• *László Halpern–Balázs Muraközy* •

THE RELATIONSHIP BETWEEN COMPETITION AND R&D

Theoretical Approaches and Quantitative Results

This study is an attempt to examine and model the relationship between (the presence and intensity of) competition and corporate level R&D expenditures. Hungarian firm-level and industry-level data populate the empirical models. A brief summary of the history of research on the much-debated competition-innovation relationship is also offered. Results from the earliest studies seem to suggest that stronger competition generally results in lower levels of innovation, while the empirical results that were born in the 1990s showed some evidence for the opposite relationship. The seminal model of *Aghion et al.* [2005] indicated an inverted-U shaped relationship between the intensity of competition and the level of innovation. A discussion of the difficulties of measuring the pertinent variables and the relationship among them is followed by an elaborate investigation of the shape of the relationship. Based on our extensive empirical results, we conclude that the inverted-U shaped relationship can indeed be established in Hungary at the industry-level as well as at the firm-level. We also demonstrate that only certain types of indicators of the presence and intensity of competition seem to have had a detectable relationship with the innovative investments of firms.

INTRODUCTION

In economics, an issue of great interest concerns the factors affecting economic growth in the long run. Since the appearance of modern growth theory, the relative importance of capital accumulation and productivity growth has been continuously debated (the latter factor, at least partially, reflecting technological development). Since Robert Solow started his research programme in the 1950s[1], the key role of productivity growth has become evident. As shown by recent results, in the 20th century it contributed to annual average economic growth by over 1% (*Abramovitz–David* [2001]).

The Solow model, however, assumes that technological change depends on "exogeneous" factors, that is, factors outside the model. This is true inasmuch as the development of science and technology depends to a great extent on phenomena such as the knowable nature, complexity, or interrelatedness of natural laws.

[1] *Romer* [1996] in Chapter 1 gives a detailed and up-to-date description of the Solow model.

Endogeneous growth theory models, however, also take into account the fact that social institutions influence technological development (*Aghion–Howitt* [1998]). In market economies, technological development is attributed, above all, to the fact that firms decide to introduce new technologies in a decentralized way – in other words, they innovate. Therefore, in such economies the impact of social-economic institutions on technological development primarily means that institutions influence the firms' incentives to perform R&D and introduce innovations. Among the features of institutions and economic environment it is most probably competition whose impact on innovation and growth has been most thoroughly discussed by economists. This was due to the strong economic intuition that monopolies and highly competitive firms benefit from the development of production technology or the introduction of new products to different degrees.

This study seeks, above all, to describe the nature of this relationship. After discussing some dilemmas concerning the definition of innovation, it deals with the logic and predictions of the key theoretical models related to the issue. Then it offers details of empirical methods and key results on the relationship between innovation and competition, followed by the empirical analysis of the relationship between competition and the R&D expenditures of Hungarian firms. The study closes with a summary of conclusions.

THE CONCEPT OF INNOVATION

The economics literature places great emphasis on differentiating between innovation and research and development. Since Schumpeter's works were published, innovation has been interpreted as the actual implementation of an improvement, be it either the market introduction of a new product or the use of a new procedure during production. The former is *product innovation*, the latter is *process innovation*, and research and development may mean the development of either a product or a process. In other words, R&D is an input to the innovation process; research itself, however, is not innovation until its results appear on the market or in the production process (*Fagerberg* [2006]).

The definition of innovation given in the *Community Innovation Survey, CIS* of the European Union falls in line with the above:

- It follows that research and development (R&D) itself is not innovation but expenditure on innovation. And this is not the only expenditure of this kind. Innovation inputs also include when a firm purchases machines to implement its innovations or when managers make extra efforts to prepare the introduction of new processes or products. What is more, it is possible that the firm itself does not perform R&D activity yet it can still introduce new products or services relying, for example, on technology transfer.

This is especially true for small open economies and for countries which do not belong to the technology frontier. For such economies, implementing foreign technologies and products is a key to growth, and thus, it must be a focus of innovation policy. The significance of the issue is evidenced by the fact that while in Hungary approximately 10% of the firms that were included in the *Community Innovation Survey* (CIS) performed research and development activity on a continuous basis between 2004 and 2006, more than 30% of them introduced product or process innovation in the same period (*Halpern–Muraközy* [2010]). These data show that in Hungary, in most cases, innovation is performed without any formal research and development activity. It is evident, however, that such innovations require resources from the managers and employees of a firm. Yet such innovation efforts are not included in the R&D statistics, which means that in follower countries R&D statistics may significantly underestimate the actual innovation expenditures of firms.

THE THEORY OF THE RELATIONSHIP BETWEEN COMPETITION AND INNOVATION

The beginnings of research on the relationship between competition and innovation can be traced back, above all, to Josef Schumpeter's (1883–1950) research. In his early works, Schumpeter emphasized that new innovative entrepreneurs can break the "inertia" or "laziness" of large companies. The market entry and subsequent growth of such small enterprises explain the phenomenon of economic growth. Schumpeter termed this process "creative destruction."

Schumpeter's later works focused on the economies of scale that are achievable by big businesses in research and development and innovation. The difference between the two approaches can be interpreted in various ways. First, it can be regarded as a historical change: the growth of scientific knowledge generated economics of scale in research. Another interpretation is that the two Schumpeterian models describe different industries. In some industries, small firms carry innovative solutions (e.g. the Internet). In others, only large firms are capable of introducing innovations (e.g. the pharmaceutical industry), because of the high costs of introducing each innovation.

In and after the 1960s, based on Schumpeter's concepts and parallel with the appearance of game theory-based industrial organization models, a number of analyses have been published that examine the relationship between market structure and innovation with the aid of models of the strategic behaviour of firms. These models regard R&D as investment and, practically, do not differentiate between decisions on R&D and decisions on innovation. As a rule, the assumed decision making consists of two steps. First, a firm decides about the dimensions of its R&D

investment; second, it sells the new product (in case of product innovation) or, employing a new procedure, produces more efficiently (in case of process innovation). Competition starts playing a role in the second step. The type of the product market competition (e.g. Bertrand or Cournot competition) and its strength define the revenues of a given firm on the market. Firms make decisions about their R&D investment based on the profit they will realize in the second phase; that is, they compare the profits achievable with innovation and without innovation. For example, when strong competition decreases the amount of profit that is achievable by innovation, R&D investments and the innovation performance will be lower in competitive industries.

In the "standard" industrial organization model of innovation – regardless of the exact structure of the model – weaker competition (e.g. a monopoly) ensures higher profits for the innovating firm, and, therefore, the innovation level is expected to be higher (for a description, see *Aghion–Griffith* [2005], Chapter 1.1). When competition is stronger, the firm reaches fewer consumers, sets lower prices and, as a result, it becomes less profitable for it to invest in research. Therefore, the models introduced before the 1990s corroborated the existence of the Schumpeterian effect inasmuch as they showed that monopolized industries are innovative and thus are closer to social optimum.

