EKONOMISTA | **ARTYKUŁY**

online first
DOI: 10.52335/ekon/196231

Michał Piętal
Department of Complex Systems, Rzeszow University of Technology, Poland,
https://orcid.org/0000-0002-3928-2522, email: m.pietal@prz.edu.pl

Marcin Paszko
Department of Complex Systems, Rzeszow University of Technology, Poland,
https://orcid.org/0009-0005-8460-7487, email: paszko.mr@gmail.com

Spillover Effects and the Stability of Cartels

O stabilności karteli w kontekście efektów typu spillover

Abstract

It is widely recognized that competition is the most optimal way to ensure economic efficiency and satisfy consumer needs. However, companies are naturally motivated to gain a monopoly position, as this would increase their profits and lower their marketing expenditure. Competition policy, however, is effective in preventing this so long as appropriate regulations are in force when required. If the market is able to ensure competition unaided (e.g. in a perfectly competitive market), government intervention is not only superfluous, but costly and even socially harmful. This paper examines Nash equilibria for the classic Cournot model, as elaborated by Prokop (2011), and extends the results of that paper to cover know-how spillover scenarios. The authors consider sound and novel suggestions concerning cartels in terms of industrial policy on pro-innovation activities. This is because formally stable cartels tend to destabilize in the face of market-related (IP-related) events. The paper introduces, observes and elaborates this phenomenon.

Keywords: Nash equilibrium, heterogeneous cartels stability, know-how flows.

JEL: C10, C39, C73

Streszczenie

Powszechnie uznaje się, że konkurencja między firmami jest najbardziej optymalnym sposobem zapewnienia efektywności ekonomicznej, przy jednoczesnym zaspokojeniu potrzeb konsumentów. Przedsiębiorstwa mają jednak tendencję (wynikającą z ich motywacji ekonomicznej) do zdobywania pozycji monopolistycznej, która zapewniłaby im wyższe zyski i np. niższe wydatki marketingowe. Polityka konkurencji jest jednak skuteczna, gdy w razie potrzeby wprowadzane są odpowiednie regulacje. W sytuacji, gdy rynek sam jest w stanie zapewnić konkurencję między firmami (np. rynki o doskonałej konkurencji), ingerencja rządu jest zbędna, kosztowna, a nawet społecznie szkodliwa. W niniejszej pracy badano równowagę Nasha w klasycznym modelu Cournota, opracowanego w (Prokop, 2011), rozszerzając jego wyniki na scenariusze transferu know-how. Jako główny wniosek z tej pracy, autorzy rozważają konkretne i nowatorskie wnioski dotyczące karteli w zakresie polityki przemysłowej w obszarze działań proinnowacyjnych. Wynika to z faktu, że stabilne kartele mają tendencję do destabilizacji po wystąpieniu zdarzeń rynkowych (związanych z własnością intelektualną). Zjawisko przedstawiono i omówiono w niniejszym dokumencie.

Słowa kluczowe: Równowaga Nasha, stabilność karteli heterogenicznych, przepływy know-how.

JEL: C10, C39, C73

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1. Introduction

It is widely recognized that competition is the optimal way to ensure economic efficiency and meet consumer needs. This is because competition results in better terms for purchasers of goods and services (i.e. price, quality, reliability, durability, accompanying services, and even the aesthetics or practicality of the packaging). This leads to a seemingly unstable situation, as some providers lose market share, and some are even driven out of business, while others achieve huge profits, and new ones enter the market. However, competition has led to considerable benefits for consumers. Gorynia (1995) has developed a thesis on the regulation of mesosystems.

However, some companies are economically motivated towards gaining a monopoly position, as this would increase profitability and lower marketing expenditure. Competition policy, which is the statutory role of public supervisory and control bodies, must find the best way to prevent this. Competition policy is not effective unless regulations are only enacted and enforced when necessary. If the market is able to ensure competition (e.g. if it is perfectly competitive) unaided, then government intervention is not only superfluous, but costly and even socially harmful. For this reason, research on cartel collusion should contribute to a better understanding of the situations in which government intervention in the market is necessary and, where and when it can, and even should, be avoided.

There is a rich body of literature on groups of companies that fully or partially agree on their R&D operations. The formation of cartels is a negative development, and the government agencies charged with combating them often impose harsh penalties. Even business clusters supported by government policies sometimes turn into cartels. Some theoretical works claim that cartels are formed only in very small branches (e.g. composed of five companies), but in the central view of this publication (Prokop, 2011) it was shown that this is not true in relation to heterogeneous companies (i.e. with different cost parameters or functions). The latter assumption, however, seems natural in the case of a group of companies undertaking innovative activities or having R&D operations or departments. Once the cited model is extrapolated by slightly generalizing its reveals, however, the risk of cartelization appears to be much smaller. Moreover, an appropriate industrial policy can implement (or maintain) regulations that effectively reduce the number of cartels created. This is a pro-innovation policy that has the effect of enriching the state. Therefore, since there is a general consensus on its continuous conduct, the conclusions of this work additionally highlight the new application of this specific policy, which has not yet been seen from the perspective of the whole economy.

