

Patent Breadth and the Pharmaceutical Market

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Abstract:

Patents are viewed as instruments that protect innovation and influence welfare. How strong a country should protect innovation in order to increase welfare? A broad breadth protects the initial innovation but will discourage follow-up innovations based on that. A change in the legal system (narrowing the patent breadth) will change the market structure. On the other hand demand (medical needs) is important in determining what products will be available on the market. Can multinational firms and local manufacturers coexist in the market? A narrow patent breadth will allow domestic firms to exist and localize the multinational drugs to domestic needs.

1. Introduction

Product diversity and imperfect competition are present in many markets. The Hotelling model has been an important foundation on which to build a theory of location in product characteristic space. Hotelling analyzed the behavior of duopolists locating a single store on a bounded straight line. He made the point that the concept of location choice can be thought of in the same way as the concept of a product characteristic. The choices that firms face in locating in the geographical space are the same choices that firms face in choosing product quality. Hotelling assumed that in his problem the duopolists are able to make costless relocations, attaining a noncooperative equilibrium in the center of the market. Costless relocation is a strong assumption whether we think of the geographical space (moving the plant) or the product characteristic space (implementing a new technology to produce a new good). Relaxing this assumption is important especially when we think about a sequential entry model. In this case, firms have to choose their location in the market anticipating the decision of firms entering later on. This will also be useful in endogenizing the number of firms in the market. A variation of the Hotelling Model is the circular road model of product differentiation developed by Eaton et. al. (1975). This model helps avoid problems regarding strategical location of firms at/close to the corners of the market.

In general, models developed on Hotelling's foundation consider that firms can choose any product variety without any effort. In this paper, product differentiation will be the result of research and development. A firm developing successful innovation can obtain a patent, and thus will get monopoly rights (for a limited amount of time) for a certain interval in the product space. If we allow imitation, firms can invest into imitation in order to develop their products (instead of innovating). The closer the firms are to the innovator the easier is for them to imitate the product. Innovations are protected by patents. An increase in patent breadth prevents imitating firms from moving close to the innovator.

Patents are policy instruments meant to protect and promote innovation. Once a new product is developed, patents will constrain competitors from imitating that product. This will allow the innovator to gain enough profit to cover its research and development costs. Without this protection inventors may decide against innovating. Following this reasoning, an industry with weak patent protection should be less innovative than an industry with strong patent protection. Then, how could an industry with weak patent protection (like the Indian pharmaceutical industry)

become so innovative? In such industries, the initial innovation promotes follow-up innovations. Competitors are applying their ideas to the initial innovation increasing the pace of invention. In such industries, a stronger protection may reduce innovation and welfare.

Encaoua, Gullec and Martinez (2006) in a survey of recent patent policies noticed that some countries have experienced a weakening of the standard criteria for granting patents, and a tendency to grant patents with broader scope in the past few years. These actions might have detrimental effects on competition and follow-on invention. Changes to patent regimes should be implemented carefully based on an analysis of their economic impacts on welfare, on innovation and on technology transfer. Emphasizing the use of patents as a policy instrument would reinforce their status by highlighting the benefits they bring to society and help prescribe a careful design and implementation of the rights they confer to inventors. Economic research in the area of patents is not new, but it has expanded considerably in the recent years.

This paper aims to formulate policy recommendations regarding the optimal patent breadth for drugs. The analysis is based on a Hotelling location game with international trade between two countries: North and South. In the South there is no patent protection but there will be a legislation change that would impose patent protection (with a certain patent breadth). Northern firms are competing in both markets, while Southern firms compete only on their domestic market. When a firm in the North chooses its position in the Northern market, it will keep the same position in the Southern market (it is too costly to localize the product). The equilibrium will describe product diversity in the two markets, and firm location.

Section 2 provides a brief summary of previous findings in the literature and section 3 discusses an example from the HIV drugs market. Section 4 lays out the model. Section 5 concludes and outlines future research directions.