It follows from these theoretical results that in monopolized industries technology develops faster, which means that competition policy has to choose between static and dynamic efficiency or, in other words, has to face a difficult trade-off. But in the 1990s empirical research came to a different conclusion: the research of *Geroski* [1990], [1995], *Nickel* [1996], and *Blundell et al.* [1999] evidenced that in a given industry the stronger the competition, the higher the productivity gains, that is, the stronger the incentive to innovative.

The seminal study of *Aghion et al.* [2005] was based on endogenous growth theory and worked with a different approach, relying on the heterogeneity of firms and on nonlinear relationships. Their model shows that the response of firms to competition can take many different forms. When competition intensifies, firms on the technology frontier increase their R&D, while firms lagging behind reduce their innovative effort. Taking into consideration the resulting industry dynamics, the authors highlight that there is an inverted-U shaped relationship between the strength of competition and innovation at the industry level: in case of weak competition they are positively related, while in case of strong competition the association will be negative.

The model presented by Aghion *et al.* involves multiple time periods. Technological development takes place step by step. The most developed technology is improving to the same degree in every period, independently of the firms modelled. Some firms have the most developed technologies, while others are some steps behind. When a firm introduces a successful innovation, it can take one step forward, otherwise it will start lagging behind even more.[2] This firm faces competitors that are always one step behind the most developed technology at the given time.

If the firm uses the most developed technology, then – given that the production costs of the competitors are necessarily higher – it is in the position to set monopoly prices or, rather, prices that correspond to the expenditure level of the other firms. In case the firm in question is two steps behind the most developed technology, its competitors will be ahead of it, so it will not be able to sell its product. In this model, competition is regarded as the profit level of a firm which employs technologies as developed as those of its competitors; the stronger the competition, the lower the profit of such a firm.

A key concept presented by the authors is that those firms that use the most developed technology respond differently to strengthening competition than those lagging behind. Innovation incentive is the amount their profit would (is expected to) rise if they increased their innovation expenditure. Profit levels achieved with and without innovation are to be compared. Non-linearity is caused by the fact that competition affects both kinds of profit.

If innovation proves to be successful, firms on the technology frontier will be able to produce with the new technology, otherwise other firms catch up to them. The stronger the competition, being caught up by competitors will be the more painful. Consequently, in response to stronger competition firms that use the most developed technology increase their R&D expenditure *to escape competition.*

The situation is reversed for firms that lag behind. They are assumed to be able to make only one step forward in the process technology development. By doing so, they can indeed catch up with other firms but have no chance to leave them behind. Stronger competition means that it is less attractive to catch up to others, and consequently R&D investment is less attractive. The reason for this is that in case of successful innovation the firm will realize lower profit when competing with other firms which are at the same level of development. This means that the firms lagging behind are influenced by the *Schumpeterian effect*:[3] Innovation is a decreasing function of the strength of competition.

Which effect is stronger? The answer depends on the ratio of industries in equilibrium where firms are close to each other (and, consequently, the competition

[2] A key sectoral factor is the intensity of competition in the product market, which is measured by the authors as the difference between the expenditure of firms that employ the most developed technology and that of other firms. It may be caused by various phenomena. Primarily, greater intensity is understood as greater substitutability among products produced in the given industry. Where competition (substitution) is stronger, a leader firm has a higher profit than a follower, as in such industries prices are more important for consumers. This definition falls in line with the logic employed above: the strength of the competition is linked to the profit from innovation (relative to profit achieved without innovation), and thus it may affect R&D expenditure.

[3] The term "Schumpeterian" here refers to the second phase of Schumpeter's scientific activity.

deterrence effect is strong) to industries where there is a greater difference between firms (and, therefore, the Schumpeterian effect is stronger). As competition strengthens, the level of innovative activity increases at first, and then starts to decrease. The relationship between the two phenomena resembles an inverted-U shape or a bell curve. The monopolies as well as the industries where competition is very strong tend to be less innovative than sectors with a low number of actors.

The model built by *Aghion at al.* [2009] in this kind of a framework indicates that the increased probability of the entry of new actors who use the most developed technology also has an inverted-U shaped relationship with innovative activity in the industry. In this model, the innovation efforts made by firms at the technological frontier intensify as the probability of entry by competitors increases. This *entry deterrence effect* is analogous with the competition escape effect in the previous model. Conversely, the innovation efforts of firms that use less developed technology decrease as the probability of entry increases. Their expected profit from successful innovation is lower if they are more likely to face a competitor which uses a more developed technology than theirs. It follows from the way the equilibrium ratio of sectors is defined that the relationship between competition (defined as the probability of entry) and the innovative effort is expected to take an inverted-U shape.[4]

The models discussed so far (with the exception perhaps of Schumpeter's model) are *neoclassical* models. The firms are assumed to be well informed and, based on their knowledge, they make perfectly rational decisions about innovation and everything else. In neoclassical models, even though the outcome of innovation decisions is uncertain, the firms are perfectly aware of the possible returns on investment and the probability of their occurrence.

Studies on *evolutionary models*[5] suggest that this kind of neoclassical model is not suitable for an adequate modelling of innovative behaviour as the payoff of innovation is basically uncertain and the actors are not likely to know the probability distribution of payoffs. This is Knightian uncertainty (*Knight* [1921]). Given the above, it is not justified to assume that firms make perfectly optimal decisions. Instead, they use a heuristic approach or some other, bounded rational decision making mechanisms when deciding about research fields and the amount to be invested. Among the firms that use various decision making procedures, those with higher profits grow faster, as they are in the position to invest more. In time, poor performers go bankrupt.

A key feature of these models is that firms differ from each other in various dimensions. As opposed to neoclassical models, they do not postulate that some

[4] Recently, several other studies have discussed the issue of entry and innovation: *Asker–Baccara* [2010], *Creane–Miyagiwa* [2009], *Grossman–Steger* [2007], *Kovac–Vinogradov–Zigic* [2010], *Miller* [2007].

[5] *Nelson–Winter* [2002] gives an overview of the main issues concerning evolutionary models. The first of the evolutionary models concerning innovation is *Nelson–Winter* [1982].

firms are one or two steps behind the others, rather, that firms in the market have different information and employ different decision making mechanisms. A related issue is path dependence: the situation of firms or industries that take different directions may differ radically.

Evolutionary logic sheds light on the fact that industry productivity can grow not only when a firm introduces new products or processes, but also when the market share of firms with good "genes" or expert knowledge grows, while that of worse performers decreases. (Some of them leave the market). *Motta* [2004] (pp. 55–64) presents a simple model of this kind.

EMPIRICAL METHODS AND EMPIRICAL RESULTS

Measuring the relationship between competition and innovation

Research on the relationship between competition and innovation raises several problems (*Aghion–Griffith* [2005] Chapter 1.2.2). *First,* besides the strength of competition there are several *other factors* that define how much a firm or an industry invests in innovation. These variables may easily be correlated with competition and, for analytical purposes, they must be taken into account.

