firm. Coulter was acquired by Corixa Corporation, another small firm, in 2000. Corixa later licensed marketing rights for Bexxar to GlaxoSmithKline one of the largest pharmaceutical firms in the world. GlaxoSmithKline has a sales force specializing in Oncology and currently markets four other oncology drugs.<sup>3</sup> At the time of license Corixa was not marketing any other products and hence GlaxoSmithKline's costs to marketing Bexxar were much lower than Corixa's costs would have been.

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<sup>3</sup>Corixa was then fully acquired by GlaxoSmithKline in 2005.



It is not uncommon for the product market rights of a biotech drug to change hands several times both before and after the drug has gained FDA approval. In my later estimation, I will infer information about firms profit functions from the fact that one firm has a product and has not sold it to any other firm. In particular, one of the assumptions my model will make is that no other firm has a higher value for the product market rights of a drug than the firm that is currently marketing the product. I assume that if there was a firm with a higher value then that firm would have bought the product market rights from the lower valued firm.

Notice also that neither Coulter Pharmaceutical, nor Corixa Corporation are currently potential marketers of Bexxar as these firms no longer exists. Although I will allow for innovators to have an advantage in marketing the products they innovate due the special knowledge or relationships they may have developed that would help facilitate the marketing of their innovations I will not include all innovators as potential marketers of drugs in my final estimation. Instead, I will only include those innovators that currently market at least one drug.

In my estimation I will allow for economies of scale in marketing at the physician specialty level, and will estimate to what extent in some physician specialties these economies of scale may be more important than in others. The ability of GlaxoSmithKline to realize economies of scale when marketing to Oncologists, and the costs associated with Corixa developing a salesforces force in this area was likely one of the drivers of the licensing deal between these two firms. On the other hand, as there are very few geneticists and metabolic specialists even as a small firm, BioMarin was able to successfully develop a salesforce in this area.

Next, I will estimate an empirical model that rationalizes the observed allocation of products across firms. I will model a pharmaceutical firm's decision to market a portfolio of drugs. Writing down an economic model of this decision allows me to separate out the competing effects impacting a firm's choice of products. After obtaining my estimates I will be able to show what the bidding market for licenses looks like and show how the split of rents between innovators and marketing firms varies with market structure and product market characteristics.

### 3 Empirical Model

In this section I discuss the empirical model I use in my estimation. First I introduce some basic notation, assumptions and describe the value function I use for my estimation. Then I present the solution concept. In the last part of this section I discuss how my empirical estimates relate to innovation incentives.

The purpose of the model is to provide a framework to rationalize market structure given the exogenous characteristics of the products. These exogenous characteristics include which disease the drug treats, the incidence of the disease the drug treats, how many approved treatments there are available for that disease, the physicians that prescribe the drug, and the number of physicians in that specialty in the US. Marketers face a portfolio problem and there are several competing forces driving their product portfolio decisions. I will use a model to separate out these competing forces. My model will allow for a marketers decision about one drug to be related to their decisions about other drugs. The model therefore will both have to rationalize the observed allocation of drugs across firms, incorporate the joint decision of products a firm makes, and also allow for the complementarities and competitive externalities inherent in this industry. After estimating the parameters of the model I will be able to show what the bidding market for licenses for the marketing rights of a product looks like and hence how the split of rents between the innovator and the marketer are related to factors such as the size of the patient market the drug serves, the size of the physician specialty that prescribes the drug, and the concentration of other products across firms.

Let  $I$  be the set of all products and  $J$  be the set of potential marketers for these products. I will abuse notation by letting  $I$  and  $J$  also be the number of products and potential marketers respectively. Let  $B_j$  be the set of products marketed by firm  $j$ . An allocation  $B = (B_1 \dots B_J)$  is a partition of the products. Let  $V_j(B)$  be firm  $j$ 's valuation from marketing the bundle  $B_j$  given the total industry allocation  $B$ . I allow firm  $j$ 's value to depend on the portfolios of other firms, for instance because a firm may care about whether rival products are marketed just by one firm or by several firms.

I take the location of innovation as exogenous. I assume firms care about maximizing profits, and innovator's profits are additively separable across each of their innovations.

### 3.1 Firm Value Function

I am interested in understanding the market structure of drug marketing and distribution, so the model focuses on capturing the differences in product values across prospective marketing firms. Roughly there are three potential reasons a firm might have a high value for marketing a given drug. First, an innovating firm may have a reason to value its own drug more than any other firm. Secondly, a firm already marketing another drug in the same disease market may have an incentive to deter entry of new firms into that market. Finally, firms may realize scale economies in the overall size of their product portfolio or when marketing multiple drugs that are prescribed by physicians in the same specialty.

Innovators may value marketing a drug more than other potential marketers due to the special knowledge they have about the drug and the relationships with physicians they have formed during drug development. At the same time, new innovators may face cash constraints that prohibit them from hiring the sales force necessary to successfully market a drug. I therefore allow a potential marketer  $j$ 's value to depend on whether they were the innovator of the drug,  $I_{ij}$ , and allow the impact of this advantage to depend on the availability of a cash flow from previously approved products,  $H_j$ .

The level of competition a product will face may affect a potential marketing firm's value from marketing a drug. I will allow for two types of competitive effects in firms' value functions: competition at the disease class level (product market) and competition at the physician specialty level (licensing market). The level of competition in a disease class may impact a firm's profit from having the marketing rights to particular drug. There may also be competitive effects in the licensing market. In particular, as there are more competitive bidders for products in a physician specialty the proportion of producer surplus that goes to the innovator increases. Therefore, marketers may have an incentive to deter entry of other firms into a physician specialty. Allowing for competitive externalities implies that firm  $j$ 's value for marketing products  $B_j$  depends on the industry-wide allocation of products  $B$ . The level of competition that product  $i$  faces given industry allocation  $B$  is  $Comp_i(B)$ .

I let  $M(B_j)$  be firm  $j$ 's cost for marketing bundle  $B_j$ . I will allow  $M(B_j)$  to have scale economies at the physician specialty level as firms may be able to realize economies of scale when marketing multiple drugs in the same physician class. In addition, I allow for decreasing returns to scale at the

total product portfolio level. Anecdotal evidence suggests that a major cost for adding a product to a firm's current portfolio is the cost of their attention; coordinating the marketing of a new product distracts the firm from the other products they are also marketing. I allow for these costs  $P$  to rise with the size of the product portfolio,  $|B_j|$ .

$$V_j(B) = \sum_{i \in B_j} ( \underbrace{\alpha_i}_{\text{Inherent}} + \underbrace{I_{ij}(H_{ij})}_{\text{Innov. Adv.}} + \underbrace{Comp_i(B)}_{\text{Level of Comp.}} ) \underbrace{-M(B_j) - P(|B_j|)}_{\text{Marketing channels}} + \underbrace{\sum_{i \in B_j} \epsilon_{ij}}_{\text{Idiosyncratic}} \quad (1)$$

I let  $\alpha_i$  be the inherent profitability of marketing product  $i$  ;  $\alpha_i$  is the value of product  $i$  that does not vary across firms.

### 3.2 Identifying Assumptions on Market Outcomes

I draw on the matching literature and the literature on coalitional (cooperative) games to define a solution concept that assigns to any set of firm profit functions a set of potential licensing market outcomes (Osborne, Rubenstein 1994). Specifically, I assume the market allocation is pairwise stable. An allocation  $B$  is pairwise stable if there do not exist two firms that jointly benefit by trading some part of their product portfolios. An allocation  $B$  is pairwise stable if for any firms  $j$  and  $k$  and any  $B'$  such that  $B'_{-j,-k} = B_{-j,-k}$

$$V_j(B) + V_k(B) \geq V_j(B') + V_k(B') \quad (2)$$

For a given set of profit functions there may be more than one pairwise stable allocation.

Note that in the model I have defined, pairwise stability is a weaker solution concept than the core or competitive equilibrium. Any allocation in the core must be pairwise stable, but must also be jointly profit maximizing for all the firms in the market. I am loathe to impose such a strong assumption in a market that is imperfectly competitive. Under pairwise stability groups of more than two firms cannot coordinate on a deviation, so instead if the value to a firm from an action is greater than the externality imposed on any single firm but less than the sum of the externalities imposed on other firms the resulting outcome would still be pairwise stable even though it is not in the core.<sup>4</sup>

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<sup>4</sup>In the presence of complementarities the value of a firm for a product A and a product B separately may be less

Using the pairwise stability assumption on the current allocation I will be able to identify the drivers of the differences in firms' profits. Forces which affect the valuation of all firms equally, for example the inherent profitability of a drug, will difference out of the pairwise stability inequalities and hence will not be identified. I will defer the discussion of the specific parametrization of the value function, as well as the specific assumption I will make on the distribution of  $\epsilon_{ij}$  until later.

### 3.3 Relationship to the Incentives for Innovation

In this section, I make a specific assumption about how a single new drug might be allocated and show how the innovator's value changes with the distribution of potential licensing partners' values to license this product. This section relates the drivers of the differences in firms' profits to the incentives for innovation, and in addition will be used as a framework for my later counterfactuals.

Consider the decision of an innovator to develop a new drug taking the allocation of all currently approved drugs as fixed. The decision to innovate depends on the total return from innovating the drug and hence in the presence of a licensing market on the marketing value the innovator and the value all potential licensors will have for the innovated product.

I assume there is some firm independent value  $\alpha_i$  from marketing product  $i$  and some value  $D(X_{ij})$  which depends on  $X_{ij}$  which are characteristics of the marketing firm and the product.

Therefore, the marketing valuation of firm  $j$  for product  $i$  is:

$$V_{ij}^M = \alpha_i + D(X_{ij}) \quad (3)$$

Suppose that firm  $k$  gets the opportunity to innovate drug  $i$  at some cost  $C_k^i$ , and the lowest cost innovator, the innovator with the lowest  $C^i$ , gets the opportunity to invent first. Therefore, the first innovator who has positive value from innovating a product innovates and no other firm can innovate

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than the value of the firm for product A and B together. Hence considering bilateral deviations is not sufficient to show there are no acquisitions involving many firms which would make all firms better off. For example, suppose firms have concave marketing cost functions and consider the allocation of products  $\{A, B, C\}$  all in different product markets but in the same physician class across firms 1, 2, and 3. Suppose firm 1 innovated product A, firm 2 innovated product B, and firm 3 innovated product C. Suppose the extra value an innovator receives for marketing their own innovation is 3. The value of a firm of marketing any single product (excluding the value an innovator receives for marketing their own innovation) is 1, any two products is 4 and all three products is 15. In this case, the aforementioned allocation, one product in each of the three firms, would not be in the core, but it would be pairwise stable.

the same product.

After a product is innovated the marketing rights of the drug are sold to the firm with the highest valuation of the drug, or kept by the innovating firm if the innovator has the highest value. Next I will show that when the values of potential licensors of a product vary widely at the top of the value distribution an innovator with a low value for marketing the product herself gets held up in the licensing market.