2. Literature review

2.1 The Hotelling Model

Hotelling (1929). Two plants sell a homogeneous product to consumers located (uniform distribution) in the interval $[0, l]$. Consumers are distributed uniformly along this interval. The firms have equal marginal cost and there are no fixed costs. Prices are fixed and firms choose location in order to maximize profits (market share, in this case). Consumers buy from the nearest firm.

Initially, it is assumed that firms choose different locations. Firm 1 chooses location z_1 and firm 2 chooses z_2 , where $z_1 < z_2$. Then, firm 1's market share is:

$$S_1 = \frac{z_1 + z_2}{2l}$$

Firm 2's market share is:

$$S_2 = 1 - S_1 = \frac{2 - z_1 - z_2}{2l}$$

Prices are constant and do not depend on the distance between consumers and the firm. To maximize its profits, firm one will move towards firm 2 in order to acquire more clients from firm 1 (if firm 1 is located in the second half of the interval) or jump over firm 1 and position to its left (if firm 1 is located in the first half of the interval). Then, the best position for firm 1 would be the middle of the interval, and firm 2 will locate at the same position. The unique equilibrium is $z_1 = z_2 = \frac{l}{2}$. This result is called *the principle of minimum differentiation*. This equilibrium still holds for constant transportation costs, but it will not minimize the aggregate transportation cost. The location that minimizes this cost is $z_1 = \frac{l}{4}$ and $z_2 = \frac{3l}{4}$.

2.2 Location of a given number of firms

Eaton and Lipsey (1975). With only one firm in the market, the location of the firm is uncertain. With two firms in the market, they have to be paired (both are peripheral firms) and the location is going to be the middle of the interval. This is the standard Hotelling result. With three firms in the market, there will be no pure equilibrium. If the firms are not clustered, one of them can increase its profits by moving towards one of the others. If the firms are clustered, one of them can move

away from the cluster and increase its market share. With four firms in the market, there is a unique equilibrium when firms are paired at the first and third quartiles. With five firms, four will pair at the first and fifth sextiles and the fifth one will be in the middle of the interval. When the number of firms is bigger than 5, peripheral firms are paired while the other firms can be isolated or paired.

These location are different from the socially optimum conditions, when firms serve equal shares of the market and are located at the middle of their segment.

To avoid boundary issues, Eaton and Lipsey change the market space to a circle. With one firm, the location can be anywhere on the circle. With two firms, they locate at opposite sides of the diameter. With more than two firms there will be multiple equilibria. In this case the symmetric location around the circle (which is also the socially optimum location) is also an equilibrium. If firms are able to relocate, after another firm enters the market, then there will be a unique equilibrium with firms equally spaced along the circle.

2.3 Location under free entry

Anderson, de Palma and Thisse (1992). Firms now have a fixed cost, F . Firms that remain in the market must make at least F profits. If the price is normalized to 1, than the fixed cost can be represented as the minimum length a firm requires to be in the market. In this case, $(\text{length of the market})/F$ will bound the number of firms that can coexist in the market. If this fraction is ≤ 2 or equal to 4, the equilibrium is as described in the previous section (location with a fixed number of firms). If the fraction ≥ 6 , the equilibrium is not unique. One equilibrium corresponds to the *densest packing condition* presented by Losch (1940), when firms pair at $2F$ distance apart. If the fraction is not an integer, all firms but two of them will get zero profits. Those two will make positive profits, smaller than the fixed cost. Another equilibrium is based on the *loosest packing condition*, when all interior firms are isolated and located at $2F$ distance apart and the peripheral firms are paired.

2.4 Sequential Entry

Kats (1986). Once a firm enters the market, it cannot relocate to a different location. With two firms, the first firm that enters the market would like to locate at the middle of the interval and the

second firm will locate at the same position. The result is the same as in the simultaneous game. Any other location (for example the firm chooses to locate in the first half of the interval) will enable the second firm to locate just to the right of the first firm and maximizing its market share. With three firms, firm 1 would like to locate as close as possible to the center without giving firm 2 the opportunity to "push" firm 3 just to the left of firm 1. In this case firm 1 will locate at $1/4$, firm 2 will go at $3/4$ and firm 3 will be at $1/2$. With n firms, the equilibrium will have the same configuration. First two firms locate at the extremes, with the following firms locating towards the middle of the interval. The last firm will locate at the midpoint between any of previously entered firms.