Second, the relationship between competition and innovation in an industry is not a one-way causal relationship; rather, it is *simultaneous,* which means that innovation also influences market structure. In general, panel data are needed to handle simultaneity. When such data are available – and it is assumed that market structure is pre-determined (that is, innovation in a given period of time affects only future market structure) – the issue of simultaneity can be handled with the use of lagged explanatory variables. Weaker assumptions are needed when, for the purposes of analysis, exogenous changes of economic policy and regulation (e.g. free trade agreements) are used as instrumental variables (e.g. *Aghion et al.* [2005]).

Third, a major issue is that of *measurement errors in explanatory variables*. The analyst is interested in the impact on innovation of competition. The indicators that describe the market structure (number of firms, concentration, etc.) do not measure competition directly. This problem is aggravated by the fact that in open economies external competition needs also be taken into account in some way. Consequently, in theory it is more practical to use an indicator that has a more direct link with competitive pressure than market structure does. Such indicators include the Lerner-index or some other indicator of the market power of firms.

Fourth, the selection of the dependent variable *(a measure of innovation)* is not an easy task either. As referred to above, R&D activity is an input to innovation, not a measure of innovation itself. While for large companies it may have a strong correlation with innovation, smaller firms may introduce important innovations without spending on R&D. As for the outputs of innovation, the number of patents is the measure most widely used. The main problem with this is that not every patent is of equal significance or entails the same level of innovation. Therefore, researchers often decide to weight the number of patents by the number of times it has been referred to in another patent (*Jaffe* [1986]). Theoretically variables showing innovation output (from innovation surveys) are better measures than the numbers of patents. This holds especially true for countries which are not at the technology frontier, therefore, the majority of innovations do not entail patent registration. In practice, however, in most countries these indicators are available only on a relatively small sample of firms and, therefore, fail to reflect the total innovative performance of the economy. When there are no available indicators that directly show spending on and results of innovation, then innovation may be approximated with variables indirectly related to innovation. Such variables include, for example, the productivity of the firm in question (labour productivity or total factor productivity, TFP). Nevertheless, productivity gains depend on several other variables beside technology. For example, it is often difficult to filter out the effect of the economies of scale.

The nature of the measurement of innovation also affects the appropriate estimation methods. For R&D expenditures, for example, the value is zero for a large number of firms; consequently, a tobit model is to be used. When we ask which firm introduced innovation, then probit or logit models may be used.

Fifth, as *Aghion at al.* [2005] state, the relationship between competition and innovation *is not necessarily linear* (Chapter 3.1). According to *Aghion–Griffith* [2005], the results of some early studies contradict each other from time to time, as the authors did not consider this possibility and examined only the linear effects of the competition variable. Nonlinearity is to be dealt with by using quadratic terms or nonparametric models.

Empirical results

Ahn [2002] and *Aghion–Griffith* [2005] offer a summary of the specialized literature on innovation published in the 1990s. These empirical studies failed to corroborate the Schumpeterian hypothesis that the presence of large firms or a greater concentration may lead to higher levels of innovation. A number of studies state that there is a strong positive relationship between competition in the product market and productivity. Further research has shown that the effect of different changes in the economic environment – regulatory changes, greater exposure to global competition, the introduction of competition for non-profit enterprises – justify that competition contributes to productivity, wealth and long-term growth. It is also pointed out that it often takes a long time for enterprises and consumers to adjust to a new context and for the competition to fully exercise its positive impact on efficiency.

Major articles of the 1990s include those by *Geroski* [1990], [1991], [1994], *Blundell et al.* [1995], [1999]. These studies examined the firm-level and industry-level panel data of the 1970s and 1980s, and revealed that competition has a positive impact on innovation. *Pohlmeier* [1992], taking into consideration the fact that this is a simultaneous relationship, found – instead of the theoretically assumed positive relationship – a negative relationship between market concentration and product and process innovation in 2,200 German firms by 1984. *Crépon at al.* [1996] analyzed the 1991 data of approximately 10,000 firms. Results on the relationship between market concentration and innovation differed depending on which innovation indicator was used. When the number of patents and other performance indicators of innovation were used, a negative relationship was established with market concentration, while in the case of the sale of new products a positive relationship was found. As for R&D investment, no relationship was established.

As mentioned in the theoretical summary: *Aghion et al.* [2005] showed that, theoretically, an inverted-U shaped relationship is possible between competition and innovation. Aghion and his colleagues performed empirical studies which established the inverted-U shaped relationship between product market competition (measured with the Lerner index) and innovation (measured with the number of patents). As it was referred to above, in a later study they described a similar theoretical relationship between the probability of entry and the level of innovation (*Aghion et al.* [2009]). Positive relationship was also indicated by panel data on UK firms for the period between 1987 and 1993. The effect of market entry analyzed at the four-digit industry level (especially foreign market entry) is positive in industries where the UK is on the technology frontier, and weak or negative in industries which lag behind. In line with the theoretical model, the results indicate that the relationship between competition and innovation may also be affected by the distance to the technological frontier.

Later, other studies also corroborated the hypothesis of the inverted-U shaped relationship. For example, *Tingvall–Polsdahl* [2006] quantified such a relationship between competition (measured by the Herfindahl index) and innovation on data gathered in Sweden between 1990 and 2000; however, no significant results were found for the price-cost margin. *Brouwer–Van der Wiel* [2010] succeeded in establishing a clear positive relationship between competition and total factor productivity for Dutch industries. In addition, for the Netherlands – at least for the manufacturing industry – these authors provided evidence for the inverted-U shaped relationship between competition and innovation, in other words, for the fact that competition (if significantly stronger than observed) has a negative impact on productivity because of the lower innovation expenditure. The reverse relationship did not show up in the data, which means that the intensity of competition does not decrease because of innovation.

From the models establishing an inverted-U shape, it can be concluded that the shape of the relationship is influenced by the distance of the firms of a country to the technological frontier. *Acemoglu et al.* [2006] studied, among others, this issue and observed a positive correlation between the cross-sectional productivity and R&D expenditure of a country, as well as between the distance to the technological frontier and R&D expenditure. The growth rate of countries where – due to high barriers to entry – competition is weak falls more sharply when the country in question gets closer to the technological frontier than the growth rate of countries with strong competition. The weakness of competition exercises its adverse effects in countries which are close to the technological frontier. *Lee* [2009] came to similar conclusions. Relying on the data of more than 1,000 Canadian, Japanese, South-Korean, Taiwanese, Indian and Chinese businesses, he concluded that the way firms respond to competitive pressure depends on the level of their technological expertise: firms at a higher level step up their R&D efforts, while those at a lower level reduce them.