Rank potential licensors in terms of marketing values  $V_{iJ}^M$ ,  $V_{iJ-1}^M$  etc where firm  $J$  has the highest valuation from marketing product  $i$ . If the innovator, firm  $k$ , has the highest valuation that is  $V_{ik}^M > V_J^M$  then the innovator will not license the drug and value from innovation to firm  $k$  is equal to:

$$V_{ik}^I = V_{ik}^M - C_k^i \quad (4)$$

Otherwise the return from innovation for firm  $k$  is as follows where  $\gamma$  is the bargaining coefficient:

$$V_{ik}^I = (\max(V_{ik}^M, V_{iJ-1}^M) + \gamma * (V_{iJ}^M - (\max(V_{ik}^M, V_{iJ-1}^M))) - C_k^i \quad (5)$$

ross firms. Therefore we would expect

Therefore we see that the returns to innovate increase in both the levels of the  $V_i^M$ 's and in the concentration of the  $V_i^M$ 's. The later point is due to the holdup problem.

When the spread of  $D(X_{ij})$  is large and the difference between  $V_J^M$  and  $V_{J-1}^M$  is large the most efficient innovator, the innovator with the lowest  $C_j^i$ , may not find it profitable to innovate as there is a large potential for holdup in the downstream market. Therefore, in this case the return from innovation depends on the innovator's ability to market the products themselves and innovation will be skewed towards "good" marketing firms. Also in this case some products which would be innovated in the presence of a competitive licensing market may not be innovated. For the purpose of my empirical analysis I will assume this is not the case.

The subsequent empirical estimation in this article quantifies the determinants of the magnitude and variance of  $D(X_{ij})$  across firms for different downstream product markets. These are of interest as they reveal information about the competitiveness in the licensing market, and identify in which

markets the distortion of the returns on innovation across firms will be most severe.

The mean of  $V_{ij}^M$ 's will also affect the incentives of innovating firms to innovate. I cannot however identify the mean of the  $V_{ij}^M$ 's as I do not have data on the sales and revenue received by firms when marketing a particular drug. If I had this information I would be able to identify  $\alpha_i$  and hence the mean value of the  $V_{ij}^M$ 's. As the mean shifts upward the return to an innovator will increase and if we take the variance as fixed (as well as the outside options and innovation costs) the probability that innovation is skewed will decrease. However if the costs of innovation shift 1-1 with the upward shift in the mean value of the  $V_{ij}^M$ 's the return to innovation will remain the same.

## 4 Data

### 4.1 Data Construction

My sample includes 149 tradenames of biotech drugs approved between October 1982 and July 2006. Figure 4 shows the FDA approval dates for the drugs. A tradename is included in my sample if in July 2006 it was listed as an approved biotechnology drug on both the Recombinant Capital Database and on the Biotechnology Industry Organization websites.

Information about the innovators of each drug, as well as information about product licensing comes from the Recombinant Capital Database, a proprietary database documenting the clinical development activities and marketing alliances of biotechnology firms. I have added to and cross referenced this information using press releases from companies, as well as company 10-K reports. The current marketer of each drug was collected from company websites and verified using company 10-K reports.

In my analysis I use information about which firm had control of domestic marketing rights when the drug went into phase 1 FDA trials (innovator) and who was currently marketing the drug in the US in August 2006 (marketer). From the Recombinant Capital Database I have information on 385 licensing agreements, 144 involving the domestic marketing rights of these 149 biotech tradenames.<sup>5</sup>

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<sup>5</sup>I have definitive information on which firm had marketing rights when the product entered phase one trials and who is currently marketing the drug. I used 10-K reports and press releases to verify this information when it was available in the Recombinant Capital Database and when it was not available this information comes directly from

For each marketer of a biotech drug, excluding large traditional pharmaceutical firms (for example Merck), I gathered information about their entire product portfolios. In my estimation I will control for the fact that I do not have the full product portfolios for the large traditional pharmaceutical companies. For each innovator of a drug the approval dates for all of the products they have innovated were ordered and this ranking is used as a proxy for the presence of cash constraints.

The approved indications for a drug as well as approval dates for these drugs were obtained from the FDA website. The drugs were then classified into physician specialties, that is which types of physicians prescribe the drug, and then within a physician specialty I classified the drugs into indication classes, that is which drugs treat the same conditions. This classification as well as information about the market size of the indication and controls for the other available treatments for a disease not already included in my dataset has come from numerous interviews with physicians.

In my physician interviews I had physicians rank the diseases (treated by drugs in my sample) that are cared for by physicians in their physician specialty from 1-5 in terms of the frequency a typical physician in their physician class treats the disease; 1 is rare and 5 is common. The relative market size of a indication class within a physician specialty is used as a proxy for the relative level of the marketing cost required to market a drug in given physician class.<sup>6</sup>

Information on alternative treatments available as well as which drugs compete with each other was cross referenced using the databases Micromedex, Uptodate, and as well as several medical textbooks. I use the number of other treatments for a disease obtained through physician interviews, as well as the number of firms marketing these treatments as proxies for the level of competition a product faces in a given disease market. Similarly, the number of other products in a physician specialty, as well as the number of firms marketing these products are used as a proxies for the level of competition in a given licensing market.

The number of physicians in a physician specialty was collected from the AMA (American Medical

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these alternative sources. I do not have comprehensive information on licensing deals occurring between phase one and today; if firm A licensed to firm B in phase 2 who in turn licensed to the current marketer C after the product was approved by the FDA then in my estimation I will say firm A is the innovator and firm C is the marketer. I do not use information that firm B had marketing rights from phase 2 until approval. I do not have comprehensive information about these “intermediate” licensing arrangements and therefore I interpret 144, the number of licensing deal I have information on, to be a lower bound on the total number of times the domestic marketing rights of these 149 tradenames have been transferred from one firm to another.

<sup>6</sup>Market size information from these interviews was cross referenced with Medicaid prescription drug information.



Association) website. The size of physician specialties represented in my sample varies from 2,452 physicians classified as Vascular Surgeons to 99,913 physicians classified as General Practitioners. Figure 6 shows the number of physicians in each of the twenty-five physician classes in my sample. The number of physicians in a physician specialty is used a proxy for the relative level of the marketing costs required to market a drug in that specialty.

## 4.2 Basic Summary Statistics

Many of the drugs in my sample treat multiple diseases. These 149 biotech drugs were classified into 182 indication classes treating different diseases/disorders. A product is defined as a firm, tradename, indication class combination. There are a total of 294 biotech products in my sample. Between one and four firms in my sample have products in a given market/indication class. On average there are 1.5 biotech drugs in each indication class and on average a total of 3 treatments for each indication.<sup>7</sup> Figure 5, presents a histogram of the number of biotech pharmaceuticals in a given indication class.

There are twenty-five physician classes that span the 182 indication classes treated by one of the biotech drugs in my sample. On average there are seven indication classes in each physician class, and there are on average 12 products in each physician class. Oncology, the physician class with the largest number of products, has 51 products. Figure 6 shows the allocation of biotech pharmaceuticals across physician classes.

Firms on average market 2 products in a given physician specialty however there is quite a bit of variation across physician specialties in the average number of products a firm markets in that specialty as shown in Figure 7. This figure displays the average number of products a firm in my sample markets in a given specialty conditional on it marketing at least one drug in that specialty. The relationship between how the number of products a firm markets in a specialty and the number of physicians in that specialty is not clear from this figure.

Not all products treat similar sized patient markets. In Figure 8, I examine how a firm's presence in a physician specialty varies with the number of physicians in that specialty. Recall, in my physician interviews I had physicians rank the diseases that are cared for by physicians in their physician

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<sup>7</sup>This number includes non biotechnology pharmaceuticals

specialty from 1-5 in terms of the frequency a typical physician in their physician class treats the disease; 1 is rare and 5 is common. In Figure 8 presence is defined as the sum of the market sizes of the diseases treated by drugs a firm markets in a physician specialty.<sup>8</sup> The average presence of a firm in a given physician specialty is plotted against the number of physicians in that specialty. From this figure we see that the average presence of a firm in a physician specialty varies widely and tends to increase with the size of the physician specialty; a firm is less likely to have a small presence in a physician specialty with a large number of physicians. This trend is consistent with importance of economies of scale in marketing increasing with the physician specialty size. This type of scatter plot can not separate out these economies of scale in marketing from the competitive pressures firms face or the advantages innovators may have when marketing their own innovations. In the next sections I will move towards estimating a model that will allow me to separate out these competing effects.

Finally before beginning my regression analysis I will show several more tables of summary statistics that display some of the basic patterns in the data. A potential marketer in these next two tables is defined as the innovator of the product as well as any other firm that currently markets any biotechnology pharmaceuticals. Tables 4 and 5 both show summary statistics of firm, product and the interactions between firm and product characteristics. In Table 4 the unit of analysis is an actual observed current marketer, product pair, while in Table 5 the unit of analysis is a potential marketer, product pair. By comparing these two tables we can learn about what variables predict which firm actually markets the product. From Table 4 we see the current marketer of a drug on average markets one other product in the same physician class, while Table 5 shows the average potential marketer markets 0.4 other drugs in the same physician specialty. Comparing these tables also shows the actual marketer of the drug is more likely to market other products that treat the same disease as the drug. Finally we see that 30% of products are marketed by the innovators of the drug. These tables suggest that a potential marketer is more likely to be the actual marketer of a drug if they innovated the drug, if they are marketing other products in the same physician class, and/or if they are currently marketing other products that treat the same disease.

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<sup>8</sup>As in the previous figure this is calculated conditional on a firm marketing at least one product in a physician specialty.

## 5 Descriptive Analysis

In this section I use logistic regressions to consider two related questions. The first estimation examines what variation in innovator characteristics and product market characteristics are associated with innovators marketing the products they innovate. In the second set of regressions the estimation is expanded to study how the interaction of firm and product characteristics predict which of the potential marketers end up with commercialization rights. Throughout this section the allocation of a single product is considered taking the allocation of all other products as fixed.

The results presented in this section are designed to be descriptive in nature; these preliminary results motivate the parametrization of the model used in my later estimation. Under assumptions discussed later, the estimates are also consistent estimators of the drivers of the differences in firms profits. The results in this section are qualitatively and quantitatively very similar to the results of my later estimation.

### 5.1 When do innovators keep the marketing rights of the products they innovate?

Less than one third of the products in the sample are marketed by the firms who innovated them. On average innovating firms have successfully innovated three to four products. In the first regression the probability an innovator keeps the marketing rights of the drug they innovate is estimated as a function of innovator and product characteristics using a logistic regression.

$$V_{i,innovator}^M = X_i\beta + \epsilon_i \tag{6}$$

The distribution of  $\epsilon_i$  is assumed to be type 1 extreme value, and  $X_i$  are characteristics of the product and innovator.

The dependent variable in Table 7 is a dummy which equals one if the innovator of the drug is currently marketing the drug. An observation is a unique combination of tradename, current marketer, and indication class. The coefficients represent how firm and market characteristics affect the probability the inventor keeps the marketing rights of a product.