Business clusters can work together in certain areas, which can, objectively, have different effects on industry, consumers, and the economy. Nowhere in the theory of clustering is it posited that clusters cannot - as it were in parallel – form cartels. Moreover, if it is assumed that clusters are innovative (the close connection between clustering and innovation has been clearly demonstrated (Kowalski, 2013), including on a microeconomic scale), then they can claim a number of exemptions to defend antitrust proceedings brought as a result of EU regulations. Thus, the duly empowered authorities will in principle waive proceedings when the following four conditions are met (see: Article 81(3) of the EC Treaty):

- the agreement shall contribute to the improvement of production or distribution or to technical or economic progress;
- the buyer shall receive part of the benefits of the agreement;
- it does not impose on its members conditions other than those necessary to achieve its objectives;
- it does not provide the participants with the opportunity to eliminate competitors.

As seems intuitive, if a cluster deals with 'innovative activity', it has effective defences against charges of competitive collusion. However, the present authors contend that it can nevertheless influence the market by creating hybrid structures, i.e. cluster-cartels (Kowalski, 2013) has made the same claim). It would therefore be desirable that the relevant control or supervisory bodies had specific means of verifying clusters, or alternatively, that there were economic mechanisms that would make the creation of cartel collusion within existing clusters impossible or at least economically irrational.

2. Theoretical basis

2.1. Cartels

Cartels are socially and economically harmful. A cartel comprises several companies from a given industry that collude in order to shape supply, prices, and other factors in the marketplace. Typically, a cartel is supply-dominant. As such, it has the potential to distort competition. Competition is clearly desirable because it lowers prices and improves quality and other characteristics of goods and services. Decision-makers obviously stand on the side of consumers rather than suppliers.

Legal regulations prohibit the creation of cartels, and provide severe penalties (often up to ten percent of the member companies' annual revenues) for infractions. Although many cartels have been detected, the companies concerned have often disputed their convictions. Cartels are extremely difficult to detect, as there is seldom any concrete evidence of their existence. This compels the conclusion that any measure that preempts, or failing that, detects, cartels would be very beneficial to the economy. Detecting cartels is extremely difficult. Cartels are usually detected in the course of investigations into price collusion, which rely on witness testimonies (which are often lacking), documentary evidence (which is extremely difficult to obtain), and econometric analyses (which are by nature simplified and which sometimes inadvertently attribute cartelization to groups of companies that have not made any agreement at all).

Prokop (2011) contends that cartelisation is possible in any nonhomogeneous industry. Cartels are created by the ($k < n$) most cost-efficient companies. He also shows that cartels created in this manner form a stable subset (more precisely, a Nash equilibrium), as it is not profitable for any member company to leave the cartel or any outside company to join it. These are extremely important conclusions, as the present authors plan to generalize the reported dependencies by introducing events into the model (thereby generalising it and making it more realistic). Assuming the occurrence of particular, otherwise natural market events, this sort of modification makes it possible to re-analyse the stability of cartels and to revise previous conclusions. It should be noted that the work cited above was largely inspired by earlier works by e.g. d'Aspremont (1983).

Similar issues have been addressed in other papers. Prokop (1999) stated that stable cartels are always formed in industries composed of ($n \leq 5$) companies. However, as the number of companies in a given industry increases, the likelihood of cartelisation decreases (e.g. for $n = 300$, the probability is 0.1405). Prokop (2015) also describes a scenario somewhat analogous to the one derived in this thesis, i.e. one in which the mutual cost function of two colluding companies was determined by the exchange of know-how between them. Moreover, assuming profit maximisation, it was shown that this parameter should be positive, but less than one, which is optimal at the level of the balance sheet for the entire economy.

2.2. The Cournot competition model

The classic competition model of Cournot (Cournot, 1838) is based on the simultaneous decisions on the production volume of all companies, and assumes that information on the production of other companies can be derived. According to the linear cost model, the following dependencies obtain:

$$q = q_1 + q_2 + \cdots + q_n \tag{1}$$

$$C_i(q_i) = cq_i \tag{2}$$

$$p(q) = a - bq \tag{3}$$

$$\pi_i: (a - bq)q_i - cq_i = (a - c)q_i - bq_i q \tag{4}$$

where:

q	total supply
qi	company supply
Ci(*qi*)	cost function
pq	demand function
π*i*	profit function

This model is used in the present paper, but with the added assumptions of a square cost function and a linear demand function.