Anderson, de Palma and Thisse (1992). They consider an endogenous number of firms. Firms have a fixed cost K , and they will not enter the market if the space available to them is smaller than this cost. Location is going to be chosen in order to deter entrance. When the fixed cost belongs to the interval $1/2 > K \geq 1/4$, two firms can cover their costs and they will locate at K and $1-K$. If the two firms will get closer to the middle of the interval, other firms will have an incentive to enter at the ends on the interval. If $1/4 > K \geq 1/6$, three firms can cover their costs and prevent a fourth firm from entering the market. First firm locates itself at K , the second firm chooses $1-K$ and the third one will be at the middle. With n firms, the first two will locate at K and $1-K$. Following firms will locate at a $2K$ distance from existing firms.

2.5 Location and Price Competition

Firms can charge different prices and consumers will purchase the good from the firm that offers the lowest full price (the mill price plus transportation costs). Firms have the same constant marginal cost. The indirect utility function is:

$$V_i(z) = y - p_i + a - t(|z - z_i|)$$

Simultaneous choice of location and price. This setting does not have an equilibrium. A firm that is earning less than a competitor can choose to locate at the same location of the competitor and undercut the price.

Location then price equilibrium. d'Aspremont, Gabszewicz and Thisse (1979). They considered two firms, linear transportation costs and uniform distribution of consumers. If firms choose the same location then there will be a unique equilibrium price equal to their marginal costs. For a

different choice of location an equilibrium might exist if they choose to locate far apart from each other (not to have an incentive to undercut each other). The profit functions are not quasi-concave and the best response functions for prices are not monotonic. To solve this problem they considered transportation costs to be a quadratic function of distance $t(|z - z_i|) = t(z - z_i)^2$. There is a unique location equilibrium with the two firms choosing the ends of the interval. In this model there is a trade-off between increasing market shares (moving towards the center) and increasing price competition.

Kats and Neven (1990) look at the case with three firms and quadratic transportation costs. They find the optimal locations to be $1/8$ for firms 1, $7/8$ for firm 2 and $1/2$ for firm 3. The firm at the center serves almost half of the market at a low price, while the other firms serve about a quarter each and charge a high markup.

2.6 Research and Development

Harter (1993). In the previous literature, firms choose a variety (location) and begin production without any effort. Harter employs a Hotelling Model with two firms. The two firms play a three-stage game. In the first stage, the firms simultaneously choose the potential locations on the unit interval for which successful "invention" (achieved through RD) is necessary. At some point, one of the firms successfully innovates, initiating the second stage where the non-innovating firm decides on the future of its RD program. Then, if and when both have entered the market, the firms engage in price competition. Because of the nature of the RD process, the firms will enter sequentially even though they choose locations simultaneously, allowing one of the firms to enjoy monopoly rents until the other firm has successfully innovated. The order of entry, of course, is not known, but the probabilities are. The RD technology is represented by a known, Poisson discovery process. Each firm must incur a fixed cost F to begin its RD and an invariant flow cost z during the time that it continues its RD. The RD process is location-specific. Thus, once a firm has chosen a potential location, it begins its RD in order to invent that exact product variety. The marginal cost of production is zero. The market is populated by a continuum of consumers, each of whom has a preferred good z (distributed uniformly on the unit interval). When a firm innovates, the follower must decide whether to continue with the original RD plan, re-focus its RD efforts towards another variety, or discontinue its RD altogether. If the RD costs are high, no firm will do RD. Lower research cost will allow only one firm in the market. As the RD costs decrease, both firms will do RD and will locate towards the middle of the market (like in the original Hotelling Model).