There are three main findings from these regressions. First of all, innovators are more likely to market a product after they have already invented other products, consistent with the existence of cash constraints on new innovators. Secondly, the logistic results in Table 7 suggest innovators are more likely to enter markets when they are already marketing another product in the same physician specialty. In addition, as the potential market size of a drug increases, the importance that the innovator is already marketing another product in that physician class increases.<sup>9</sup> This is consistent with firms being able to economize on marketing costs by marketing multiple products in the same physician class.

Finally, the results show the level of competition in a market and in a physician class affect the valuation of an innovator from keeping the marketing rights for their innovation. As the number of biotechnology competitors in a market increases, the probability the innovator markets the product decreases. Similarly as the number of other biotechnology products in a physician class increases the probability an innovator markets the product decreases. Surprisingly, the number of non-biotech competitors in a market has no effect on the innovator's probability of marketing a drug.

This regression fails to take into account the valuations of all other potential marketers for a given product which I will do in the next section. From this regression we see that economies of scale at the physician class level, cash constraints faced by new firms, competition at the physician class level and competition at the product market level all seem to affect innovators choice of whether or not to license their product.

## 5.2 Which firm ends up with marketing rights?

The next set of regressions examine what characteristics of firms and products predict a high value match; conditional on the location of innovation and the characteristics of a product and potential marketers, I look for predictors of which firm markets the product. A potential marketer in this section is defined as the innovator of the product as well as any other firm that currently markets any biotechnology pharmaceutical. Therefore, an observation is a product potential marketer pair, and the regressors are firm characteristics and interactions between firm characteristics and product

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<sup>9</sup>Market size in these regressions is the ranking of the disease within the physician class (1-5) multiplied by the size of the physician specialty

characteristics. The dependent variable is a dummy variable that equals one if a firm markets a particular drug.

In the following regressions I assume that the firm with the highest marketing profit from a particular drug markets it. If we assume that a firm's marketing value from marketing drug  $i$  is:

$$V_{ij}^M = X_{ij}\beta + \epsilon_{ij}^M \quad (7)$$

Then if firm  $j$  markets product  $i$  that implies that  $V_{ij}^M$  is the maximum among all  $J$  firms' profits. Therefore the statistical model is driven by the probability that firm  $j$  markets product  $i$ :

$$Prob(V_{ij}^M > V_{ij'}^M) \forall j' \neq j \quad (8)$$

I assume also that  $\epsilon_{ij}^M$  is distributed iid type 1 extreme value and condition my estimation on one potential marketing firm marketing each product. Therefore, we have the McFadden choice model where (McFadden 1978):

$$Prob(Y_i = j) = \frac{e^{x_{ij}\beta}}{\sum_{k=1}^J e^{x_{ik}\beta}} \quad (9)$$

My estimation includes a product fixed effect. The characteristics of marketing costs that do not vary across the potential marketing firms of a given product fall out of the probability. Therefore, I cannot identify, for example, the effect of market size on the probability of a firm acquiring a drug but rather only how the effect of market size differentially affects small vs. large firms' probability of acquiring a drug.

The regressors are proxies for why one firm's profit from marketing a drug may be different from another firm's profit from marketing that same drug. In the first column of Table 8, these predictors are the number of other products that a firm markets in a physician specialty and whether or not they were the innovator of the drug. In addition, a dummy which controls for the fact that I do not have information about the portfolios of the large traditional pharmaceutical firms is included.

The second column of table 8, presents the results of repeating the above exercise while adding more covariates. Results from both columns of Table 8 show that having other drugs in a physician

specialty increases the probability of a firm marketing that drug, particularly in large markets. In addition these results suggest having other products in the same indication class increases a firm's probability of acquiring a drug, however this effect decreases with the number of other biotechnology products in that indication class. This is consistent with the idea that the incentive to deter entry decreases with the number of other products already in the market.

Similar to the results in the previous innovator regressions, innovators are more likely to market the products they invent especially as the number of approved products they have previously successfully innovated increases. This is consistent with the idea that new biotechnology firms face cash constraints keeping them from marketing their early innovations. After a new firm already has a source of cash flow from an approved drug, then these constraints are less binding.

In the regressions in Table 8, I also include a dummy for the large traditional pharmaceutical firms that controls for the fact that I do not have the full portfolios of these firms. The coefficient on this dummy is positive as expected.<sup>10</sup>

From these regressions I find that competitive effects at the physician specialty level and at the product market level seem to be important drivers of the differences in firms profits. In addition these regressions suggest that all other things equal innovators have higher valuation for the products they innovate and that this innovator's advantage increases as the firm has innovated more products. Finally these regressions suggest that firms are able to realize economies of scale in marketing at the physician specialty level.

## 6 Model Estimation

In the previous regressions the rest of the portfolio of a firm is assumed to be exogenous. If we believe a firm makes portfolio decisions jointly across products, this assumption is violated. The next part of the estimation employs a rank based matching estimator that does not require assumptions about the exogeneity of the rest of the portfolio.

In addition, the previous estimation does not fully take into account the rivalrous nature of the

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<sup>10</sup>All these results do not change qualitatively and change very little quantitatively if instead of a product fixed effect I add a market fixed effect and condition on the number of firms that enter a markets.

product firm match; if one firm markets a product they prevent another firm from marketing that product. Firms may care not only about whether or not they market a product but also who markets the product if they do not; by allowing another firm to enter a market an incumbent firm faces increased competition. In the following estimation I also make the additional assumption that there are no profitable bilateral trades of products in addition to assuming there are reallocations of single products.

The next section describes the parametrization of the value function of a firm from marketing a bundle of products and is followed by the empirical estimation strategy. Finally, the estimated parameters of the structural model are presented and used to demonstrate how competition in the licensing market varies across physician specialties and indication classes.

## 6.1 Parametrization of the Value Function

Define  $V_j^D$  to be the deterministic part of firm  $j$ 's value from marketing bundle  $B_j$  given an industry wide allocation  $B$ :

$$V_j(B) = V_j^D(B) + \sum_{i \in B_j} \epsilon_{ij} \quad (10)$$

I label the inherent profitability for a given product  $i$  as  $\alpha_i$ .  $I_{ij}$  is a dummy which indicates if firm  $j$  innovated product  $i$ , and I allow the innovator of a drug  $i$  to realize cost savings  $\theta$  from marketing their own invention. The magnitude of the innovator's advantage is allowed to vary with  $H_j$ , the number of approved drugs a firm has previously innovated

Again, I allow for two types of competitive effects in my estimation. First of all, firms may face competitive effects in the downstream product market; more competitors in a given indication class  $m$  may lower the profits a firm realizes from operating in that market. Therefore, if the number of products in a market is fixed, firms may have an incentive to decrease competition by acquiring multiple products in a given indication class preventing other firms from entering. I therefore allow a firm's value for marketing a drug to decrease log linearly in the number of other firms marketing a product in the same indication class  $F^m$ .

The second type of competition occurs at the physician class level; as there are more competitive

bidders for a given product in a physician class  $d$ , the share of producer surplus may shift towards the innovator. Hence marketers may have an incentive to acquire multiple drugs in a physician class in order to preserve their future market power in the licensing market. Although this effect is dynamic for now it will enter into the valuation equation a static way. I therefore allow a firm's value for marketing a drug to decrease log linearly in the number of other firms marketing a product in the same physician class,  $F^d$ .

In addition, a firm  $j$ 's costs from marketing a bundle of products in a given physician specialty  $d$  is allowed to vary both on the size of the physician specialty  $S_d$  as well as with sizes of the indication classes  $S_i$  these products treat. The number of physicians in a physician specialty enters the equation logarithmically. In addition  $\gamma$  scales the impact of the size of the physician class on overall marketing costs. If  $\gamma$  is estimated to be zero then that would be interpreted as the amount a firm can economize by marketing multiple drugs in the same physician specialty does not depend on the number of physicians in the physician specialty.

Marketing costs at the physician specialty level are allowed to increase nonlinearly, that is I allow for economies of scale in the marketing presence a firm has in a physician specialty. I also control for the fact that I do not have the full product portfolios of large traditional pharmaceutical firms by adjusting their portfolio sizes in all physician classes by a constant to be estimated;  $L$  is a dummy which equals one if a firm is a large traditional pharmaceutical firm. In my estimation I also allow for firms to realize decreasing returns to scale in the total number of total products they market  $|B_j|$ .

The total marketing cost  $M$  that a firm  $j$  incurs from marketing bundle  $B_j$  is:

$$M(B_j) = \sum_{d \in D} (\mu_1 ((\sum_{i \in B_j} S_i) + \mu_2 L) * \log(S_d)^\gamma) + \mu_3 ((\sum_{i \in B_j} S_i) + \mu_2 L) * \log(S_d)^\gamma)^2 \quad (11)$$

If there are economies of scale in marketing then  $\mu_3$  would be negative. The total deterministic value firm  $j$  has for marketing the bundle  $B_j$  given the market-wide allocation  $B$  is:

$$V_j^D(B) = \sum_{i \in B_j} (\alpha_i + \theta * I_{ij} + \beta_1 * I_{ij} * H_{ij} - \beta_2 \log(F_i^m) - \beta_3 \log(F_i^d) - M(B_j) - \beta_4^{|B_j|}) \quad (12)$$

Note that neither  $\alpha_i$  nor  $\mu_1$  can be identified using the estimation strategy used as the effects cancel



on each side of the inequalities used in estimation. In addition, there will need to be a normalization of one of the parameters in order to estimate the model.  $\theta$  is normalized to be equal to one and the parameters  $\beta_1, \beta_2, \beta_3, \beta_4, \mu_2, \mu_3$ , and  $\gamma$  are estimated.

## 6.2 Estimation Strategy

The empirical model is estimated using the set of pairwise stability inequalities following the methodology presented in Fox 2007.<sup>11</sup> I will find the parameter values which maximize the number of the pairwise stability inequalities that hold. The statistical consistency of the estimator depends on a non-parametric assumption on the joint distribution of firm product match specific error terms  $\epsilon_{ij}$  that I will discuss later.

### 6.2.1 Objective Function

Next I will describe the objective function used in estimation. I assume the observed distribution of products across firms is pairwise stable, and will use the revealed choice inequalities implied by that assumption in my estimation. Define  $\Theta_{j,k}^B$  to include the subset of all partitions of size  $J$  of the set of products  $I$  where firm  $j$  and firm  $k$  switch products from the allocation  $B$  or firm  $j$  increases (decreases) the size of its portfolio  $B_j$  and firm  $k$  decreases (increases) the size of its portfolio  $B_k$ . Looking across all pairs of firms I define  $\Theta^B = \bigcup_{j=1}^J \bigcup_{k=j+1}^J \Theta_{j,k}^B$ . Next I will define the parameter space as  $\Omega = \Re^m$  where  $m$  is the number of parameters to be estimated, and let  $B^*$  to be the observed allocation.  $V_j^D(B; \omega)$  is the deterministic value of firm  $J$  from allocation  $B$  given parameter values  $\omega$ . In my estimation I find  $\omega^*$ , where  $1[\cdot]$  is an indicator function:

$$\omega^* = \arg \max_{\omega \in \Omega} \left( \sum_{B \in \Theta^{B^*}} 1[V_j^D(B^*; \omega) + V_k^D(B^*; \omega) - V_j^D(B; \omega) - V_k^D(B; \omega) > 0] \right) \quad (13)$$

Note that this function is not smooth and therefore numerical techniques are used to find the parameters which maximize this equation. Following the recommendation of Fox (2007) the method known as differential evolution is employed to find the optimal parameter values.