2.3. Game theory, including the Nash equilibrium

The Nash equilibrium (Nash, 1950) is a concept that comes from game theory, which is currently quite extensively applied. This theory was created to model mathematical decision-making by 'players' (here: market participants). After years of development, it has found many applications, including econometrics, mathematical modelling in economics and population biology, behavioural psychology, and sociology.

Each of (n > 1) players can choose options from a set C (often a two-element set, e.g. {Y, N}). The game has what is known as a U payoff matrix, which assigns each 'scenario' (a set of choices for all players, i.e. vector (G1, G2, …, GN)) to the benefit (payoff) obtained. According to the U matrix, each decision set yields a distinct payoff for each player. Thus the payoff is also a vector and can vary depending on the choice vector. The game consists of a sequence of turns, i.e. t = 0, t = 1, etc., so the payoff values can be stored and summed for each player.

The players receive a payoff for each turn, so can develop numerous strategies, e.g. cooperation. Nash Equilibrium can emerge at any 'step' (subgame). Nash equilibrium can be defined as follows: Equilibrium in the Nash sense - an outcome in a noncooperative game for two or more players, in which no participant can gain by a unilateral change of strategy if the strategies of the others remain unchanged.

The article elaborates further on companies operating in a single industry (finite number), some of which can create cartels. At each step, every company votes on whether to form a cartel. The emergent cartel then fixes prices. Companies outside the cartel make their own decisions (Prokop, 2011).

3. Simulations and calculations of new models

3.1. Main model and assumptions

Most of the models and designs introduced in this work are taken from Prokop (2011). The following model is identical to his. As the number of companies is finite, it is assumed that there are n companies in a given industry. However, it is also assumed that this is not a de facto monopoly (n > 1). The next assumption is that these companies produce the same product, and primarily differ in manufacturing costs. The cost function is as follows:

$$C_i(q_i) = \frac{q_i^2}{2\beta_i} \tag{5}$$

where:

q_i production function
β_i efficiency of the company
$\beta_1 > \beta_2 > \ldots \beta_n > 0$

Market demand is defined by the formula:

$$Q = a - bp \tag{6}$$

As shown (Prokop, 2011), in each case, the k (where 1 ≤ k ≤ n) most cost-efficient companies will create a cartel, and the remaining (n – k) companies will remain outside it. This will happen because in the context of the payoff matrix in a multi-dimensional game like the prisoner's dilemma, the set (k, n – k) represents a Nash equilibrium. This is achieved using the following profit function definitions (profit maximisation is assumed):

$$\pi_{d,i}^{*} = \frac{a^2}{2} \frac{\beta_i}{(b + \sum_{j=1}^{n} \beta_j)^2 - (\sum_{j=1}^{k} \beta_j)^2} \tag{7}$$

for a cartel company and:

$$\pi_{c,i}^{*} = \frac{a^2}{2} \frac{\beta_i (b + \sum_{j=1}^{n} \beta_j)^2}{((b + \sum_{j=1}^{n} \beta_j)^2 - (\sum_{j=1}^{k} \beta_j)^2)^2} \tag{8}$$

for a non-cartel company. Table 1 shows the size of a stable cartel for a set of companies with different β parameters. Additional assumptions are: a = 100, b = 1. On these fifteen sets of parameters, the authors made calculations described in the later part of the work.

Table 1.

Number of cartel participants for sets of cost parameters β, for branches of different size

Number of companies in branch – n	β1	β2	β3	β4	β5	β6	Number of companies in cartel – k
2	1	0.3					1
2	1	0.6					2
2	1	0.8					2
3	1	0.3	0.2				1
3	1	0.7	0.4				2
3	1	0.8	0.6				3
4	1	0.8	0.6	0.5			2
4	1	0.95	0.9	0.85			3
4	1	0.99	0.98	0.97			4
5	1	0.7	0.4	0.3	0.2		2
5	1	0.9	0.8	0.7	0.6		3

Number of companies in branch – n	β1	β2	β3	β4	β5	β6	Number of companies in cartel – k
5	1	0.99	0.98	0.97	0.96		4
6	1	0.6	0.5	0.4	0.3	0.2	2
6	1	0.9	0.8	0.7	0.6	0.5	3
6	1	0.99	0.98	0.97	0.96	0.95	3

Source: Prokop, 2011.

3.2. Definition of R&D scenarios and their impact on the model

In the theory of economics and management, there is a common consensus that knowledge related to the main business process is a key factor in the company's success. In fact, it is the main source of competitive advantage, as it impacts the bottom line by reducing costs and directly affecting other parameters (e.g. quality, product durability). For this reason, the present paper takes the model derived above and modifies its parameters (especially the production cost parameter in the case of certain companies) so as to observe whether the stability of the cartel can be disturbed for any set of parameters shown in Prokop (2011). This can be achieved by creating certain reasonably market-based scenarios, when there are changes in the cost parameters of some companies.