To sum up, the empirical results of the last two decades have corroborated that competition has a basically positive impact on innovation. Nevertheless, numerous problems with the measurement and empirical methodology have not been properly solved. The creation of targeted corporate databases on innovation is a huge step forward, yet problems (such as measuring competition in an industry, the management of international relations or the adequate consideration of lagged effects) still persist.

THE RELATIONSHIP BETWEEN COMPETITION AND INNOVATION IN HUNGARY

Data

Our major data source was the database of the Hungarian Tax Authority, more specifically, the data from the balance sheets and profit and loss accounts of firms with double-entry accounting from the period between 1992 and 2006. *Table A1* in the Appendix shows the distribution of the firms contained in the database (by industry and size). From 2000 onwards, sampling has been designed to ensure that all large companies and exporting firms are included without exception; however, numerous smaller firms were omitted. The firms in the sample represent more than 90% of employees, turnover and export. As only a very low number of micro firms perform R&D activities, firms with less than 5 employees were excluded from the sample. We perform our analysis in the manufacturing, as the relationship between competition and innovation is easier to measure and interpret in this industry than in services. As in certain cases we used lagged variables as well, we restricted the sample to those firms that were included in the database both in 2003 and 2005.

Finally, for the purpose of data cleansing, we excluded from the analysis firms with a negative value added.

The database contains four-digit NACE number industry classification of the firms, the number of employees and the balance sheet data. Unfortunately, NACE industries do not necessarily correspond to markets as interpreted in industrial organization or competition policy. An industry may consists of several separate markets or a firm may perform productive activity in more than one industry, which then may result in a certain bias during the measurement of the effects of competition. We approximate the innovation efforts of businesses with R&D expenditures between 2003 and 2005.

Table *A2* of the Annex shows the summary statistics of the explanatory variables. *R&D intensity* measures the firm's R&D expenditure relative to its turnover. *Value added* is calculated from the balance sheet. *Labour productivity* is the ratio of corporate value added and the number of employees. *Capital intensity* is the value of tangible assets per employee. Data include information on foreign ownership share. We created a binary dummy variable. When its value is 1, it indicates that at least 10% of the company's equity is owned by foreigners. Data also give information on the firm's export activity. Again, we created a binary dummy variable. When its value is 1, it indicates that the firm performs export activities.

Variables that measure competition can also be defined from the database. We calculated the indicator C_3 to show the share of the three largest companies from the industry's turnover. The *Hirschman–Herfindahl index,* calculated on the basis of turnover, is an alternative measure for concentration. As mentioned above, the concentration variables often fail to measure the market power accurately. Therefore, we also used the indicator *ROA (return on assets)* to show the ratio of a firm's pre-tax profit to its assets.

Other indicators in the competition database of the Hungarian Competition Authority (Hungarian acronym: GVH) were also used as alternative indicators of the strength of competition.[6]

Models

The question is: What is the impact of competition on the innovation of firms? In our basic model, the (firm- or industry-level) R&D activity is the dependent variable, while the explanatory variables include measures of competition as well as control variables.

Three models have been estimated. In the first one, industry-level R&D intensity was modelled with industry competition variables and other explanatory variables. *Aghion et al.* [2005] employed a similar industry-level analysis.

[6] http://www.gvh.hu/gvh/alpha?do=2&st=1&pg=54&m5_doc=5635&m251_act=4.

$$R\&D\ intensity_{j,\,2005} = \alpha + \beta competition_{j,\,2005} + \gamma X_{j,\,2005} + \varepsilon_{j,\,2005} \qquad (1)$$

where j indicates industries; the time index indicates the fact that we used cross-sectional data of the year 2005 for the analysis; $R\&D\ intensity_{j,\,2005}$ is the industry's average R&D intensity; $competition_{j,\,2005}$ is an indicator of the competition; $X_{j,\,2005}$ contains other sectoral-level explanatory variables (labour productivity, capital intensity); and $\varepsilon_{j,\,2005}$ is random error. In the model, β shows the impact of competition on the R&D intensity of the industry.

We run the other two models at the firm level. In the first case, the dependent variable indicates whether the firm in question performed R&D activity in 2005. As the dependent variable is binary, we used a probit model.

$$P(RD_{i,\,2005}) = F(\alpha + \beta competition_{j,\,2005} + \gamma X_{j,\,2005} + \delta Z_{i,\,2005} + \varepsilon_{j,\,2005}) \qquad (2)$$

where i stands for the firm and j for the firm's industry, as the competition variable can be interpreted at the industry level. $X_{j,\,2005}$ contains industry control variables (binary industry dummies based on two-digit codes). $Z_{i,\,2005}$ contains some features of the firm (labour productivity, size and capital intensity). As the dependent variable is binary, the model can be interpreted as the probability of R&D activity. The function $F(x)$ is the normal distribution function.

In the last model, the dependent variable is the firm-level R&D intensity:

$$RD_{i,\,2005} = \alpha + \beta competition_{j,\,2005} + \gamma X_{j,\,2005} + \delta Z_{i,\,2005} + \varepsilon_{j,\,2005} \qquad (3)$$

As a large number of firms do not perform R&D activity – and, thus, the dependent variable is zero for them – this equation is estimated with a tobit model.

The *first* question is: How can we take into account the various variables that may possibly influence the dependent variable? A major problem may arise when at the industry level the nature of technology is such that it is related to the competition variable. Industrial technology is approximated by productivity and capital intensity. Here, the impact of the competition variable is identified from the comparison of the industries which use similar technologies. In the firm-level models, the heterogeneity of the industry is depicted with the aid of two-digit industrial codes. We address the issue of firm heterogeneity with the introduction of size dummies and variables measuring firm productivity, export status, foreign ownership and capital intensity. In the firm-level regressions some explanatory variables are industry-level variables, which may cause heteroskedasticity. We handle this with clustered standard errors.

The *second* question pertains to the issue of endogeneity; in other words, the fact that innovation in a given year is determined simultaneously with market structure. They mutually influence each other. To handle this, we ran all regressions with lagged explanatory variables (from 2003). Since innovation in year 2005 cannot affect the market structure variables in year 2003, we hope that the coefficients thus derived exhibit a causal relationship.

The *third* question is that of measuring competition. First, we performed all measurements with three competition variables. Two of them approximate the market structure, while ROA approximates the profit margin. After that, the firm-level regression is run on all variables of the competition statistics database of the Hungarian Competition Authority.

The *fourth* question pertains to the variable that reflects innovation. In this respect, the best solution would be to use the definition of innovation given in the Community Innovation Survey (CIS) of the European Union. However, as it is available only for a relatively small sample of firms, we decided to use the R&D value of year 2005, which was available for all firms.

Finally, as *Aghion et al.* [2005] (Chapter 3.1) emphasize this, the relationship between competition and innovation is not necessarily linear. To examine this relationship, we also estimated the model using a quadratic specification. The inverted-U shape is corroborated if the coefficient of the linear term is positive and that of the quadratic term is negative.