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<sup>11</sup>Intuitively the estimator finds the parameters that maximize the number of local pairwise stability inequalities that hold given the observed allocation of products across firms without relying on the error term.

As mentioned before, using this estimation technique I will be able to identify the relative importance of different covariates on firms' valuations for bundles of products. An attractive feature of this estimator is that any drug specific omitted variables affecting all firms' valuations for that drug equally difference out of the previous inequalities and therefore do not bias the structural parameters. Using this estimation technique implies only effects that vary across allocations can be identified. Therefore, the part of a firm's value which is the same for all firms, the product fixed effect, will not be identified in my estimation.

### 6.2.2 Rank Order Condition and Asymptotics

Statistical consistency rests on the joint distribution of the firm  $j$  product  $i$  match specific error terms  $\epsilon_{ij}$  following the rank order condition. The rank order condition implies that for any two allocations  $B$ , and  $B'$  such that for some  $j, k$   $B_{-j,-k} = B'_{-j,-k}$  the following condition holds:

$$V_j^D(B) + V_k^D(B) > V_j^D(B') + V_k^D(B') \Leftrightarrow P(B) > P(B') \quad (14)$$

Where  $P$  is the probability to the econometrician that the allocation  $B$  is the observed market outcome.

The rank order assumption implies first that if every pair of firms prefers  $B$  to  $B'$  whenever the epsilons are zero then from an ex-ante perspective  $B$  is more likely to occur than  $B'$  after the epsilons are drawn and the pairwise stable outcome is selected, using an equilibrium selection rule if there are multiple pairwise stable equilibria. This assumption also assumes that if from an ex ante perspective  $B$  is more likely to occur than  $B'$  then every pair of firms must prefer  $B$  to  $B'$  if all the epsilons were zero.

If the pairwise stability inequalities hold,  $B'$  cannot be an stable allocation of the deterministic game, as there exists a deviation which would make two firms better off. In a stochastic game, both  $B$ , and  $B'$  may occur with positive probability. The local pairwise stability inequalities can be violated at allocations that occur with positive probability. However, as discussed in Fox (2007) when a given inequality is evaluated at the true parameter values an allocation that violates the inequalities is

assumed to be less likely to occur than a nearly identical allocation that satisfies the inequalities. In a game with multiple stable assignments, the rank order property will not hold if the selection rule selects assignment  $B'$  more often than  $B$ . Therefore the rank order assumption implies that the equilibrium selection rule cannot work to counteract the signal in the data.

The rank order property may not hold if the idiosyncratic match values are iid across firms and products. However, Fox (2007) and Bajari and Fox (2007) present evidence using Monte Carlo experiments suggesting that the bias imposed by assuming a firm product specific error term that is iid across firms and products is small especially when the number of agents in the market is large.<sup>12</sup> I have also performed several simulations using a simplified framework testing how the assumptions of the variance of the iid error term affect whether or not the rank order condition holds given the actual level of variance in firms' values predicted given my estimated structural parameters. These results are presented in an appendix. This simulation and previous Monte Carlo evidence suggests the assumption that the error terms are iid across firms and products, while does not imply the rank order condition will hold, in some cases should impose little bias on the estimates.

The asymptotics of the estimator are in the number firms observed in a very large market.<sup>13</sup> Confidence intervals are calculated using subsampling; successive parameter estimates are calculated using subsamples of marketing firms (and their entire product portfolios) drawn without replacement from the observed data (Politis, Romano, Wolf 1999). Consistency of this estimator under the previously described assumptions when only using a subset of necessary conditions is shown in Fox (2007). If we are worried that the allocation we observe in the market is actually determined by a stronger assumption about market outcomes, for example it is in the core, the estimates using the set of inequalities implied by the local pairwise stability assumption are still consistent. In addition I need not include all inequalities in order to obtain a consistent estimator, instead I must include enough inequalities so that the identification theorems outlined in Fox 2007 still hold and these inequalities must preserve the symmetry property also outlined in Fox 2007.

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<sup>12</sup>If instead we believe the error term is allocation specific and iid across allocations, or if there is a iid shock to each product (constant across firms) then the rank order condition holds.

<sup>13</sup>This asymptotic argument assumes we keep observing more and more firms in the market not that the true size of the market increases. In particular in my application, the literal assumption is the pharmaceutical industry is infinitely large and as I keep observing more and more firms (and their entire product portfolios) in this industry my coefficients will converge to their true values.

### 6.3 Estimates

In my estimation the set of potential marketers includes any firm that is currently marketing at least one biotechnology pharmaceutical. I do not include innovators who do not market any products as potential marketers as these firms may face constraints that I do not observe, or these firms may no longer exist. Hence the coefficient  $\theta$  on the innovator dummy is interpreted as follows: conditional on a firm being able to market at least one drug,  $\theta$  is the increase in value the innovator has compared to all other potential marketing firms for a product they have innovated .

There may be nonlinear costs to increasing the size of a firm's product portfolio rapidly as well as regulatory constraints which prevent multi-product trades or acquisitions of another firms entire product portfolio from occurring. I do not explicitly model these costs and therefore will only include a subset of inequalities implied by the pairwise stability assumption where these costs are likely not to play a large role. In particular in my estimation I only include those inequalities where some firm  $j$  sells one of their products to another firm  $k$  and those implied by the counterfactual trade between firm  $j$  and firm  $k$  of one product each allowing for an accompanying transfer of money between the two firms.

The point estimates with 90% confidence intervals are presented on Table 9. These estimates demonstrate as expected that profits decrease in the number of other firms marketing drugs treating the same indication and also in the number of other firms marketing products in the same physician specialty. In addition, my estimates show the presence of increasing returns to scale in marketing at the physician specialty level, and decreasing returns in the total number of drugs a firm markets. The innovator's advantage is the strongest effect determining the location of marketing, especially if the innovating firm already has approved drugs. The model was estimated using several specifications and the results are fairly similar across all specifications. Recall that the estimates are only identified up to a scaling term (the normalization of the coefficient on the innovator dummy  $\theta$ ).

For the last two columns in Table 9, I estimate the model using a subset of inequalities used in the previous estimation, namely only those that result from one firm acquiring a single product from another firm. This estimation uses a substantially smaller number of inequalities. When using this smaller set of inequalities my coefficients are not well identified as evidenced by the very wide

confidence intervals around some of the parameter estimates. This set of estimates helps me see to what extent each type of inequality (sales of single products and trades) are driving the identification of my point estimates. Qualitatively the point estimates are similar to the previous estimates.

In Table 10, I present average marginal effects. The values on this table are calculated by first taking the firm specific value (firm specific value excludes the product fixed effect recall is not identified) of all potential marketers of a product and comparing that with how much a firm's value would be for a product if certain product and market characteristics changed. The values presented in Table 10 are the average change in values across all potential marketers and all products.

### **6.3.1 Innovator's Advantage**

All effects are estimated relative to the magnitude of the innovators advantage. Recall the interpretation of this coefficient is the increase in value an innovating firm has for their innovation relative to all other firms conditional on the innovating firm marketing at least one drug. From the point estimates in Table 9 we see that consistent with the logistic regressions, as innovators innovate more products the magnitude of the innovator's advantage increases. This is consistent with new innovators facing cash constraints that are less important as they begin to receive revenue from previously approved products. When looking at Table 10 we see that if we look at the change in value of a firm from marketing a product if they were the innovator versus if they weren't the innovator, the increase in the firm's value is relatively large. My estimates demonstrate that when an innovator is developing a product and they are already marketing other products they are very likely to be the ultimate marketer of the product. If the innovator faces constraints which keep them from marketing a product they have innovated then other forces will guide which firm ultimately markets the drug.

### **6.3.2 Competitive Effects**

Competitive effects play an important role in the allocation of products across firms;  $\beta_2$  and  $\beta_3$  are negative and significant. As expected keeping firms out of the product market seems to be more important than deterring entry at the physician specialty level. A later section compares the size of this effect other competing forces to better understand the importance of competitive effects in

driving product location.

### 6.3.3 Economies of Scale

Economies of scale also help determine the ultimate marketer of a new innovation. My estimates demonstrate the presence of economies of scale when a firm markets multiple products in the same physician specialty. The importance of these scale economies increases in the number of physicians in the physician specialty prescribing the drug. In addition, my estimates suggest that firm's face diseconomies of scale in the overall number of products in their portfolio.

The point estimate of  $\mu_3$ , the coefficient on the squared term of the marketing costs, is negative indicating firms realize economies of scale when marketing multiple products in the same physician class. The estimate of the physician specialty scaling term  $\gamma$  is positive, demonstrating that marketing costs increase in the size of the physician specialty and the cost savings of a firm with multiple products in the same physician specialty versus a firms with fewer other products in the same physician specialty is larger when the number of physicians practicing in the specialty is larger. Finally  $\beta_4$  is greater than one indicating the presence of decreasing returns to scale in the total number of products a firm markets.

## 6.4 Comparing the Influence of Economies of Scale and Competitive Externalities in Driving Firms' Values

Figure 9 shows how the contribution of competitive externalities and economies of scale to potential marketers values vary across product markets and across physician specialties. A point in this figure indicates how a potential marketing firm's value for a product would vary with changes to the size of their marketing presence in a physician specialty and with changes to the number of competitors in an indication market. A point on the 90 degree line indicates the increase in value a firm would have from adding the product to their portfolio if they had three more average sized products in the same physician specialty is equal to their increase in value from adding the product to their portfolio if there was one less firm competing in the indication market.

From the parameter estimates we see all other things equal the contribution of scale economies is

larger in physician specialties with more physicians and the contribution of the competitive effects varies with the number of other firms already marketing competing products. Figure 9 compares products in two different sized physician specialties, Cardiology and Rheumatology, both with a physician specialty Herfindahl-Hirschman Index=.12 (calculated using the distribution of products marketed by any firm in my sample within a physician specialty). There are 21,117 board certified Cardiologists in the US and only 4,248 board certified Rheumatologists. This figure shows that in Cardiology the cost savings from economizing on marketing costs are a larger driving force than in Rheumatology. From this figure we also see there is substantial variation in the size of the competitive externalities a firm faces across product markets. As the size of the competitive effect is independent of the number of physicians in a specialty we see this effect dominates the effect of scale economies in specialties with fewer physicians.

## 6.5 Variation in Potential Marketing Firm's Values Across Product Markets

This subsection shows how potential marketing firms' values for adding a product to their portfolio varies with characteristics of the product market and physician specialty. Using the allocative mechanism described in subsection 3.3 as a framework, I consider a new innovation where the innovator of the drug decides to license the marketing rights of the product. Using my parameter estimates I show how potential marketers' values for a product vary while taking the location of all other products as fixed.<sup>14</sup>

Figures 10 and 11 show the ten potential marketers' values with the highest values for different products. In Figure 10 I show how the distribution of potential marketing firms' values shift with market size (number of patients with the disease the drug treats) of the drug. I compare two drugs in the same physician specialty treating different sized patient populations. The y-axis in these graphs measures firms' values for marketing a product net of any product fixed effects ( $\alpha_i$ ). I refer to the value on the y-axis as the firm specific value for a product. Firm specific values increase with the size of the patient population the product treats. This occurs because firms' marketing costs are concave

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<sup>14</sup>Potential marketer is defined as any firm currently marketing at least one biotechnology drug

in the firm's presence in a physician specialty. Notice also the difference between the first and second highest bidder is larger in the smaller market again due to the concavity of the cost function.