Consider the following examples of economic developments closely linked to innovative markets:

1. Sharing of know-how within the cartel;
2. Joint investment in R&D within the cartel;
3. Discovery or acquisition of innovative R&D knowledge (e.g. a patent);
4. New business knowledge on the market (e.g. a published scientific discovery);
5. Expiration of exclusive R&D rights (e.g. a patent), outside the cartel;
6. Expiration of exclusive R&D rights (e.g. a patent), inside the cartel.

The above, exemplary market events created for the purpose of this paper affect the cost coefficients (βi) as follows:

1. All cartel members increase cost parameters;
2. All cartel members decrease cost parameters;
3. Cartel members increase cost parameters by a fixed amount;
4. All companies in the industry (both cartel and non-cartel) increase cost parameters by a fixed amount;
5. All companies in the industry, except one (non-cartel), increase cost parameters by a fixed amount;
6. All companies in the industry, except one (cartel), increase cost parameters by a fixed amount.

According to the formation of a cartel within the model described earlier in this article, each of the above events (considered separately) should be implemented in the model under the following assumptions:

- n companies, βi coefficients, and a cartel size of $1 \leq k \leq n$;
- starting from step t = i, the cost parameters are changed according to the above formulas;

- the analysis is to examine whether the game will show a new Nash equilibrium, i.e. $l \neq k$, for $t \geq i$.

3.3. The scenarios – analysis results

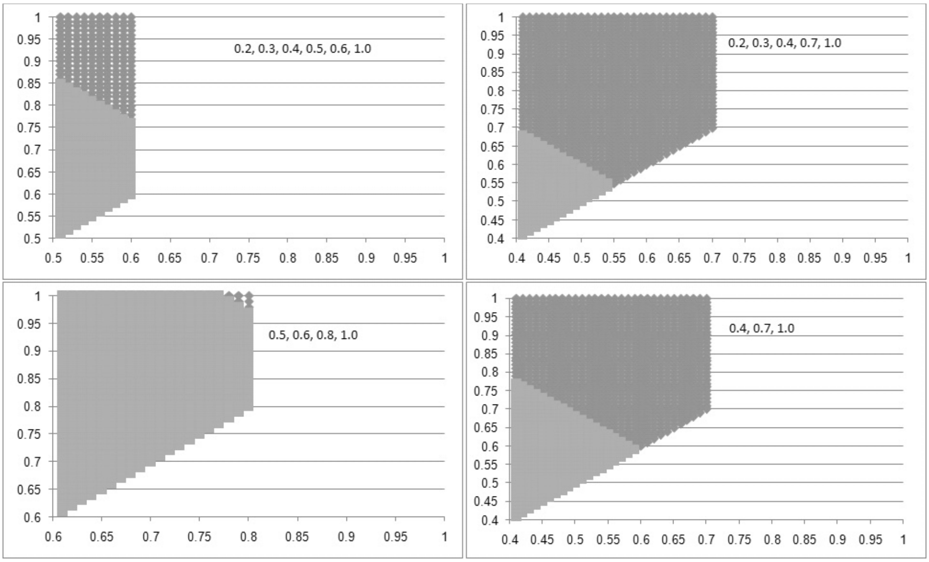
In summary, the model is defined as in the previous works cited only here it is sequential (i.e. discrete time spanning one day which is in accordance to IP law conditions). Every day, β parameters are altered (on the course of simulations). In some cases, this causes the Nash Equilibrium to alter to another cartel size. This is the theoretical model. But in order to observe the phenomenon, the example parameters (β1 and β2, within their initial bounds from the Table 1, taken from (Prokop, 2011)) were taken and iterated over these bounds, with a step of 0.01. So, having β1 and β2 valued at 1.0 and 0.7, we altered these, whilst β2 becoming 0.71, 0.72 and so and β1 becoming 0.99, 0.98 and so. The inequality: β1 > = β2 > = β3 etc. was preserved. Afterwards, by collecting the possible Nash equilibria for all possible values, the simulation graphs presented below were constructed. The areas highlighted by distinct colours are Nash Equilibria that cause distinct cartel size values. This led to the conclusion that there exists a time-bound and probable path and a corresponding parameter sequence that drives the model from one Nash Equilibrium to another.

1. **Sharing know-how.** All companies in the cartel decide to share their knowledge about the production or provision of goods andservices. This can be simplified in such a way that the most effective company (β1) 'transfers' its cost parameter to other companies, which makes it a common cost parameter in the cartel. Companies outside the cartel maintain their own cost parameters. The simulations showed that the same k sets of companies were created as a cartel as in the original case.
2. **Joint investment in R&D.** In this case, each company in the cartel (temporarily) lowered its cost parameters. Since the costs of the cartel vary, different schemes for joint financing of investments can be imagined. In such a situation, a sufficient assumption for simulation is lowering of the value of β within the cartel, based on an arbitrary, rational scheme (e.g. proportional to the cost efficiency of the company).