2.7 International Trade

Schmit (1995). He derives jointly the pattern of trade (equilibrium price and quantity) and the international market structure (the number of firms, their market of production and the attribute of each product). There are two markets/countries, each of them being defined in the unit interval. The intervals represent consumer preferences and product characteristics. Goods that are sold from one market to another are subject to a tariff t . Consumers are uniformly distributed along the interval. The density in country A is greater than or equal to the density in country B. Consumers buy exactly one unit of these goods for which their utility is maximized. Within markets, firms charge the same price to their customers. Across markets they charge different prices. Product differentiation is associated with market sharing, while product imitation and monopoly are associated with market separation. The international barriers to trade and the size of each market are the two key elements which determine the equilibrium product configuration. Product imitation is not possible without barriers to trade and it is made easier by asymmetric market size.

2.8 Patent protection

Scotchmer and Thisse (1998). Firms sequentially improve each other's products, and a patent can terminate either because it expires or because a noninfringing innovation displaces its product in the market. They defined the length of time until one of these happens as the effective patent life, and show how the effective patent life depends on patent breadth. In order to do that they distinguish between lagging breadth (which protects against imitation) and leading breadth (which protects against new improved products). Analyzing leading breadth under different patent policy (narrow and broad) they find that when patents are finite but very broad the effective life of a patent coincides with its statutory life, and when patents are long but narrow the effective life of a patent ends when a better product replaces it. The former policy improves the diffusion of new products, but the latter has lower R&D costs.

2.9 Research Contributions

Product differentiation is the result of research and development. A firm developing successful innovation will get monopoly rights (for a limited amount of time) for a certain interval in the product space. If we allow imitation, firms can invest into imitation in order to develop their products (instead of innovating). The closer the firms are to the innovator the easier is for them to

imitate the product. Innovations are protected by patents. An increase in patent breadth prevents imitating firms from moving close to the innovator (by increasing their costs).

I introduce a North-South model of international trade between two countries. Northern firms are competing in both markets, while Southern firms compete only on their domestic market. When a firm in the North chooses its position in the Northern market, it will keep the same position in the Southern market (it is too costly to localize the product). The equilibrium will describe product diversity in the two markets, and firm location. This is especially important if the two markets have different consumer distributions.

3. A case study: HIV drugs

The following information was provided by AIDSinfo (a U.S. Department of Health and Human Services). Antiretroviral drugs are medications for the treatment of infection by retroviruses, primarily HIV. Different classes of antiretroviral drugs act at different stages of the HIV life cycle. Reverse transcriptase inhibitors (RTIs) are a class of antiretroviral drug used to treat HIV infection. RTIs come in three forms: nucleoside analog reverse transcriptase inhibitors (NARTIs or NRTIs), nucleotide analog reverse transcriptase inhibitors (NtARTIs or NtRTIs) and Non-nucleoside reverse transcriptase inhibitors (NNRTIs).

Nucleoside analog reverse transcriptase inhibitors (NARTIs or NRTIs) compose the first class of antiretroviral drugs developed. Drugs developed initially contained only one active ingredient. Such drugs were (just to name a few):

Retrovir (active ingredient: Zidovudine)

Epivir (active ingredient: Lamivudine)

Ziagen (active ingredient: Abacavir)

Later on, new drugs were developed combining two of the active ingredients that prior to this were used separately:

Combivir (active ingredients: Zidovudine and Lamivudine)

Epzicom (active ingredients: Lamivudine and Abacavir)

More recently, HIV drugs combine three active ingredients to make the drug more efficient:

There are more than three nucleoside analog reverse transcriptase inhibitors (active ingredients) which translate into more varieties of cocktail drugs.

A study made by the UK Group of Transmitted HIV Drug Resistance showed that people in different countries exhibit different resistance to these drugs. For example, in countries with a high rate of baseline resistance, resistance testing is recommended prior to starting treatment; or, if the initiation of treatment is urgent, then a "best guess" treatment regimen should be started which is then modified on the basis of resistance testing. In the UK, there is 11.8% medium to high level resistance at baseline to the combination of zidovudine + lamivudine + efavirenz, and 6.4% medium to high level resistance to stavudine + lamivudine + nevirapine. In this case the demand for antiretroviral drugs across countries will be different depending on local characteristics (there will not be a drug that dominates all the others).