Figure 11 shows how firms' values for a product vary with the concentration of products across firms in the physician specialty. In this figure I compare two products which treat the same sized patient population but are in different physician specialties. Product A is in a physician specialty with an Herfindahl-Hirschman Index=.06 (calculated using the distribution of products marketed by any firm in my sample within a physician classes). The second product, product B, is in a physician specialty with HHI=.14. We see in the concentrated physician specialty the firm with the largest presence in this market has a strong incentive to acquire the product due to their ability to realize economies of scale and their incentive to deter entry by new firms into the physician class. The second highest bidder for product B has a much lower value for acquiring the drug. Therefore, even though the highest bidder for product B has a much higher value for the product than any other bidder for product A, the return to the innovator of product A may be larger in the less concentrated market.<sup>15</sup>

Figures 12 and 13 show how the difference between the potential marketer with the highest value and the second highest value for a product varies with product market attributes. In order to create these next figures, I first calculated each potential marketing firm's value for adding a given product to their portfolio assuming that product is the last product to be allocated. Then I calculated the difference between the potential marketer with the highest value and the second highest value for each product. Next, I took the average of that difference across every product in a given physician specialty. From these graphs we see that the difference in values between the firms with the highest and second highest valuations increase with the HHI of the physician class and the size of the physician specialty. An increase in the size of a physician class by 10,000 physicians increases the difference between the firm with the highest valuation and the firm with the second highest valuation by 2% on average.<sup>16</sup>

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<sup>15</sup>The total return also depends on the product fixed effect

<sup>16</sup>This calculation was made by first calculating the difference between the firms with the first and second highest valuation for each product and then recalculating firms valuations assuming there were 10,000 more physicians in every physician class. I then compare the original difference between the top two firms with the difference after the counterfactual increase in physician specialty size. Next I divide the difference by the size of the original difference of the top two firms for the product and take the average across all drugs in a physician specialty.



### 6.5.1 Interpretation of Results

Recall from section 3.3 in markets where the difference in potential marketers' values is largest, the threat of being help up in the licensing market decreases the incentives for innovation for innovators with low values for marketing the product themselves. My estimates show that the low marketing value innovators are those small startup innovators with no established cash flow and no marketing experience. My results also show small innovators face the greatest threat of holdup when innovating products that are prescribed by specialties with the most physicians and specialties where the distribution of products across marketing firms is most concentrated.

## 7 Conclusions

In this article, I empirically demonstrate how lack of competition in licensing markets depresses incentives for innovation for startup innovators in many large health care markets.

Using assumptions about the pairwise stability of the observed allocation of U.S. marketing rights for biotechnology pharmaceuticals, I analyzed a unique dataset collected from many sources to empirically estimate a structural model of potential marketing firms' profits. I find there are various factors driving the allocation of products across firms including: a firm's ability to realize economies of scale at the physician class level, competitive externalities at the product market level, and competitive externalities at the physician class level. In addition, my results suggest that innovators have an advantage over other firms in marketing their innovations, all other things equal, and this advantage increases as innovators have another established source of cash flow.

These results have several implications. First, these results provide an additional explanation for why as research has trended towards drugs treating smaller patient populations innovation increasingly occurs in small startup firms and why these small firms are today more likely than innovating firms in the past to keep the marketing rights for their innovations. The findings in this article also suggest that in addition to considering the effects mergers have on competition in the downstream product market, it is also important to consider the effects potential mergers may have on competition in the licensing market for new technology. In particular, a merger between two firms that do not compete

directly with each other in a given product market but are dominant in a given physician specialty may decrease the competitiveness of the licensing market for new products and therefore skew incentives for future innovation by small firms. This effect is especially important to consider when merging firms operate in the largest physician specialties.

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# Appendix

## A. Annual and 10-K reports

### AtheroGenics, Inc. 10-k, 2004

” We plan to collaborate with large pharmaceutical companies to commercialize product candidates that are for patient or physician populations in broad markets. We believe that collaborating with large companies that have significant marketing and sales capabilities provides for optimal penetration into broad markets, particularly those areas that are highly competitive. In contrast, we plan to develop a sales force to commercialize the products targeted at appropriate patient and physician populations in narrow markets. By using our own sales and marketing organization, we believe we can retain a higher percentage of the profits generated from the sale of our products.”

### Celgene 10-k, 2004

”This agreement is strategically valuable to us because it provides us with an approved oncology product that complements our drug candidates, Thalomid and Revlimid, which are demonstrating potential in late-stage clinical trials for the treatment of multiple myeloma and myelodysplastic syndromes. At the 2004 American Society of Hematology, or ASH, meeting, clinical trial data was presented. In combination with other anti-cancer therapeutics, including Thalomid, Alkeran was a key component of several investigational multiple myeloma studies which reported positive results. Sales and Commercialization-We have a 197-person U.S. pharmaceutical commercial organization. These individuals have considerable experience in the pharmaceutical industry, and many have experience with oncological and immunological products. We expect to expand our sales and commercialization group to support products we develop to treat oncological and immunological diseases. We intend to market and sell the products we develop for indications with accessible patient populations. For drugs with indications involving larger patient populations, we may partner with other pharmaceutical companies. In addition, we are positioned to accelerate the expansion of these sales and marketing resources as appropriate to take advantage of product in-licensing and product acquisition opportunities.”

### MedImmune Annual Report 2005

”Was the impetus for your 2005 decision to buy out the U.S. co-promotion rights to Synagis from Abbott Laboratories to help assure MedImmune’s future earnings growth whether or not Numax is developed successfully?

In short, yes; but this transaction has other strategic benefits for MedImmune. First, we believe that sales of Synagis will benefit from having one focused and fully committed sales force. We believe that at this stage of the product’s life cycle, a single owner of all commercial and development decisions is a more efficient way to sell the product, service our customers and optimize patient care. Second, by using this opportunity to

fund the expansion of our pediatric sales organization in 2006, we can more adequately prepare for the continued growth of our overall pediatric infectious disease business. Third, restructuring our co-promotion arrangement with Abbott helps us provide for a smoother transition and more positive ending of the strong collaboration we have had since 1998 with Abbott in the United States. Overall, the partnership has been a successful working arrangement, beneficial to both companies and to the product's ultimate success. Finally, the most obvious benefit of buying back our rights to Synagis is that we no longer will pay more than \$200 million in annual co-promotion fees to Abbott after 2006. Previously, we needed Numax to succeed to eliminate this expense."

## B. Simulation Results

In the following simulation I look to see how relationship between the variance of an iid firm product random shock and the level of variation in the deterministic variables, affect when the rank order condition holds. There is not a proof about the tradeoff between the standard deviation of the error term and the standard deviation of the deterministic values of firms for a given product so I have performed some basic simulations to examine this tradeoff given the estimated variance of the deterministic values of firms in my sample.

I consider the allocation of three products across three firms without externalities. I find that when the standard deviation of firms' values is comparable to the standard deviation of the error term then the rank order condition holds in simulations. On the other hand, when the standard deviation of the error term is much larger than the standard deviation of the deterministic values of firms the rank order condition is violated. In my simulation these violations are rare.

My structural estimation suggests the mean standard deviation in firms' values for products is .78. Using this number I first make three draws of a product's value. I repeat this three times. I then have a data set of three firms values for three different products. Using this I can rank all possible allocations in terms of the deterministic values firms have for that allocation. I only consider allocations where each firm has one product. There are 6 possible allocations.

Next I assume the firm product match specific error is distributed normally with mean zero and standard deviation  $\sigma$  which I vary. For a given standard deviation, using 1,000,000 random draws of nine firm product match specific errors, I numerically calculate the probability of each allocation occurring. Next I look to see if the rank order condition holds, that is the deterministic value of a

given allocation A is greater than the deterministic value of allocation B if and only if the probability of allocation A is greater than the probability of allocation B.

For each value of  $\sigma$  I repeat the above process 5 times for 5 different draws of deterministic product values. The values of  $\sigma$  I use are: .78, 1.5 and 8. I find that for all 5 draws of product values the rank order condition holds when  $\sigma$  is equal to .78 and 1.5. When  $\sigma$  is equal to 8 the rank order condition holds 4 out of 5 times and is only violated when deterministic product values are very close.

Table 1: Outcomes of Biotechnology Pharmaceutical Innovators with 1+ Approved Drugs

<b>Firm Status</b>	<b>Number of Firms</b>
Operating	31
Acquired	34
Merged	7
Bankrupt	1
<i>Total</i>	<i>73</i>

Firm Status in July 2006 of 73 (out of 100 total) Innovators of Approved Biotechnology Pharmaceutical Drugs. Firm status information comes from company websites, press releases, and Recombinant Capital Database.

Table 2: Number of Approved Biotech Pharmaceuticals Successful Innovators Control Marketing Rights for at time of Merger or Acquisition

<b>Number of Products</b>	<b>Firms</b>
0	14
1	17
2	5
3	3
4	2
<i>Total</i>	<i>41</i>

Sample of firms are the 41 innovators with at least 1 approved biotechnology drugs (out of 73 total innovators information was available for -Table 1) who either merged or were acquired by another firm prior to July 2006. Information comes from press releases and company 10-k reports.

Table 3: Number of Indications treated per tradename

<b>Indications Treated</b>	<b>Tradenames</b>
1	67
2	67
3	7
4	6
5	1
6	1
<i>Total</i>	<i>149</i>

Information comes from Physician Interviews and FDA website. An indication is defined as a particular condition that the drug treats ex. rheumatoid arthritis.

Table 4: Summary Statistics: Product Level

Variable	Mean	Std.Dev	Min	Max
The innovator is the current marketer of the drug	0.3	0.46	0	1
Number of other products current marketer also markets that are prescribed by physicians in the same physician specialty	0.89	1.29	0	6
Number of other products current marketer also markets treating the same disease	0.25	0.68	0	5
Relative size of patient population with the disease the product treats within physician specialty	3.14	1.5	1	5
Number of physicians in the physician specialty that prescribes the drug	21,425	27,726	2,452	99,913
Log(Relative disease size within Phy. Specialty * Physician Specialty Size)	10.46	1.02	7.8	13.12
Number of other Biotech Products treating the same disease	1.18	1.18	0	4
Controls for Non-Biotech Products treating the same disease	1.2	0.2	0	3
Large Traditional Pharmaceutical firm currently markets the drug	0.15	0.36	0	1
Observations=294				

Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. Drugs were classified into physician specialties and disease/indication classes through physician interviews.

