

Competition or innovation: How much monopoly is needed for technical progress?

Ilona Sologoub

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We develop a modification of quality ladder model, which allows us to analyze how different market structures influence firms' innovativeness. The first results we received show that (1) profits are inversely related to competition (as competition parameters we use elasticity of substitution between goods and market shares); (2) in the presence of competition, firms should invest all their profits in either of the three activities – marketing, buying technology or R&D; (3) the return on investment is less than 100%, which is usually the case, R&D investment brings higher expected value gain than other activities. However, if competition is sufficiently high (and retained profits low), firms will be able to invest only in marketing before their profit reaches minimum threshold of R&D or technology investment.

Introduction.

Economic science considers competition to be the first best option for a society. However, from the point of view of firms more market power means higher profits, hence, a monopolist position is the first best for them. Their wish to “escape” from competition, to gain at least temporary monopoly over some market stands behind product differentiation, process innovation and by and large behind the entire technological progress.

By introduction of the patent system several centuries ago, the society recognized that to encourage inventors, they should be granted the right to guaranteed higher profits from their inventions. On the other hand, appearance of antitrust legislation shows the recognition that too much concentration can be harmful for society. Indeed, a monopolist would not need to innovate if his profits can be sustained at lower cost without it (for example, by keeping spare capacities or lobbying for administrative barriers to entry).

Where is the “golden middle” of concentration or what is the optimal degree of monopoly power on a market? In fact, it is the question that entire Industrial Organization literature has been trying to answer (a natural extension for it is the question of boundaries of a firm, first addressed by Coase).

We look at this question from the perspective of technological progress. Specifically, using the model of firm growth developed in Klette and Grilliches (2000), which is a modification of “quality ladder” models, we try to find the conditions under which a firm finds it more profitable to innovate (i.e. produce new products or with new technologies) rather than maintain its monopolistic power in existing markets (which, among other, can be done by lobbying) or push its “old” product into new markets.

A similar study was performed by Aghion et al (2002) concerning UK and US firms. However, if firms in developed countries mostly work along the “technology frontier”, for Ukrainian firms, as well as for firms in developing states, innovation often means adopting existing technologies, which sometimes are already considered obsolete in developed countries.

Technology development and switching to advanced goods production is an urgent question for the majority of world economies. The obvious reason for this is that other competitive advantages such as cheap labour or abundant natural resources are exhaustible in the middle- to long run whereas inventiveness is not, and technological advances can be made forever. At the firm level, innovating is profitable because it provides temporary monopoly over some market and respective monopolistic profits. The further is firm’s invention from competitor’s goods, the longer it will enjoy these benefits. This logic easily extends to the country level: a nation producing more unique products will be wealthier.

The “innovative-investment model of development” is among the phrases most often used by Ukrainian politicians. Although most of the time it does not mean anything, the appearance of it in the lexicon of Ukrainian officials reflects general recognition that it is beneficial for a country to produce and export high value-added technologically advanced goods rather than raw materials or semi-finished products. In Ukraine, we observe exactly this: in 2003 non-precious metals and their products constituted 36.8% of Ukrainian exports, whereas machines and electronics - 10.1% and high-tech products produced in techno-parks – only about 0.01%.

Very few of Ukrainian firms purchase new (for them) technologies, let alone invent their own. Ukrainian government tries to encourage innovative activity of enterprises by creating tax privileges (see the law “On innovation activity”-2002) for them and techno-parks, whose number is planned to increase from 8 to 15 in 2005¹. At the same time, the number and share of innovating firms reported by Derzhkomstat, has been steadily decreasing in the last 10 years, reaching 13% (1238) in 2003 as compared to 26% (2181) in 1994.

We can name two reasons why Ukrainian firms innovate so little.