Results

Table *A2 of the Annex* contains the key summary statistics. It demonstrates that out of the 7,575 firms of the sample, only 256 (3.4%) performed R&D activities in 2005. By international comparison, this rate is very low, but – as mentioned in the first section – the true rate of innovative firms was higher. Approximately one-fifth of the firms in the sample were in foreign ownership and more than half of them performed export activity.

The first glimpse on the relationship between competition and innovation is given in *Table 1*. Based on the strength of the competition, we categorized the four-digit industries into four quartiles. In each column, we used a different competition indicator for the purpose of categorization. The numbers indicated in the

TABLE 1 • **Concentration and average R&D intensity, 2005**

NACE4 industries	Concentration (C_3)	Herfindahl index	ROA
1st quartile	0.096	0.096	0.092
2nd quartile	0.136	0.280	0.138
3rd quartile	0.350	0.196	0.140
4th quartile	0.043	0.053	0.257
F-test	4.24	2.36	1.1
p-value	0.006	0.072	0.348

Note: The Table shows the average R&D intensity in the industry quartiles defined on the basis of competition indicators. The *F-test* examines the hypothesis that these are equal.

Table show the average R&D intensity of the firms that fall into the given quartile. The bottom rows show the results of the F-test whose null hypothesis, that the industries belonging to each quartile exhibit the same average R&D intensity, could not be rejected.

The results shown in the table indicate significant differences between the quartiles for the two concentration indicators. This pattern falls in line with the model and empirical results of *Aghion et al.* [2005]: the relationship is depicted by an inverted-U shaped curve. R&D intensity is the highest in those industries where competition is of medium strength. However, there is no significant difference between the R&D intensity of the sectors in terms of the quartiles defined on the basis of ROA.

The relationship between average R&D intensity of the industries and competition was also examined with the industry-level regression shown in equation (1). The results are presented in *Table 2*. This Table contains three equations for all the three competition indicators. The first equation contains only the competition indicator. The second equation contains industry productivity and capital intensity as well, and thus takes into consideration the technological features of the industry. In the third equation, by including the square of the competition indicator, competition is allowed to have a non-linear impact on the dependent variable.

TABLE 2 • **Impact of competition on the R&D intensity in the industry**

Variable	OLS	Extended	Quadratic	OLS	Extended	Quadratic	OLS	Extended	Quadratic
Concentration (C_3)	0.042	0.006	1.685***						
	(0.075)	(0.068)	(0.575)						
Concentration² $(C_3)^2$			–1.313***						
			(0.439)						
Herfindahl index				–0.126**	–0.154**	0.506*			
				(0.053)	(0.067)	(0.293)			
Herfindahl index²						–0.668**			
						(0.296)			
Average ROA in industry							0.214	0.126	1.624
							(0.385)	(0.344)	(1.330)
ROA²									–3.657
									(2.531)
Labour productivity		0.001	0.002		0.002	0.002		0.001	0.001
		(0.002)	(0.002)		(0.002)	(0.003)		(0.002)	(0.002)
Log capital intensity		0.051	0.052		0.053	0.041		0.051	0.049
		(0.047)	(0.046)		(0.048)	(0.047)		(0.047)	(0.046)
Constant	0.127***	0.070	–0.377**	0.201***	0.12**	0.044	0.141***	0.066	–0.003
	(0.047)	(0.073)	(0.188)	(0.047)	(0.052)	(0.061)	(0.031)	(0.068)	(0.103)
Number of observations	231	231	231	231	231	231	231	231	231
R^2	0.000	0.007	0.031	0.005	0.015	0.026	0.001	0.008	0.018

Note: The dependent variable is the average R&D intensity of the industry (in percentage). The observation units are four-digit industries.

* Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

In line with the descriptive statistics, for C_3 and for the Herfindahl index the results show an inverted-U shaped relationship between competition and R&D intensity. The results for the ROA indicator are not significant. To examine robustness, we ran the same regressions on industry-level data aggregated to three digits, and the results were the same. To handle the issue of simultaneity between competition and innovation, we performed the calculations with lagged explanatory variables as well, and came to the same conclusions.

Overall, it was found that the industry-level data support the hypothesis of the inverted-U shaped curve. The low explanatory power of the models, however, indicates that (albeit competition does have an impact on R&D expenditure) technological and other differences between industries play a much more decisive role.

We now turn to the firm-level regressions. *Table 3* shows our estimation results for equations (2) and (3). The dependent variable is the probability of a positive

TABLE 3 • **Impact of competition on the R&D of firms**

Variable	Probit	Tobit	Probit	Tobit	Probit	Tobit
Concentration (C_3)	0.007** (0.003)	3.191 (1.267)				
Herfindahl index			0.005 (0.004)	1.923 (1.374)		
Average ROA in industry					0.010 (0.015)	2.725 (5.316)
Labour productivity	0.000 (0.000)	0.038 (0.048)	0.000 (0.000)	0.040 (0.049)	0.000 (0.000)	0.042 (0.051)
Log capital intensity	0.001** (0.001)	0.506** (0.235)	0.001*** (0.001)	0.526** (0.239)	0.002*** (0.001)	0.55** (0.242)
Size: 25–50	0.03*** (0.006)	5.882*** (1.373)	0.03*** (0.007)	5.846*** (1.369)	0.03*** (0.007)	5.813*** (1.367)
Size: 50–250	0.073*** (0.010)	7.825** (1.336)	0.073*** (0.011)	7.81*** (1.335)	0.073*** (0.011)	7.774*** (1.332)
Size: 250	0.269*** (0.035)	11.079*** (1.804)	0.274*** (0.036)	11.116*** (1.809)	0.276*** (0.036)	11.136*** (1.817)
Exporter	0.006*** (0.002)	2.617** (1.058)	0.007*** (0.002)	2.695** (1.077)	0.007** (0.002)	2.751** (1.080)
Foreign ownership > 10 %	–0.003*** (0.001)	–1.325** (0.646)	–0.003*** (0.001)	–1.27** (0.642)	–0.003** (0.001)	–1.285** (0.646)
Constant		–22.37*** (4.150)		–21.315*** (3.921)		–21.24*** (3.880)
Observations	7,125	7,575	7,125	7,575	7,125	7,575
Pseudo R^2	0.342	0.218	0.339	0.216	0.338	0.215
Log Likelihood	–726.1	–1267	–728.8	–1271	–729.6	–1272

Note: The dependent variable of the probit models indicates whether the firm in question performed R&D activity in 2005. The dependent variable of the tobit models show the firms' R&D intensity (in %). For the probit models, the table shows the average marginal effects at the sample mean. We calculated competition variables for four-digit NACE industries. Regressions also include two-digit industry dummies. We clustered standard errors at the industry level.
* Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

R&D expenditure in the probit columns, and the firms' R&D intensity in the tobit columns. For the probit model, the table contains the average marginal effect of the variables at the sample mean. The equations contain two-digit industry dummies as well; however, the table does not show the point estimates for them.