Table 5: Summary Statistics: Potential Marketer \* Product Level

Variable	Mean	Std.Dev	Min	Max
Potential marketer was the innovator of the drug	0.014	0.120	0	1
Number of other products potential marketer also markets that are prescribed by physicians in the same physician specialty	0.39	0.86	0	6
Number of other products potential marketer also markets treating the same disease	0.022	0.180	0	5
Relative size of patient population with the disease the product treats within physician specialty	3.14	1.50	1	5
Number of physicians in the physician specialty that prescribes the drug	21,418	27,672	2,452	99,913
Log(Relative disease size within Phy. Specialty * Physician Specialty Size)	10.46	1.02	7.8	13.12
Number of other Biotech Products treating the same disease	1.18	1.18	0	4
Controls for Non-Biotech Products treating the same disease	1.20	0.82	0	3
Large Traditional Pharmaceutical firm currently markets the drug	0.12	0.31	0	1
Observations=20,448				

Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. A potential marketer is defined as any firm currently marketing at least one biotechnology pharmaceutical or is the innovator of the product. An observation is a potential marketer, product combination. Drugs were classified into physician specialties and disease/indication classes through physician interviews.



Table 6: Summary Statistics: Disease Class

Variable	Mean	Std.Dev	Min	Max
Relative size of patient population with the disease the product treats within physician specialty	3.03	1.49	1	5
At least one drug that treats the disease is marketed by the innovator of that drug	0.42	0.50	0	1
At least one large traditional pharmaceutical firm is marketing a product treating the disease	0.24	0.43	0	1
Number of other Biotech Products treating the same disease	0.76	1.05	0	4
Controls for Non-Biotech Products treating the same disease	1.20	0.81	0	3
<i>Observations=182</i>				

Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. An observation is as an disease/indication class. Drugs were classified into physician specialties and disease/indication classes through physician interviews.

Table 7: Logistic Regression: Innovators Probability of Marketing their Innovation: *Excludes products innovated by Large Pharma*

Innovator Markets Product	dy/dx	Std. Error	P> z
<i>Cash Constraints</i>			
Number of Products with FDA Approval Firm previously Innovated	0.014	0.010	0.15
<i>Market Size= Size of Physician Specialty*Relative Market Size</i>			
Log of the Size of the Market	-0.017	0.030	0.57
<i>Scale Economies</i>			
Number of other Products Firm Markets in the same Physician Class	0.08	0.04	0.08
Firm markets at least one other product in same Physician Class * Log(Market Size)	0.03	0.01	0.00
<i>Competition</i>			
Number of Other Biotech Products in Indication Class	-0.045	0.026	0.06
Controls for Non Biotech Products in Indication Class	0.04	0.03	0.25
Number of other Biotech Products in Physician Class	-0.004	0.001	0.02
<i>Observations=288</i>			$R^2=0.21$

Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. An observation is a product. Products innovated by large pharmaceutical firms are excluded from the regression.

Table 8: Conditional Logistic Estimates

Firm and Product Match	Odds		Odds	
	Ratio	Std. Error	Ratio	Std. Error
<i>Innovator Advantage</i>				
Firm is the Innovator				
Firm is Innovator * Number of Previously Innovated Products with FDA approval	36.87	(5.05)	15.74	(3.09)
			1.23	(0.06)
<i>Scale Economies</i>				
Number of other Products Firm also markets in same Physician Class	1.55	(0.07)	1.16	(0.11)
Firm markets at least one other product in same Physician Class * Log(Market Size)			1.06	(0.03)
Firm is Large Traditional Pharma	2.07	(0.35)	2.08	(0.35)
<i>Competition</i>				
Number of other Products Firm also markets in same Indication Class			2.92	(0.69)
Firm markets at least one other product in Indication.* Number of Other Biotech Products in Ind.			0.75	(0.13)
Firm markets at least one other product in Indication * Controls for Non-Biotech Products in Ind.			1.20	(0.32)
<i>Observations=20,448</i>	$R^2=0.20$		$R^2=0.24$	

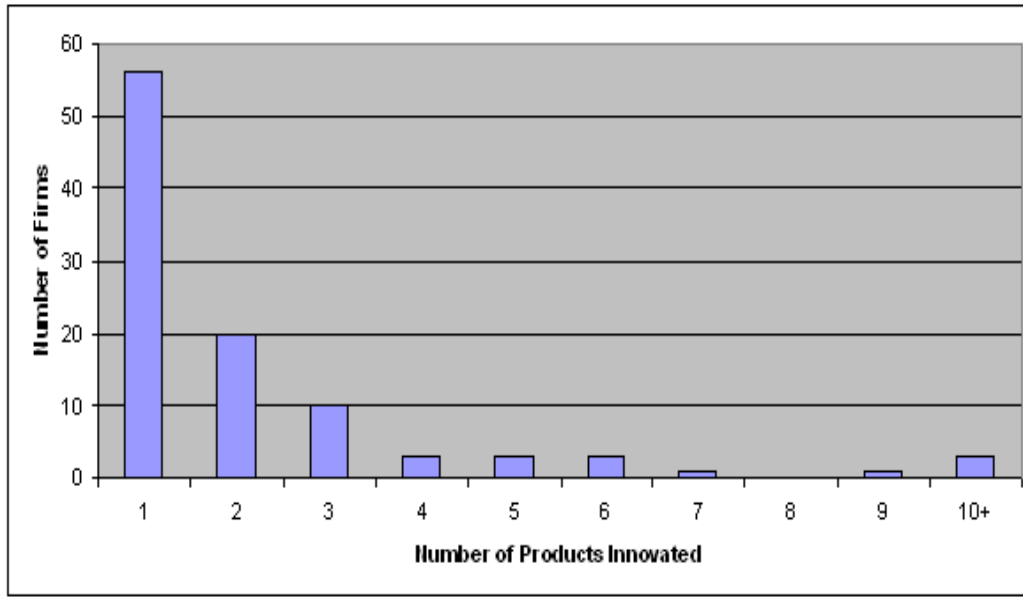
Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. A potential marketer is defined as any firm currently marketing at least one biotechnology pharmaceutical or is the innovator of the product. An observation is a potential marketer, product combination. The regression includes product level fixed effects, and is conditioned on only one of the potential marketing firms marketing the product. The table presents odds ratios. The interpretation of a coefficient on a variable A equal to X is: the odds of being the marketer of the drug given a change in the characteristic A are X times as large than before the change.

Table 9: Market Allocation Estimates

Firm Value Function Parameter	Coeff	90% Conf. Int.	Coeff	90% Conf. Int.	Coeff	90% Conf. Int.	Coeff	90% Conf. Int.
<i>Innovators Advantage</i>								
Innovator Dummy -Normalization - $\theta$	1		1		1		1	
# of approved drugs innovator previously innovated - $\beta_1$	0.582	[ 0.332, 0.772 ]	0.669	[ 0.278,0.755 ]	0.1106	[ 0.0318, 0.4517 ]	0.5642	[ 0.142,0.567 ]
<i>Scale Economies</i>								
Dummy for Large Traditional Pharma - $\mu_2$	5.35	[ -3.27, 11.85 ]	3.30	[ -0.71,7.56 ]	53.23	[ 8.29, 109.35 ]	28.204	[ 7.24,32.11 ]
(Marketing Costs Scaled by Indication Size) <sup>2</sup> - $\mu_3$	-0.00012	[-0.0002, 0.0000]	-0.00002	[-0.0002,-0.00001]	-0.000041	[-0.0010, -0.0000]	-0.000176	[-0.0009,-0.0000]
Log(Physician Class Size) Scale - $\gamma$	0.059	[ 0.023, 0.242 ]	0.396	[ 0.088,0.511 ]	0.111	[ 0.044, 6.09 ]	1.325	[ 0.325,8.06 ]
Firm Diseconomies - $\beta_4$	1.11	[ 1.05,1.19 ]	1.13	[ 1.06,1.15 ]	1.100	[ 1.03,1.13 ]	1.084	[ 1.03,1.13 ]
<i>Competition</i>								
Log(Number of Other Firms in Indication Class) - $\beta_5$	-0.041	[ -0.1382, -0.0061 ]	-0.041	[-0.0949,-0.0145]	-0.078	[ -0.492, -0.029 ]	-0.09	[ -0.464,-0.040 ]
Log(Number of Other Firms in Physician Class) - $\beta_6$	-0.026	[-0.0976, 0.0124]			-0.165	[ -11.92, 0.86 ]		
<i>Inequalities Used in Estimation</i>								
Single Product Portfolio Inc/Dec & Trades of Single Products	84.13%			84.06%			Single Product Portfolio Inc/Dec Only	
% of Inequalities Correctly Predicted							79.14%	

90% Confidence Intervals are presented and were calculated using subsampling by firm product portfolio. Subsampling uses 300 replications, 40 firm portfolios per replication and a convergence rate of  $\sqrt{firms}$ , as shown by Sherman (1993). Data comes from physician interviews, Recombinant Capital Database, as well as from FDA, company and AMA websites. A product is defined as a current marketer, tradename, indication class combination. A potential marketer is defined as any firm currently marketing at least one biotechnology pharmaceutical. Estimation uses a matching estimator (Fox 2007).

Figure 1: Size Distribution of Innovators



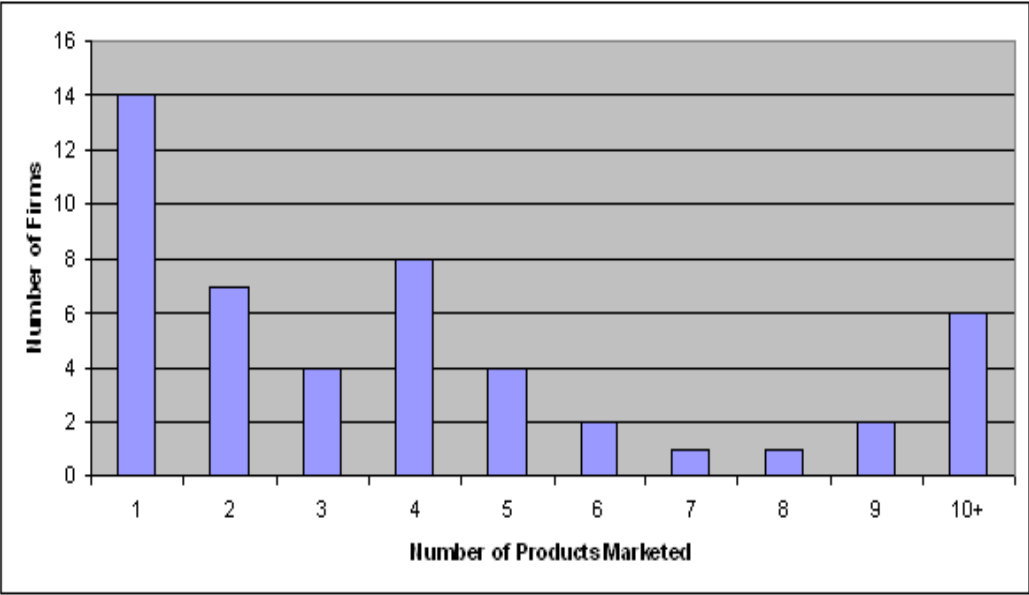
Data comes from company websites, and Recombinant Capital database. A product is defined as a current marketer, tradename, indication class combination. The innovator is defined as the firm which had control of marketing rights when the product entered phase 1 FDA trial.