- 1) They *don't need to* due to low development of domestic market with consumers searching for cheaper products and paying less attention to quality. Many Ukrainian firms still sell what they can produce instead of trying to produce what is (potentially) demanded. Some of them compete in unfair way – by lobbying for state support or import duties, for example. If this is the case, then increase in competition and removing of privileges will spur innovation.
- 2) They *cannot* due to absence of funds for buying or developing new technologies because of high interest rates and uncertainty towards the future. Officials often state that different fiscal privileges can stimulate enterprises to innovate, implicitly claiming that absence of

¹ These techno-parks had 1.3 bn UAH output in 2002-2003 and in 2003 exported products worth UAH 143 million (which, however, is only 0.12% of total Ukrainian export for that year).

finance is the only problem of Ukrainian would-be innovators. If this is true, then more adequate policy for innovation development would be strengthening patent protection and easing access to finance (for example, introduction of state guarantees for credits or state grants for invention development).

Naturally, the most interesting question is which of these reasons is stronger. We suppose that, while financing is important, subsidising uncompetitive firms will not be the best strategy for society. And, if both of the above named obstacles to innovation exist on a certain market, removing the first one is a prerequisite for starting to cope with the second. How can we decide that there is “the right” degree of competition on the market? Is there at all a market structure optimal for innovation? We try to develop a model that allows us to address these questions. The rest of the paper is organized as follows: section 2 reviews the literature, section 3 presents model assumptions, section 4 solves the model, and section 5 concludes.

Section 2.

Modern theoretical literature on technical change mainly uses some modification of a “quality ladder” model to explore one or several aspects of firms’ innovative behaviour. To name only a few, Stein (1997) models comparative advantages of both incumbents and newcomers on a market, Klette and Grilliches (2000) explain several stylised facts of innovation development, and Klette and Kortum (2002) extend this work; Keuschnigg (2003) develops a general equilibrium model of venture capitalism.

Numerous empirical [1] and theoretical [2], [5], [10] papers explore the relation between firm size and its innovativeness. The most often found relation is U-shaped. Acs and Audretsch (1988) found that in the most innovative industries small firms (under 500 employees) have 6 times more innovations per employee than large ones. Furthermore, innovative activity decreases with industry concentration and unionisation. However, the more large firms are there in an industry, the

more innovations will arise in it, but they will mostly be produced by small firms. Gifford (1992) takes into consideration the degree of obsolescence of current firm products and shows that with low obsolescence innovation decreases with size, otherwise it is independent of both firm and market characteristics.

Empirical studies of developing countries (Basant and Fikkert (1996) for India and Braga and Willmore for Brazil) find that purchases of technology are more profitable for firms than own R&D because introduction of a “ready-made” technology immediately increases output whereas own-developed technology often requires some time and effort for getting it “into shape”. They also find that buying technology does not crowd out domestic research.

There are studies investigating all the aspects of innovation and factors influencing it - exports, finance, various government policies. A great number of empirical studies investigate the effectiveness of technical assistance programs directed at SME innovation development. Their main message is that simply pumping money into projects is the least efficient way of innovation development.

Studies of transition economies usually emphasize absence of finance and good management as a considerable obstacle to innovation. Importance of financial constraint for small enterprises is stressed also by Himmelberg and Petersen (1994). Investigating a sample of small firms in high-tech industries, they find that small firms must heavily rely on internal financing for R&D investments because of financial markets imperfections.

Section 3.

There is one market with differentiated consumer good (i.e. with monopolistically competitive market structure). There is fixed number of firms on the market, no entry or exit occurs. By changing the initial number and size of firms, we can look at different market structures.

The number of **consumers** is normalized to 1. Each of them has CES utility function of the form $u = (1/\rho)\ln(\sum_{i=1}^K x_i^\rho)$, where x_i is the consumption of good produced by i -th firm, K is the number of firms on the market, and ρ - the elasticity of substitution between the goods.

Each consumer supplies one unit of labour, which can be spent either on consumer good production or on R&D. We assume that labour supply is infinitely elastic and each activity pays the same wage normalized to 1. Hence, consumer's budget constraint is $\sum_{i=1}^K P_i x_i = 1$.