Larger firms with higher capital intensity that perform export activity have a higher-level innovative activity. An interesting result is that productivity does not affect R&D decisions when size and capital intensity are taken into consideration. Another surprising finding is that foreign-owned firms *ceteris paribus* perform less R&D than those owned by Hungarians. Our study *Halpern–Muraközy* [2010] established neither a negative nor a positive impact on the data taken from the Community Innovation Survey of the European Union. This can be attributed to the fact that the innovation expenditure of foreign business in Hungary exhibit only a weak correlation to the innovations implemented in Hungary.

As for the competition indicators, only the concentration indicator (C_3) is significant. It is positive, which means that firms in the relatively more concentrated industries are more likely to perform R&D, and their R&D intensity is higher. The Herfindahl index and ROA are not significant.

As indicated by the industry-level regressions, a possible reason is that the relationship between competition and innovation is not linear. *Table 4* shows the results of the estimation which involves a quadratic term in the equation. With regard to the competition indicators, an inverted-U shaped relationship was established for the concentration indicator (C_3) and the Herfindahl index. In this model, no significant effect was revealed for ROA. *Table A3* of the Appendix shows the results achieved with the use of lagged explanatory variables. The results of these specifications are similar to those of the previous estimations, but the coefficients of the competition variables are not as significant. For the other variables, the results are the same.

It has been mentioned above that concentration indicators are not necessarily the best tools to measure the strength of the competition actually affecting the market. Therefore, it is of great importance to examine which competition indicators are linked to the innovation efforts of firms and to what extent. For this purpose, we estimated equation (2) for 70 further competition indicators of the competition statistics database of the Hungarian Competition Authority. For the purposes of estimation – to handle the problem of simultaneity – we used the lagged values (of year 2003) of the indicators. *Table A4* of the Appendix shows the marginal effect of the competition indicators and their squares in the sample mean for the R&D binary value.

The results corroborate the conclusion that the concentration variables showing the share of the biggest companies are in an inverted U-shaped relationship with the innovation efforts of firms. The results were affected only to a small degree by whether concentration was calculated on the basis of assets or turnover. The strength or the direction of the relationship is not affected by whether the indicator shows the share of the three, five or ten largest firms. Interestingly, for

TABLE 4 • **Non-linear impact of competition on the R&D of firms**

Variable	Probit	Tobit	Probit	Tobit	Probit	Tobit
Concentration (C_3)	0.027** (0.011)	13.659** (5.306)				
Concentration² $(C_3)^2$	−0.018* (0.009)	−9.178** (4.382)				
Herfindahl index			0.019* (0.011)	9.721** (4.624)		
Herfindahl index²			−0.018 (0.012)	−10.009** (5.098)		
Average ROA in industry					0.009 (0.038)	2.964 (13.054)
ROA²					0.006 (0.090)	−0.687 (30.215)
Labour productivity	0.000 (0.000)	0.042 (0.049)	0.000 (0.000)	0.044 (0.051)	0.000 (0.000)	0.042 (0.051)
Log capital intensity	0.001** (0.001)	0.516** (0.237)	0.001*** (0.001)	0.524** (0.238)	0.001*** (0.001)	0.551** (0.242)
Size: 25–50	0.03*** (0.006)	5.91*** (1.372)	0.03*** (0.006)	5.859*** (1.374)	0.03*** (0.007)	5.813*** (1.366)
Size: 50–250	0.071*** (0.010)	7.803*** (1.325)	0.073*** (0.011)	7.796*** (1.338)	0.073*** (0.011)	7.774*** (1.331)
Size: 250 <	0.268*** (0.035)	11.106*** (1.804)	0.272*** (0.036)	11.085*** (1.812)	0.277*** (0.036)	11.135*** (1.814)
Export	0.006*** (0.002)	2.543 (1.038)	0.006*** (0.002)	2.636** (1.062)	0.007*** (0.002)	2.752** (1.077)
Foreign ownership 10 % <	−0.003*** (0.001)	−1.386** (0.659)	−0.003*** (0.001)	−1.331** (0.647)	−0.003** (0.001)	−1.285** (0.646)
Constant		−24.656*** (4.765)		−21.825*** (4.039)		−21.249*** (3.912)
Observations	7,125	7,575	7,125	7,575	7,125	7,575
Pseudo R^2	0.343	0.220	0.340	0.217	0.338	0.215
Log Likelihood	−724.4	−1265	−727.6	−1268	−729.6	−1272

Note: The dependent variable of the probit models indicates whether the firm in question performed R&D activity in 2005. The dependent variable of the tobit models show the R&D intensity of firms (in %). For the probit models, the table shows the average marginal effects at the sample mean. We calculated competition variables for four-digit NACE industries. Regressions also include two-digit industry dummies. We clustered standard errors at the industry level.
* Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

the concentration indicators that measure domestic consumption, no significant impact has been established. Similarly, the Herfindahl index (from the database of the Hungarian Competition Authority) does not exhibit a significant relationship with innovation expenditure.

Among other indicators, it is the industrial dynamics variable that has a significant impact on R&D expenditure: the intensity of entry and exit is in a convex

(U-shaped) relationship with the firms' R&D probability. These variables can be regarded as the measures of the threat of entry. It is in connection with this variable, that the model of *Aghion et al.* [2009] sets forth a prediction that is contrary to our results.[7]

As for the financial variables, the return on equity (ROE) is in a concave (albeit not inverted-U shaped) relationship with innovation efforts. Falling in line with the above calculations, the ROA obtained from the competition statistics database of the Hungarian Competition Authority is not significant, either. Finally, the presence of foreign-owned firms, the indicator is also shown to have an inverted-U shaped relationship with competition.

In sum, the empirical results show that in Hungary there is a detectable inverted-U shaped relationship between competition and innovation at both the industry and firm levels. Competition increases innovation, yet R&D intensity is somewhat lower in industries where competition is very strong than in industries with medium-strength competition. The result can be interpreted as a causal impact inasmuch as lagged explanatory variables yield the same result. The analysis of a wide range of competition indicators evidences the importance of the method of measuring competition: the concentration indicators, the industrial dynamics, ROE and the ratio of foreigners are in significant relationship with the probability of R&D activity in firms.

CONCLUSIONS

This study presents an overview of the key theories and empirical results related to the relationship between competition and innovation. Our study contributes to the ongoing debates in Hungary by sharing information on empirical results with respect to this relationship.

In recent decades, research on innovation has been calling attention to the requirement that the inputs to and the results of innovation need to be distinguished and dealt with separately. The difference between the two is important, especially in countries which are not among the technologically most advanced ones in the world. For instance, the number of Hungarian firms that introduced innovations in 2006 was three times as high as the number of those that performed R&D activity continuously in the preceding years (*Halpern–Muraközy* [2010]).