Table 10: Average Marginal effects

Variable	Average Change in Potential Marketers' Values for Acquiring Product
Increasing Physician Class Portfolio Size by three Average Sized Products	0.010
Increasing Competition in Physician Class by one firm	0.014
Increasing Competition in Indication Class by one Firm	0.015
Innovator Advantage	1.000
Increasing # of Products Firms Previously Innovated by 1 (if Innovator)	0.582
Average Firm Specific Value	-0.50

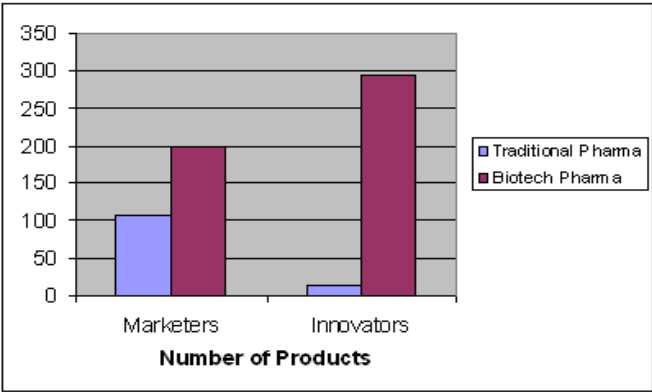
Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. A potential marketer is defined as any firm currently marketing at least one biotechnology pharmaceutical. Estimation uses a matching estimator where the inequalities used in estimation come from the assumption of the pairwise stability of the observed allocation. Inequalities used in estimation include firms making trades of single products or firms adding (decreasing) the size of their portfolios by one product. Average marginal effects are calculated using full estimation (8 parameters). For every product I first calculate the change in a potential marketing firm's value for a product they would experience if there was a change in a given characteristic of the firm or product. Then the average of these values across firms and products are calculated.

Figure 2: Product Portfolio size of Marketing Firm: *Excluding large traditional pharmaceutical firms*



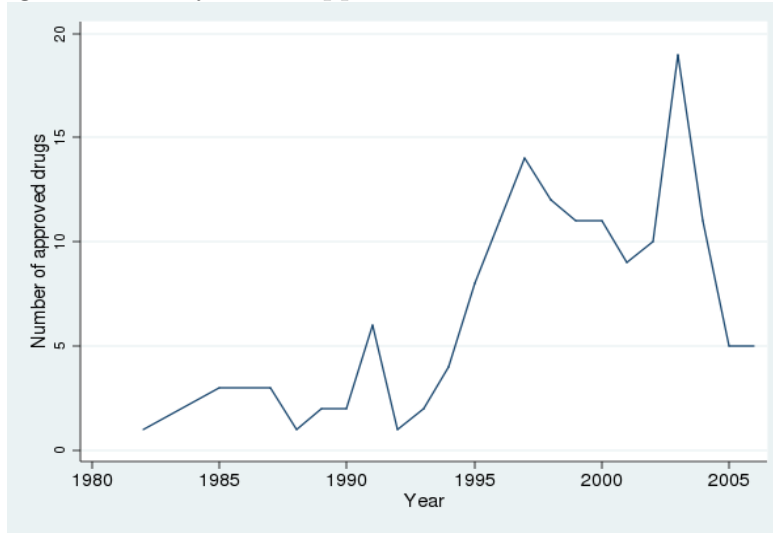
Data comes from company websites, and Recombinant Capital database. A product is defined as a current marketer, tradename, indication class combination. A marketing firm is defined as a firm who had control of US marketing rights in July 2006 of at least one biotech product. Their product portfolio is all of the products they market in the US in July 2006.

Figure 3: Innovation and Marketing by Biotech and Traditional Pharmaceutical Firms



Data comes from company websites, and Recombinant Capital database. A product is defined as a current marketer, tradename, indication class combination. The innovator is defined as the firm which had control of marketing rights when the product entered phase 1 FDA trial. The marketer is defined as the firm who had control of US marketing rights in July 2006.

Figure 4: Yearly FDA Approval of Biotech Pharmaceuticals



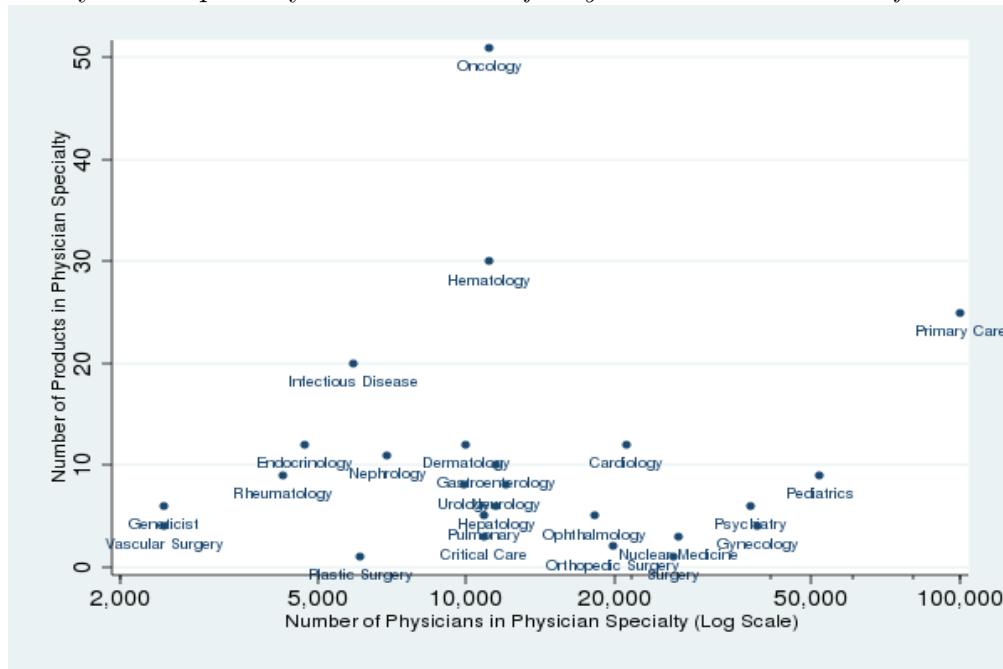
Data comes from FDA website. Approval date is the first date a tradename was approved for any indication by the FDA.

Figure 5: Histogram: Distribution of Products across Indication Classes



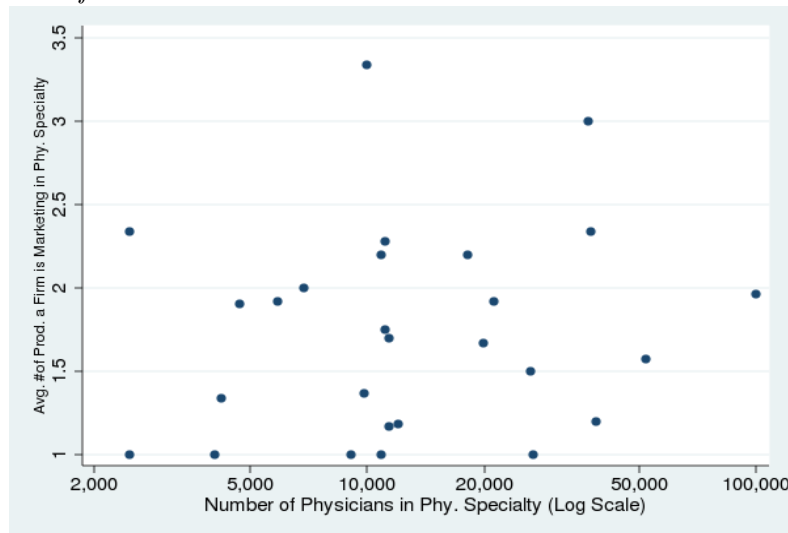
Data comes from physician interviews, FDA website, AMA website, Micromedex, and Uptodate. Which products treat the same indications was verified through physician interviews. All products marketed by any firm (excluding large traditional pharmaceutical firms) currently marketing at least one biotechnology pharmaceutical are included in this figure. Other treatments for a given indication not marketed by a firm in my sample are not included. Drugs in the same indication/disease class compete with one another to be prescribed by a physician when a patient has a particular disease or disorder.

Figure 6: Physician Specialty Size: *Number of Physicians and Number of Biotech Drugs*



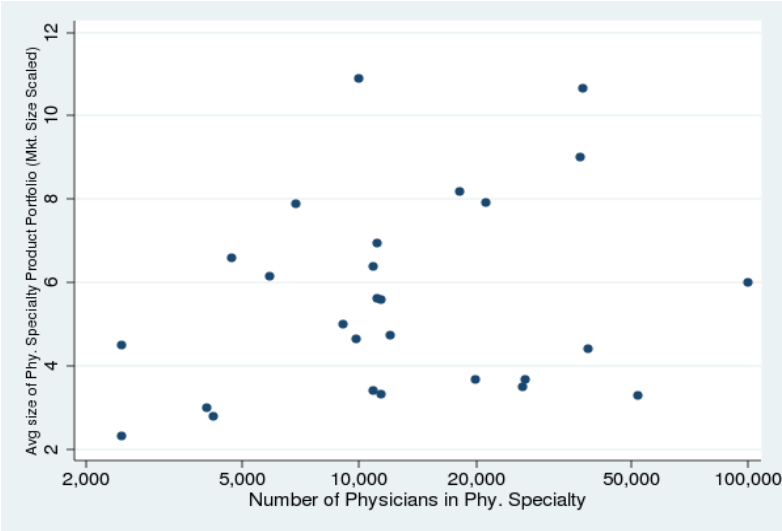
Data comes from physician interviews, FDA website, AMA website, Micromedex, and Uptodate. A product is defined as a current marketer, tradename, indication class combination. The indications that a product are prescribed for were classified into the physician specialties which typically treat the indication through interviews with physicians. All biotech drugs in any firm in my sample's portfolio (excluding non-biotech products marketed by large traditional pharmaceutical firms) are included in this figure.

Figure 7: Average Number of Products a Firm Markets in a Physician Specialty: *Excluding large traditional pharmaceutical firms*



A point on this figure is the average number of products a firms in my sample is marketing conditional on it marketing at least one product in that physician specialty. Data comes from physician interviews, FDA website, AMA website, Micromedex, and Uptodate. A product is defined as a current marketer, tradename, indication class combination. The indications that a product are prescribed for were classified into the physician specialties which typically treat the indication through interviews with physicians. All drugs in any firm in my sample's portfolio (excluding large traditional pharmaceutical firms) are included in this figure.