Firms have production function of the form $Y_i = A^{\alpha_i} L_i$, where α measures the technology level of the firm, and $\alpha=1$ for the firm with basic (the lowest) level of technology. Consequently, $A > 1$ measures the size of basic innovation. Firm's revenue is $P(\alpha)Y$, where price is an increasing function of technology (or product quality).

Variable cost of a firm is equal to the number of its employees. Firm's profit is

$$\pi_i = P_i Y_i - L_i = P_i A^{\alpha_i} L_i - L_i = Y_i (P_i - 1/A^{\alpha_i})$$

But besides variable cost, firms make sunk investment connected with their effort to raise profits. Depending on the degree of goods substitutability (ρ), raising profits can mean raising price, market share or both.

Sunk investment S_i can be spent in three ways.

- 1) increasing profits without changing quality of the product. We will call this type of spending marketing.
- 2) buy ready-made technology. If firm is the first to do this, it receives higher profit than competitors for one period (its MC falls while theirs doesn't), but the next period competitors catch up with it.

- 3) invest in R&D. The firm performing R&D moves one step up the quality ladder with probability p . R&D expenditure is increasing in p and equal to $\beta p^2/2$.

If a firm undertakes one of the three kinds of investment, it can set price higher than its marginal cost, which are equal to I/A^{ai} . The markup is proportional to investment, and respective future profit is equal to $\gamma_j S_i$, where j is the index of activity – marketing (M), technology purchase (T) or R&D (R), and $\gamma_M < \gamma_T < \gamma_R$. To consider the simplest case, we assume that ρ is sufficiently low (close to 0), so that marketing effort raises price of the good but not market share. Later we will change this assumption. One more assumption we need to make is about existence of some minimum investment level in the case of technology purchase and R&D. Hence, marketing expense $M \in [0; \infty)$, whereas $T \in [R_0; \infty)$ and $R \in [R_0; \infty)$.

Section 4.

Given the above assumptions, we can characterize the industry by $K-I$ parameters representing differences between markups of the leader and each of the followers. Let us assume the duopoly and m being the industry characterizing parameter ($m \geq 0$).

Each firm chooses investment to maximise its next period value:

$rV_m = \pi_m - S_m + p_m(V_{m+1} - V_m) + p_{-m}(V_{m-1} - V_m)$ for the technological leader or in case of equal firms ($m=0$)

$rV_{-m} = \pi_{-m} - S_{-m} + p_m(V_{-m-1} - V_{-m}) + p_{-m}(V_{-m+1} - V_{-m})$ for the technological follower in case of unequal firms.

In words, the compounded value rV_m of being a leader with the gap m is equal to current profit minus investment plus expected value gain from doing innovation ($V_{m+1} - V_m$) and expected loss of value ($V_{m-1} - V_m$) if the follower innovates. The same is true for the follower: its

value loss is equal to $(V_{-m-1} - V_{-m})$, and value gain from own innovation – to $(V_{-m+1} - V_{-m})$. Clearly, if a firm does not engage in innovation, the respective term in each equation (value gain) should be set equal to $\gamma_j S_m$ for the leader or $\gamma_j S_{-m}$ for the follower, where $j = M, T$. If the competitor does not perform R&D, the respective capital loss terms are set to 0.

Solution to these equations is found by replacing innovation expenditures S_i with $\beta p_i^2/2$ ($i=m, -m$ or 0) and taking derivatives with respect to p_i . Hence, for firms engaged in R&D, the solution is $V_{i+1} - V_i = \beta p_i$. Substituting this, say, into leader's value function, we get $rV_m = \pi_m - \beta p_m^2/2 + \beta p_m^2 + p_{-m}(V_{m-1} - V_m) = \pi_m + S_m + p_{-m}(V_{m-1} - V_m)$. Hence, the optimal strategy is investing entire current profit into R&D (remember that firms cannot attract external finance).