In this case, many of the cartels in the database proved stable. Four cartels acquired a new member (as the Nash equilibrium point had changed) for some of the generated sets of values of cost coefficient β. Figure 1 graphically illustrates the relationship between parameters β1 (y-axis) and β2 (x-axis) in the context of these changes. Green: new cartel members; $l = k + 1$. A straight line is clearly visible, which distinguishes the sets of β1 and β2 parameters, causing a different number of cartels. A set of β parameters was applied to each of the graphs.

Figure 1.

Simulation points on the plot: the sequence of numbers on the graph denotes initial β parameters of cartel members



Source: own calculation, based on simulations. Sample source numerical values taken from (Prokop, 2011, Table 1) or also sampled within the intervals between these values, with a step of 0.01. See also: Table 1.

The graphs clearly show that the phase transition area between cartel size k and l = (k + 1) is given by:

$$\beta_1 = B - \beta_2 \qquad (9)$$

In the case of the model, it is apparent that in order to change the number of cartel members, i.e. $l \neq k$ (e.g. $l > k$), a necessary but not sufficient condition is that B is a positive number. The MathCAD program was used to calculate the numerical values of B for the four cases in the figure, as shown in Table 2.

Table 2.

Calculation of parameter B for constant values of other parameters: β, b and A

values of other model parameters	value of B
a = 100; b = 1; β3 = 0.4	1.1836
a = 100; b = 1; β3 = 0.6; β4 = 0.5	1.7754
a = 100; b = 1; β3 = 0.4; β4 = 0.3; β5 = 0.2	1.0920
a = 100; b = 1; β3 = 0.5; β4 = 0.4; β5 = 0.3; β6 = 0.2	1.3621

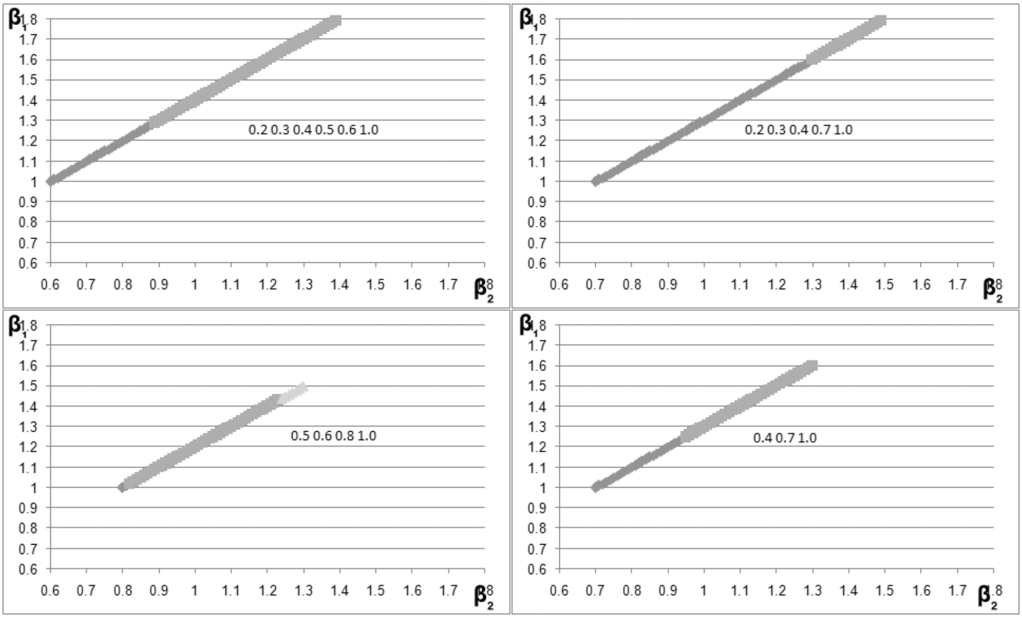
Source: own calculation based on solution of equation: eq. (7) = eq. (8), with all parameters set to constant. All data (parameters) mentioned within rows.

3. **Discovery or acquisition of new R&D knowledge.** This scenario is built on the example of the discovery (as the result of group project or a single company sharing this resource) of new knowledge protected by exclusive IP rights (e.g. a patent). An additional assumption, as in previous cases, is that knowledge is relevant to cost, i.e. it improves productivity. Because it is new knowledge, it increases the parameters β within the cartel evenly and by a fixed amount. In this case, however, the parameter of the most effective company, β1, should also be increased, thereby limiting the variability of the parameters by max (β1, βk). In this particular scenario, there was no change in the stability of the parametrised cartels.
4. **The emergence of new business knowledge.** This scenario can be realized through any event related to business knowledge (know-how), which becomes public and, as before, affects the productivity of companies. For example, new scientific knowledge sufficient for implementation is discovered and made public (published), or alternatively, the effect of a publicly funded project (e.g. EU funds) is transferred to the public domain, on the basis of the relevant provisions of project regulations and the consent of the company.