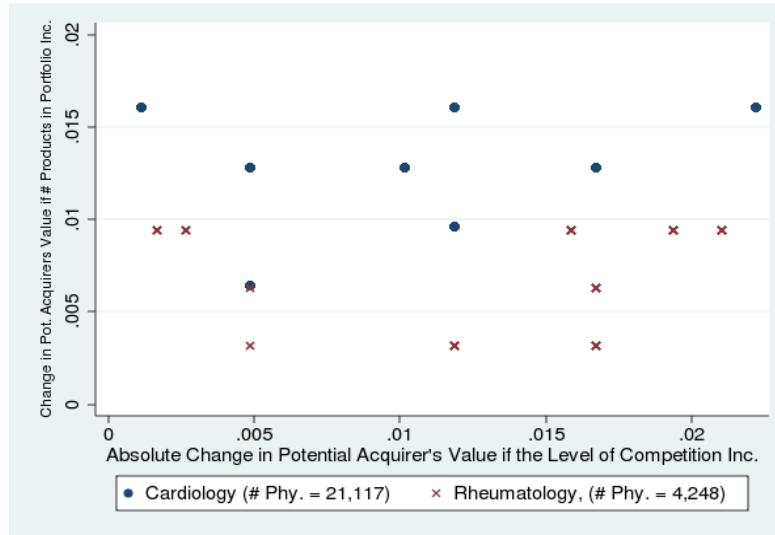
Figure 8: Average Physician Specialty Presence of Marketing Firm: *Excluding large traditional pharmaceutical firms*



The size of a firms physician class presence is defined as the number of products a firm is marketing in a physician specialty scaled by the prevalence of the disease the drug treats, that is if a firm owns the product market rights to five drugs that treat very rare diseases or one drug that treats a very large common disease their presence in that physician specialty is the same. A point on this figure is the average presence of firms in my sample that are marketing at least one product in that physician specialty. Drugs are classified into the physician specialty that most frequently treats the disease that a given drug treats and then are ranked by prevalence within a physician specialty. Data comes from physician interviews, FDA website, AMA website, Micromedex, and Uptodate. A product is defined as a current marketer, tradename, indication class combination. The indications a product are prescribed for were classified into the physician specialties typically treating the indication through interviews with physicians. All drugs in any firm in my sample’s portfolio (excluding large traditional pharmaceutical firms) are included in this figure.

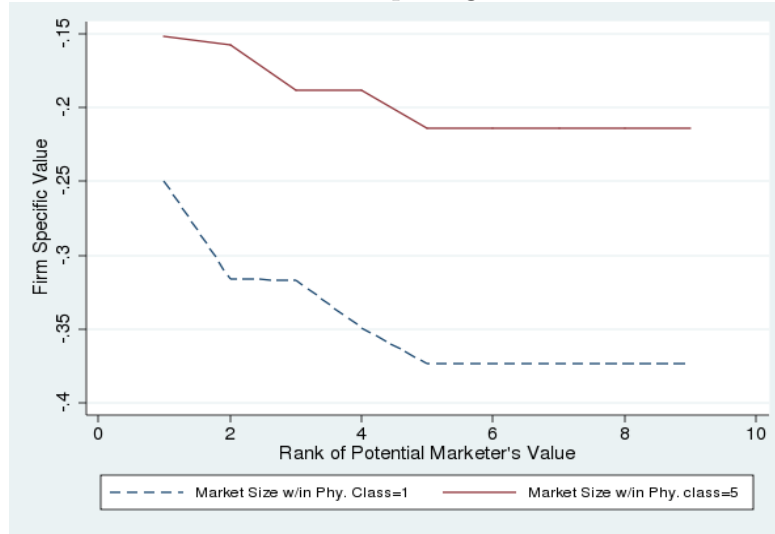


Figure 9: Comparing the Influence of Economies of Scale and Competitive Externalities in Driving Firms' Values



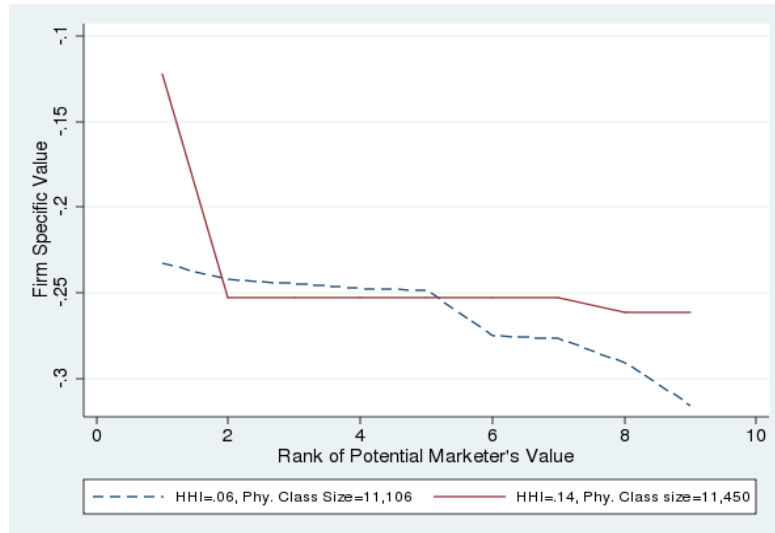
Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. A potential marketer is defined as any firm currently marketing at least one biotechnology pharmaceutical. Estimation uses a matching estimator where the inequalities used in estimation come from the assumption of the pairwise stability of the observed allocation -inequalities used in estimation include firms making trades of single products or firms adding (decreasing) the size of their portfolios by one product. Average marginal effects are calculated using full estimation (8 parameters). Firm specific value is the marginal value a firm has for a product minus a product fixed effect ( $\alpha_i$  and the linear part of the cost function). For each product in each specialty I calculate the change in a potential marketing firm's value for a product they would experience if there were changes to characteristic of the firm or product. The Y axis represents the change in value each potential marketing firm would experience if the size of their portfolio in that physician specialty increased by 3 average sized products. The X-axis represents the change in value each potential marketing firm would experience if the number of firms in the market increased by 1. For points below the 90 degree line product market competitive effects are larger than economies of scale in marketing. The red points represent firms values for a Rheumatology product and the blue points represent Cardiology.

Figure 10: Potential Marketer's Value for Acquiring New Product: Variation in Market Size



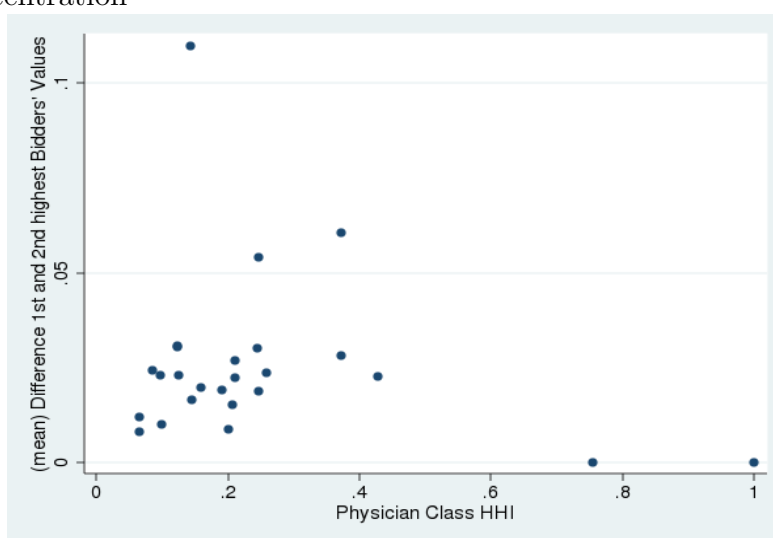
Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. A potential marketer is defined as any firm currently marketing at least one biotechnology pharmaceutical. Firm specific value is the marginal value a firm has for acquiring a product from the current marketer minus a product fixed effect ( $\alpha_i$  and the linear part of the cost function). For every potential marketer of each product the firm specific value of the potential marketer for adding the product to their portfolio is calculated taking the allocation of the rest of the products as fixed. Parameter values used to calculate firms specific values were estimated using full matching estimation (8 parameters).

Figure 11: Potential Marketer's Value for Acquiring New Product: Variation in Physician Class Concentration



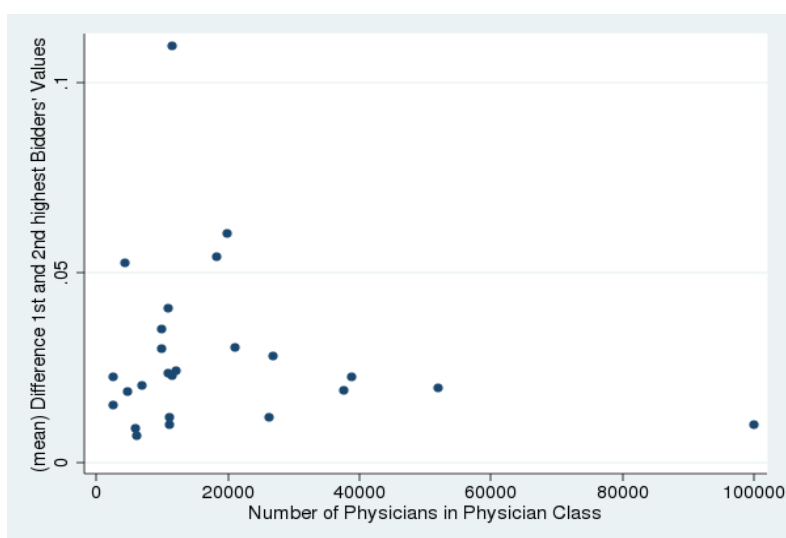
Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. A potential marketer is defined as any firm currently marketing at least one biotechnology pharmaceutical. Firm specific value refers to the marginal value a firm has for acquiring a product from the current marketer minus a product fixed effect ( $\alpha_i$  and the linear part of the cost function). For every potential marketer of each product the firm specific value of the potential marketer for adding the product to their portfolio is calculated taking the rest of the products as fixed. Parameter values used to calculate firms specific values were estimated using full rank based matching estimation (8 parameters). HHI is calculated using the distribution of all the products marketed by any firm in my sample in a physician class weighting their market presence by the relative market size of the drugs within that physician class.

Figure 12: Average difference between 1st and 2nd Firm's Value for Acquiring Product: Sorted by Physician Class Concentration



An observation this graph is a physician class. Each point represents the average difference between the highest and second highest potential marketer's value for adding a product in that physician class to their current portfolio. Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. A potential marketer is defined as any firm currently marketing at least one biotechnology pharmaceutical. Parameter values used to calculate firms values were estimated using full rank based matching estimation (8 parameters). Each potential marketer's value for adding each product was calculated and the difference between the firms with the first and second highest valuation was calculated. The mean of this value across all products in the physician class was then calculated.

Figure 13: Average difference between 1st and 2nd Firm's Value for Acquiring Product: Sorted by Physician Class Size



An observation this graph is a physician class. Each point represents the average difference between the highest and second highest potential marketer's value for adding a product in that physician class to their current portfolio. Data comes from physician interviews, Recombinant Capital Database, the FDA website, company websites and the AMA website. A product is defined as a current marketer, tradename, indication class combination. A potential marketer is defined as any firm currently marketing at least one biotechnology pharmaceutical. Parameter values used to calculate firms' values were estimated using full rank based matching estimation (8 parameters). Each potential marketer's value for adding each product was calculated and the difference between the firms with the first and second highest valuation was calculated. The mean of this value across all products in the physician class was then calculated.