Theoretical models explaining the relationship between competition and innovation have a long history. Schumpeter's theory holds that large firms often perform R&D more efficiently and, as a result, some market power is required for a firm to implement a large number of innovations. Important new developments were pre-

[7] However, this relationship can be explained by other circumstances. For example, it is possible that the entry and exit rates are higher in countries with several, geographically segmented markets.

sented by *Aghion et al.* [2005]. Their empirical models yielded inverted-U shaped relationships, which suggest that innovative activity is lower in firms that operate either in highly concentrated or highly competitive industries than in firms in moderately competitive sectors of the economy.

The measurement of the relationship between competition and innovation raises a number of problems. In addition to the difficulties related to measuring the explanatory and dependent variables, another grave issue is presented by the simultaneity of the relationship between competition and innovation.

As evidenced by research in the 1990s, growing competition, in general, strengthens corporate innovation. In the 2000s, some authors came to the conclusion that the relationship is non-linear but an inverted-U shaped relationship can be frequently established.

We analyzed an extensive set of data on Hungarian firms, based on methods we derived from leading international literary sources. The main conclusion from our efforts is that the inverted-U shaped relationship can indeed be established at the industry-level as well as at the firm-level. By applying several competition indicators to our models, we also discovered that only certain types of indicators of the presence and intensity of competition seem to have had an impact on the innovative investments of firms.

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APPENDIX

TABLE A1 • **Sample size**

Industries	Number of employees in sample				Total
	1–25	25–50	50–250	250 <	
	employees in company				
Manufacture of food products and beverages	549	222	279	61	1111
Manufacture of tobacco products	1	0	2	2	5
Manufacture of textiles	137	45	48	10	240
Manufacture of wearing apparel	186	85	115	24	410
Tanning and dressing of leather	50	26	41	9	126
Manufacture of wood and wood products	316	72	47	6	441
Manufacture of pulp, paper and paper products	68	27	33	8	136
Publishing and printing	372	76	63	9	520
Manufacture of coke, refined petroleum products and nuclear fuel	0	0	0	3	3
Manufacture of chemicals, chemical products	107	34	44	19	204
Manufacture of rubber and plastic products	319	107	124	18	568
Manufacture of non-metallic mineral products	172	55	60	19	306
Manufacture of basic metals	40	17	38	10	105
Manufacture of fabricated metal products	738	246	177	15	1176
Manufacture of machinery and equipment	442	137	167	29	775
Manufacture of office machinery and computers	19	7	7	3	36
Manufacture of electrical machinery and apparatus n.e.c.	132	45	66	47	290
Manufacture of radio, television and communication equipment and apparatus	79	23	30	25	157
Manufacture of instruments	192	38	47	7	284
Manufacture of motor vehicles, trailers and semi-trailers	51	28	37	37	153
Manufacture of other transport equipment	35	11	11	8	65
Manufacture of furniture	273	81	64	6	424
Recycling	25	7	8	0	40
Total	4,303	1,389	1,508	375	7,575

TABLE A2 • **Summary statistics of key variables**

Dummy	Value of variable	
	0	1
Performs innovation	7,319	256
Foreign ownership > 10 %	6,025	1,550
Exports	3,503	4,072

Continuous variables	Number of observations	Average	Median	Standard Deviation
R&D intensity for all firms	7,575	0.001	0.000	0.009
R&D intensity for firms that perform R&D	7,575	0.022	0.007	0.044
Labour productivity	7,575	3.419	2.292	4.834
Added value	7,575	498.25	49.56	7265.98
Capital intensity	7,575	4.318	2.182	7.805

TABLE A3 • **Nonlinear impact of competition on the R&D of firms (lagged explanatory variables)**

Variable	Probit	Tobit	Probit	Tobit	Probit	Tobit
Concentration (C_3)	0.010 (0.008)	6.262* (3.464)				
Concentration² $(C_3)^2$	–0.005 (0.008)	–4.248 (3.522)				
Herfindahl index			0.023** (0.012)	11.838** (4.970)		
Herfindahl index²			–0.030* (0.016)	–16.616** (6.764)		
Average ROA in industry					0.014 (0.042)	8.188 (19.164)
ROA²					0.109 (0.286)	41.334 (130.920)
Labour productivity	0.000* (0.000)	0.093 (0.062)	0.000 (0.000)	0.090 (0.061)	0.000 (0.000)	0.089 (0.061)
Log capital intensity	0.002*** (0.001)	0.685** (0.287)	0.002*** (0.001)	0.697** (0.289)	0.002*** (0.001)	0.715** (0.295)
Size: 25–50	0.027*** (0.006)	5.19*** (1.086)	0.027*** (0.006)	5.18*** (1.091)	0.026*** (0.006)	5.125*** (1.089)
Size: 50–250	0.068*** (0.009)	7.483*** (1.122)	0.067*** (0.009)	7.448*** (1.124)	0.068*** (0.009)	7.457*** (1.135)
Size: 250 <	0.290*** (0.032)	11.118*** (1.698)	0.291*** (0.032)	11.15*** (1.715)	0.3*** (0.032)	11.313*** (1.758)
Export	0.006*** (0.002)	2.518** (1.038)	0.006*** (0.002)	2.582** (1.048)	0.006*** (0.002)	2.559** (1.044)
Foreign ownership > 10%	–0.004*** (0.001)	–1.622** (0.766)	–0.004*** (0.001)	–1.625** (0.762)	–0.004*** (0.001)	–1.585** (0.757)
Constant		–21.67*** (4.035)		–21.105*** (3.880)		–21.195*** (3.990)
Observations	7,125	7,575	7,125	7,575	7,125	7,575
Pseudo R^2	0.358	0.223	0.358	0.223	0.358	0.223
Log Likelihood	–708.3	–1,259	–708.2	–1,260	–708.5	–1,260

Note: The dependent variable of the probit models indicates whether the firm performed R&D activity in 2005. The dependent variable of the tobit models shows the R&D intensity of firms (in %). For the probit models, the Table shows the marginal effects for the sample mean. We calculated competition variables for four-digit NACE industries. Regressions also include two-digit industry dummies. The explanatory variables are from 2003. We clustered standard errors at the industry level.
* Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.