In this case, there are sets of parameters that result in destabilising the cartel, or having a new member join (similar to the results of previous analyses), but two companies can also join. As in the previous case, the variation in cost parameters is limited by the value max (β1, βn). Moreover, on the basis of numerical simulations, the stability of individual cartels with fixed cost parameters likewise remains impaired. However, it is not easy to draw conclusions on the basis of Figure 2, which illustrates these cases, about the limits of variation depending on the remaining size in the model (this is obviously not to say that there are no such dependencies). A set of parameters β was applied to each of the graphs. Green: $l = k + 1$; yellow: $m = k + 2$. However, this shows that, on the basis of the analyses, the same cartels are affected by instability as in the case of 'joint investment in R&D'.

1. **Expiration of exclusive R&D rights (outside a cartel)**. This occurs when one of the companies ($1 \leq$ and $\leq n$) has exclusive rights to e.g. a patent that has expired. From this point on, the technical solution and the knowledge acquired can also be used by its competitors, without their having to obtain consent or incur any costs. Such rights may be owned by a company in or outside the cartel. As a result, companies with lower efficiency ($i < j \leq n$) would 'inherit' the efficiency of a company with a monopoly until recently – βi. When the company was outside the cartel ($k < i \leq n$), no changes in its structure were observed, and so the cartels remained stable.

Figure 2.
Simulation points on the plot. A sequence of numbers on the graph denotes initial β parameters of cartel members



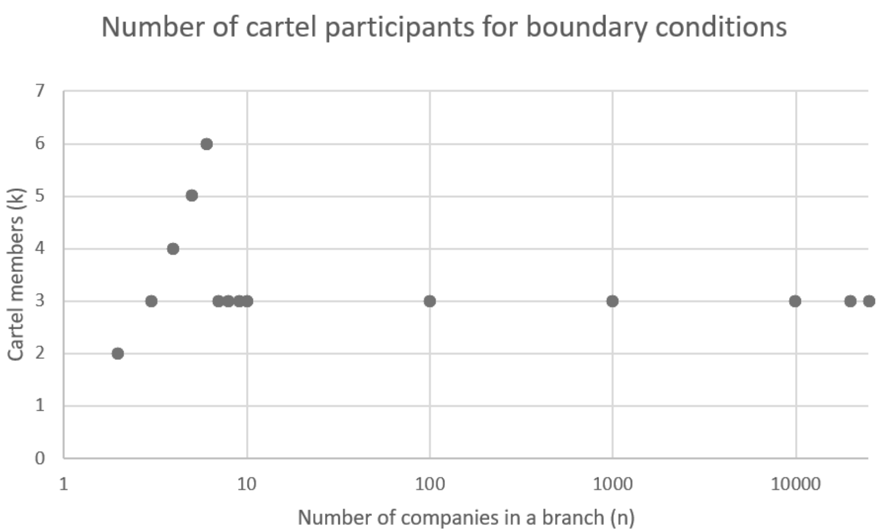
Source: own calculation, based on simulations. Sample source numerical values taken from (Prokop, 2011, Table 1) or also sampled within the intervals between these values, with a step of 0.01. See also: Table 1.

2. **Expiration of exclusive R&D rights (inside a cartel)**. Consider the analogous situation where a cartel company owns an IP $(1 \le i \le k)$. In the case of its expiration and diffusion of knowledge 'downwards' (i.e. to less efficient cartel members – if any – and other companies in the industry), there are sets of cartels (given a set of cost parameters), similar to the case of scenarios discussed earlier ('the emergence of new business knowledge' or 'joint investment in R&D'), where the cartels grow larger and therefore cease to be stable. However, these are not identical sets of cartels (i.e. sets of βi parameters), which were discussed above in the destabilizing scenarios.

4. 4 are Few

When the trend line formulas for the graphs (Eq. 7) and (Eq. 8) are compared, the decrease in efficiency is readily apparent. The directional coefficients are as follows: $3 \cdot 10 - 8$ for the random vector β and $4 \cdot 10 - 8$ for the tests with extreme values. The execution time therefore increased by $1 \cdot 10 - 8$, or 33.3%. Although the time is longer, the values are still very low. Further analysis of the situation leads to the conclusion that the loop exit occurs at very low k values. Such a relationship results in a significant increase in performance compared to functions with calculations on a triangular matrix. This is because the triangular matrix is computed in its entirety each time, which means that it will have the same performance for boundary values as for standard ones. The increase in the execution time of the function is almost entirely dependent on the length of the input vector. In order to draw further conclusions, it is necessary to analyse the values returned by the functions.