4. The model

4.1 Innovation and Imitation

Consider two firms competing in the same market (the unit interval). The ends of the interval correspond to two active ingredients that have already been discovered (let's say Zidovudine and Lamivudine). The points on the interval can be thought of as different cocktails of these two ingredients or new drugs that satisfy the same needs as the cocktails. In this setup imitation is defined as developing a product close to the ends of the interval (similar with the existing products) while innovation stands for choosing a product close to the middle of the interval (like Combivir). Imitation is a quality upgrade relative to the initial innovation (consumers will not buy the old products). For this section, there is no patent protection.

The firms play a three-stage game. Location (product to be researched) is chosen in the first stage. Firm A locate at point a (assume it locates to the left of firm B) and B at point $(1-b)$. The second stage starts when a product is successfully innovated (assume by firm 1). At this point, firm B has to decide if it will continue to research its initial product, develop a new product (or imitate the product developed by firm A), or exit the market. In the third stage, if both firms entered the market they will compete in prices. Otherwise firm A will enjoy monopoly profits. The RD

technology is represented by a known, Poisson discovery process (an exponential waiting time until successful invention). Each firm must incur a fixed cost F to begin its RD (for a certain location) and a constant research cost z during the time that it continues its RD. The RD process is location-specific. Consumers are uniformly distributed on the unit interval.

Each consumer has a preferred good x , and when they buy from location a will lose $y(x - a)^2$ (plus the price asked by the manufacturer p_a). His reservation price for the product will be denoted by s .

The expected time of invention for firm A is $1/h$, where h is the hazard rate. Let τ_A be the time of invention by firm A and τ_B for firm B. The indirect utility of consuming firm A's products is given by:

$$V_a(x) = s - p_a - y(x - a)^2$$

The constant research cost z depends on the type of the research and development activity (there is a positive relationship between the marginal cost and the distance to the end of the interval – it is more expensive to manufacture a new product/ innovate):

$$z = a$$

Until firm B will join the market, firm A will enjoy monopolistic profits at point a :

$$\Pi_{ma} = s - y(1 - a)^2 - \text{costs}$$

When firm B joins the market and produces a different product than A, the profits are:

$$\Pi_{da} = \left(\frac{y}{2}\right)(1 - a - b)\left(1 + \frac{a}{3} + \frac{b}{3}\right)^2 - \text{costs}$$

If firm B decides to imitate firm A's product then the profits become:

$$\Pi'_{da} = \left(\frac{y}{2}\right)(1 - 2a) - \text{costs}$$

Based on the above profits, the expected profit for firm A is:

$$E\Pi_a = \int_0^{\infty} (e^{-rt})[\text{Pr(onlyA)}\Pi_{ma} + \text{Pr(bothRD)}\Pi_{da} + \text{Pr(imitB)}\Pi'_{da} - \text{Pr(none)}z]dt - \text{costs}$$

For this section, where there is no patent protection, with high R&D costs one would expect only one firm to enter the market. The location choice will be a tradeoff between the middle of the interval (where you minimize “transportation costs”/maximize the price that you charge consumers) and the ends of the interval (where you reduce R&D costs). As the R&D costs start decreasing the second firm will choose to enter the market. For low enough R&D costs there will be no race to the middle of the interval (firm B might choose to locate itself at the end of the interval). Firm B will have an incentive to upgrade an old product rather than developing a new one.