For firms not engaged in R&D, we get $rV_m = S_m(\gamma_j - 1) + \pi_m + p_{-m}(V_{m-1} - V_m)$. In this case, as $\gamma_j > 1$ (otherwise optimal S_i would be 0), optimal strategy is also investing entire current profit into chosen activity. In this case firm value grows at the rate γ_j corrected by random value loss due to competitor's innovation. These results are not surprising. But if we compare the two maximized value functions, we see that R&D is more profitable than other activities if $S_m > S_m(\gamma_j - 1)$ or if $\gamma_j < 2$. In other words, R&D is more profitable than marketing or technology purchase if a dollar spent on M or T allows to raise price by less than 2 dollars. Note also that if $\pi_m < R_0$, the only option a firm has is investing into marketing. However, with the assumption that $\gamma_M > 1$ we see that profits should rise over time, and after several periods a firm may invest in another activity.

To measure the degree of competition into market, we use the elasticity parameter of the utility function – if the goods are perfect substitutes ($\rho=1$), we arrive at perfect competition (Bertrand equilibrium), and if they are no substitutes at all ($\rho=0$), instead of duopoly we have two monopolistic markets.

From consumer problem, *demand functions* for goods 1 and 2 are:

$$x_1 = P_1^{1/(\rho-1)} / (P_1^{\rho/(\rho-1)} + P_2^{\rho/(\rho-1)}), \quad x_2 = P_2^{1/(\rho-1)} / (P_1^{\rho/(\rho-1)} + P_2^{\rho/(\rho-1)})$$

Elasticity of demand faced by a firm is equal to

$\varepsilon_i = (1 - \rho x_i P_i) / (1 - \rho)$. Knowing this, we can find a measure of industry competition – price-cost ratio or Lerner index: $Le_i = (P_i - MC_i) / P_i = -\lambda_i / \varepsilon_i$ where λ_i is firm's market share and is equal to $x_i / (x_1 + x_2) = P_i^{1/(\rho-1)} / (P_1^{1/(\rho-1)} + P_2^{1/(\rho-1)})$.

Hence, *equilibrium prices* can be found from

$$P_i = \varepsilon_i MC_i / (\varepsilon_i + \lambda_i) \quad (\text{note also that } P_i x_i = P_i^{\rho/(\rho-1)} / (P_1^{\rho/(\rho-1)} + P_2^{\rho/(\rho-1)})).$$

Equilibrium profits are found from

$$\pi_i = x_i (P_i - MC_i) = -\lambda_i (1 - \varepsilon_i (1 - \rho)) / \varepsilon_i \rho. \quad \text{And markup is equal to}$$

$$P_i - MC_i = -MC_i \lambda_i / (\varepsilon_i + \lambda_i).$$

Note that for positive prices $(\varepsilon_i + \lambda_i)$ must be negative, meaning that ε_i should exceed λ_i in absolute value.

From the above expressions we see that *markups* (profit margins) *are monotonically increasing and concave in market shares and decreasing in the absolute value of demand elasticity*. Profits decline with greater elasticity of substitution between the two goods.

If we equate the two expressions for profit margin: $\gamma_j S_i = -MC_i \lambda_i / (\varepsilon_i + \lambda_i)$, we see that γ_j is negatively related to marginal cost, i.e. *the higher the technology level, the greater is the return on every dollar of investment*. We also see that γ_j is positively related to firm's market share and negatively related to the elasticity of demand for its product.

Section 5.

Hence, the preliminary results are:

- 1) profits are inversely related to competition (as competition parameters we use elasticity of substitution between goods and market shares)
- 2) in the presence of competition, firms should invest all their profits in one of the three activities – marketing, buying technology or R&D
- 3) under our assumptions we see that if the return on investment is less than 100%, which is usually the case, R&D investment brings higher expected value gain than other activities. However, if competition is sufficiently high (and retained profits low), firms will be able to invest only in marketing before their profit reaches minimum threshold of R&D or technology investment.

We have in mind the following directions for further research. We will look at different market structures, for example, the one with several firms of different sizes. We will also try to estimate the model or calibrate it and perform simulations to see the development of innovation activities over time. On the basis of this research we will derive policy recommendations.

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