TABLE A4 • **Non-linear impact of competition indicators on the R&D activity of firms (with NACE4 quadratic term)**

Competition indicator	Beta	Standard error	Beta squared	Standard error
Number of firms	–0.00098	0.00037**	0.00000	0.00000**
Concentration (C_3) on the basis of net sales	0.02706***	0.00780**	–0.00022	0.00007***
Concentration (C_3) on the basis of total assets	0.02094	0.00739**	–0.00015	0.00006**
Concentration (C_5) on the basis of net sales turnover	0.02647***	0.00868***	–0.00019	0.00007**
Concentration (C_5) on the basis of total assets	0.02457	0.00862**	–0.00017	0.00007**
Concentration (C_{10}) on the basis of net sales	0.02830	0.01130**	–0.00018	0.00008**
Concentration (C_{10}) on the basis of total assets	0.02936	0.01237**	–0.00018	0.00009*
Relative standard deviation of shares on the basis of net sales	0.02166	0.00848**	–0.00020	0.00008**
Relative standard deviation of shares on the basis of total assets	0.01609	0.00798*	–0.00012	0.00007
HHI on the basis of net sales	0.00009	0.00007	–0.00000	0.00000
HHI on the basis of total assets	0.00010	0.00007	–0.00000	0.00000
C_3 on the basis of domestic consumption (hypothesis 1)#	0.01384	0.0967	–0.00007	0.00008
C_3 on the basis of domestic consumption (hypothesis 2)#	–0.00436	0.00823	0.00000	0.00011
C_5 on the basis of domestic consumption (hypothesis 1)#	0.01687	0.01043	–0.00009	0.00009
C_5 on the basis of domestic consumption (hypothesis 2)#	–0.00683	0.00774	0.00005	0.00010
HHI on the basis of domestic consumption (hypothesis 1)#	0.00004	0.00007	0.00000	0.00000
HHI on the basis of domestic consumption (hypothesis 2)#	–0.00026	0.00015	0.00000	0.00000**
Domestic consumption	0.00000	0.00000**	–0.00000	0.00000**
Domestic consumption (% of net sales)	0.00067	0.00040	–0.00000	0.00000
Import categorized on the basis of products (% of domestic consumption)	0.00523	0.00782	0.00002	0.00007
Share of large firms in industry sales	0.00804	0.00504	–0.00006	0.00005
Share of medium firms in industry sales	–0.00584	0.00628	0.00006	0.00007
Share of small and micro firms in industry sales	0.00155	0.00823	–0.00009	0.0012
Share of large firms in industry total assets	0.00648	0.00497	–0.00004	0.00005
Share of medium firms in industry total assets	–0.00785	0.00627	0.00009	0.00007
Share of small and micro firms in industry total assets	–0.00710	0.00766	0.00001	0.00011
Ratio of the turnover of small firms to that of large firms	–0.04793	0.03223	0.00083	0.00107
Share of import in the industry total supply	0.00075	0.00038	–0.00000	0.00000
Number of firms entering the market in the given year	–0.01014	0.00315***	0.00004	0.00002**
Number of firms exiting the market in the given year	–0.01375	0.00485**	0.00009	0.00003**
Ratio of entering firms in year *t*	–0.00792	0.02294	–0.00012	0.00071
Ratio of exiting firms in year *t*	0.02923	0.02922	–0.00041	0.00119
Drop-out rate in year *t*	0.01442	0.01448	–0.00019	0.00024
Net turnover of the sale of dissolved firms in year *t* (% of total industry turnover in year *t*)	–0.06895	0.04960	0.00286	0.00264
Assets of dissolved firms in year *t* (% of total industry assets in year *t*)	–0.05556	0.01707***	0.00143	0.00045***
Net turnover of the sale of new entrants in year *t* (% of total industry turnover in year *t*)	0.00269	0.05794	–0.00268	0.00576
Assets of new entrants in year *t* (% of total industry assets in year *t*)	0.00442	0.03847	–0.00238	0.00272

Competition indicator	Beta	Standard error	Beta squared	Standard error
Profitability of exiting firms compared to the profitability of those that stay in the market	0.00001	0.00001	0.00000	0.00000
Productivity of exiting firms compared to the productivity of those that stay in the market	–0.00194	0.00118	0.00000	0.00001
Number of firms not included in the sample	–0.00393	0.00141**	0.00001	0.00000*
Industrial output price index	–0.26605	0.31791	0.00133	0.00158
Domestic sales price index	0.55400	0.38505	–0.00275	0.00189
Export sales price index	0.00030	0.10754	0.00005	0.00055
EBIT ratio	–0.00124	0.01770	0.00043	0.00077
EBITDA ratio	0.00918	0.02381	–0.00007	0.00080
Return on equity before tax (ROE1)	–0.00439	0.00153**	–0.00000	0.00000**
Return on equity after tax (ROE2)	–0.00430	0.00148**	–0.00000	0.00000**
Balance sheet earnings on equity (ROE3)	–0.00358	0.00165*	–0.00000	0.00000**
Return on capital employed (ROCE)	0.01231	0.01209	–0.00059	0.00037
Return on Sales (ROS)	–0.00700	0.01690	0.00085	0.00069
Return on Investment (ROI)	0.00353	0.00310	–0.00002	0.00004
Return on Asset (ROA)	0.01141	0.01235	–0.00029	0.00094
Return on Invested Capital (ROIC)	0.01106	0.01449	–0.00068	0.00063
Industry loss (% of net turnover)	–0.09287	0.03208**	0.00687	0.00207***
Gross added value per capita	0.01702	0.02602	0.00015	0.00071
Gross added value per unit labour cost	0.00142	0.00223	–0.00000	0.00000
Relative standard deviation of gross added value per capita	0.00741	0.01058	0.00003	0.00014
Relative standard deviation of gross added value per unit labour cost	–0.00891	0.00967	0.00014	0.00012
Simple arithmetic mean of gross added value per capita	0.24613	0.08342***	–0.01921	0.00641***
Simple arithmetic mean of gross added value per unit labour cost	–0.00040	0.00030	0.00000	0.00000***
Total factor productivity (TFP) in industry	0.00926	0.05413	–0.00175	0.00278
Relative standard deviation of total factor productivity	–0.00030	0.00997	–0.000003	0.00016
Simple arithmetic mean of total factor productivity of firms in industry	0.01017	0.01809	–0.00006	0.00020
Productivity of smaller firms compared to that of large firms	–0.00191	0.00474	–0.00002	0.00007
Numerator of the indicator of the relationship between profitability and productivity	0.00260	0.00598	0.000000	0.00005
Denominator of the indicator of the relationship between profitability and productivity	–0.00135	0.02207	0.00028	0.00094
Export share in industry total demand	0.00042	0.00067	0.00000	0.00000
Renewal of assets on the basis of implemented investments	–0.00570	0.01742	0.00036	0.00036
Rate of foreign ownership in subscribed capital	0.01691	0.00693**	–0.00015	0.00007**
Net turnover of sales in industry	0.00000	0.00000	–0.00000	0.00000
Size of industry	0.00081	0.00202	–0.00000	0.00001
Cost disadvantage ratio	0.00470	0.00456	–0.00003	0.00003

Note: For each variable, the probit model referred to in *Table A3* was estimated. The table shows the average marginal effect of the competition indicator at the sample average. Competition variables were calculated for four-digit NACE industries. Regressions also include two-digit industry dummies. The explanatory variables are from 2003. We clustered standard errors at the industry level.
[#] For the description of the two hypotheses, see: http://www.gvh.hu/gvh/alpha?do=2&st=1&pg=54&m5_doc=5635&m251_act=4.
* Significant at the 10 percent level, ** significant at the 5 percent level, *** significant at the 1 percent level.