Figure 3.
Number of cartel participants for extreme parameters



Source: Result of the script looking for the maximum number of cartel members. Sample source numerical values taken from (Prokop, 2011, Table 1) or also sampled within the intervals between these values, with a step of 0.01.

Figure 3 presents the number of cartel participants for parameters (β1 = 1, …, βn = 1), a = 1000 and b = 0, i.e. parameters that should contribute to the formation of large cartels. With a length vector of 7 there was no increase. The literature on the creation of these structures contains Reinhard Selten's definition of them: 'A Simple Model of Imperfect Competition, Where 4 Are Few and 6 Are Many' (Selten, 1973). The model obtained from experimenting with completely abstract parameters confirmed his findings. Selten did not actually perform experiments for boundary values. This explains his result of 6, despite its being very difficult to obtain. If inequality (10) is met, it is not profitable for a company outside the cartel to join it (Prokop, 2011).

$$\pi_{d,i}(\alpha_1,\ldots,\alpha_{i-1},1,\ldots,\alpha_n) \geq \pi_{c,i}(\alpha_1,\ldots,\alpha_{i-1},0,\ldots,\alpha_n) \quad (10)$$

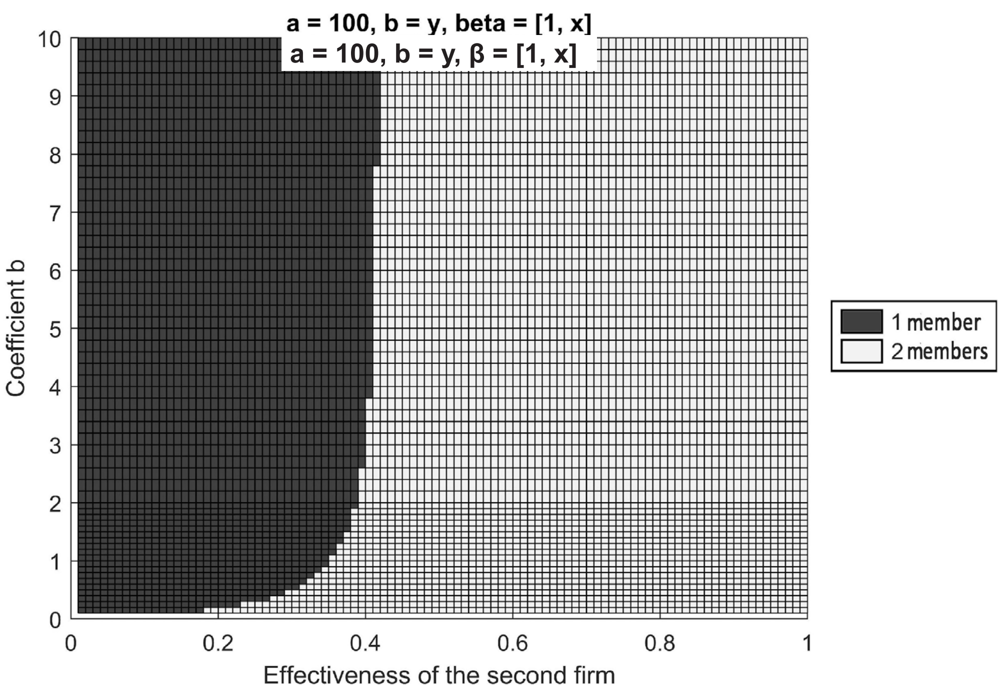
5. Graphs and analyses

5.1. Nash equilibrium

In order to graphically present the data, the script was supplemented with further functions that allow heat maps and graphs to be generated in three-dimensional space (i.e. for XYZ parameters). When the data are presented this way, the relationships that occur when individual parameters are changed become clearly visible. As already mentioned, parameter 'a' has a negligible influence on the number of companies in the cartel, and altering it resulted in no discernible differences in the heat maps. Therefore, as this parameter has no substantive value, it is not analysed in this paper.

Figure 4 shows the distribution of cartel members according to coefficient 'b' and the efficiency of the competitive company (second in order of ranking of cost parameters). Parameter 'a' is not included in the graph because it does not affect the dependencies. When comparing the two algorithms, the same results were obtained (which is intuitive). The graph presented below illustrates this distribution by factoring in the efficiencies of companies 2 and 3 and the change of parameter 'b'.