4.2 Patent Protection

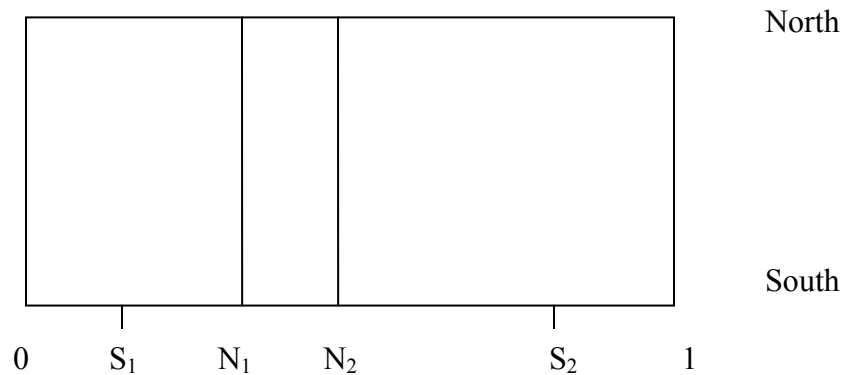
Patent protection will protect production rights for an innovating firm in the vicinity of the product. The dimension of the protected interval is the patent breadth. Translating this into costs, it will be more expensive to develop a product close to an existing product. Competing firms that infringe the IP rights and produce in the space protected by property rights will pay a violation fee. This will increase the research and development costs for both the competitors and the innovator, changing the structure of the market. Without the incentive to move close to the end of the interval and reduce the R&D costs, firm A will choose to locate at the middle of the interval and take advantage of the monopoly power until firm B will enter the market (if firm B enters the market). Once firm A has chosen its location in the middle it will receive a patent for the product and increase even more the R&D costs for firm B. In this case, there will be a race to the middle of the interval (to develop a new product).

4.3 A North-South Model of International Trade

Medical needs are different from one country to another and the treatments need to be localized. But drug manufacturers might choose to develop only one product for all markets. What characteristics should they choose for the product? Also, patentability is determined by different measures around the world, even though the principle of the patent is often the same. For example, in the case of Fluvastatin, a patent is identified in Europe that relates quite broadly to sustained-release formulations. This patent is due to expire in 2017, a full nine years after expiry of the active ingredient patent, and is considered 'blocking' in nature to any generic sustained-release competition. Despite having undergone the European Patent Office (EPO) opposition procedure, this patent is still considered to be valid (subject to appeal). Patent claims with similarly broad scope have been applied for in the US, but have not been approved. Novartis also has further

European and US patent protection on their commercial formulation in terms of the combination of the active ingredient particle size and the specific excipients used.

Having different medical needs and different legal protection across countries, makes this an interesting case for study. Let's assume that the North allows broad patents while the South supports narrow patents. In this case we can call Northern firms innovators and they can sell in both markets. Firms in the South are imitators and can only sell their products locally. When firms choose their position in the market they have to take into account consumers in both markets and competitors' reactions to their choices. Having different consumer distributions for the two countries will make the results more interesting (local firms might be able to localize the product better than foreign firms, increasing their profits). Market entry will be sequential. The initial setup will consider one two firms in each market. The firms play a three-stage game. Location (product to be researched) is chosen in the first stage. Two firms locate in the North and two firms in the South. The second stage starts when a product is successfully innovated (assume by a northern firm). At this point, the other three firms have to decide if they will continue to research their initial products, develop new products (or imitate the products developed by innovating firm), or exit the market. In the third stage, if two or more firms entered a market they will compete in prices. Otherwise the innovating firm will enjoy monopoly profits. The northern innovator has to decide his position in the two market taking into consideration the best response function from his competitors. For example, if country N has a customer agglomeration close to the end of the first half of the interval and consumers in country S are uniformly distributed on the unit interval, location choices might look something like this:



5. Conclusions

I do not have conclusions at this point in time. For the first section, where there is no patent protection, the location choice will be a tradeoff between the middle of the interval (where you minimize “transportation costs”/maximize the price that you charge consumers) and the ends of the interval (where you reduce R&D costs). In this case one would not expect a race to the middle of the interval. With patent protection, there will be a race to the middle of the interval in order to take advantage of the monopoly power until firm B will enter the market. Once firm A successfully developed the product in the middle it will receive a patent for the product and increase even more the R&D costs for firm B.

When international trade is brought in, northern firms will strategically choose their location having in mind consumers in both markets and competing firms will also change the equilibrium generating more inefficiency.

4.1 Future work

Improve the setup of the model to better reflect the reality and finish the calculations.

It would be interesting to see what happens when you add a time dimension to the model (the length of the patent). Would innovating firms have an extra incentive to develop follow-up innovation in order to extend their patent for a certain product (and develop fewer new products)?

Endogenizing the number of firms in the market would be an interesting addition. A variation of the Hotelling Model is the circular road model of product differentiation developed by Eaton et. Al. (1975). This model helps avoid problems regarding strategic location of firms at/close to the corners of the market.

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