Figure 4.
Number of cartel members for vector β length 2 (2D)



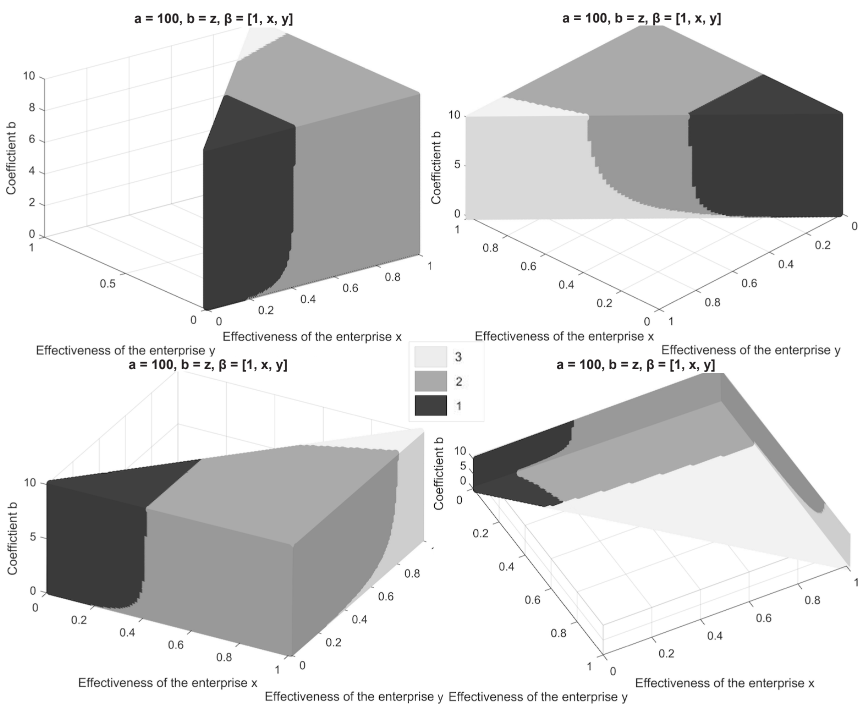
Source: Cross-sectional analysis of the results of the script counting cartel members for 2 companies. Sample source numerical values taken from (Prokop, 2011, Table 1) or also sampled within the intervals between these values, with a step of 0.01.

When analysing vectors longer than 2, the programs show discrepancies. This means that they do not return the correct values. This is not in accordance with Finding 2 in the article (Prokop, 2011), where the game describing the formation of the cartel has exactly one equilibrium point. The problem becomes apparent when the graphs are compared (Fig. 6). These are cross-sections of the figure presented in graph 5 in relation to the angle (OZ axis), which represents coefficient 'b'. The area concerned has been marked with a red circle (Fig. 6). This is due to the Nash equilibrium behaviour.

The main thread of this work, viz. the number of cartel members, better illustrates this problem. Given vector β = [1, 0.3, 0.1], coefficient b = 0.1 and a = 100, the script results in 2 cartel members. According to the assumptions of the Nash equilibrium, if one of the members, for example, the second most efficient one, changes its strategy and leaves the cartel, it will lose out on this turn of events. Similarly, if a non-member joins a stable cartel, it will disrupt the stability and also make a loss. When designing the algorithms, the aspect of equilibrium was omitted. This resulted in the iterative algorithm returning the minimum number of members, and the one that uses matrices – an incorrect one.

Figure 5.

Number of cartel members for vector β length 3 (3D)



Source: Cross-sectional analysis of the results of the script counting cartel members for 3 companies. Sample source numerical values taken from (Prokop, 2011, Table 1) or also sampled within the intervals between these values, with a step of 0.01.

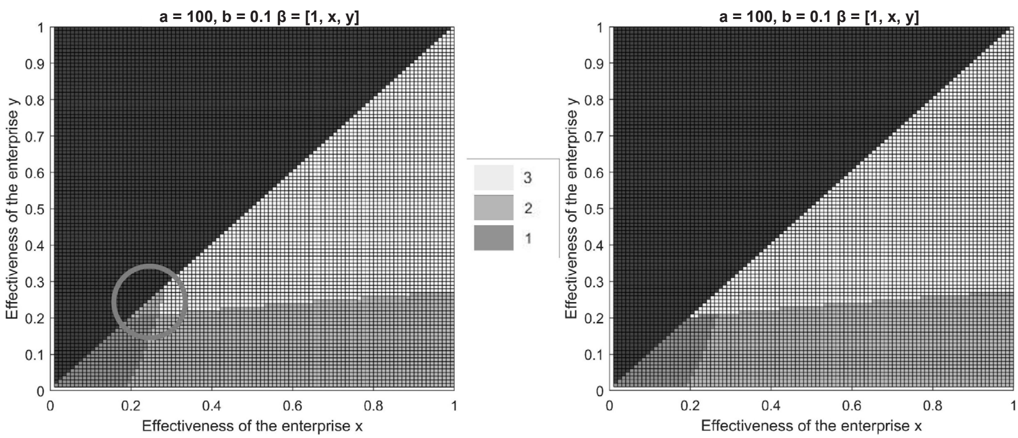
After modifying the CartelMembers function to return a matrix for counting cartel members, it can be seen that there is a gap of zeros between rows 1 and 3. This implies a Nash equilibrium for one member of a cartel or three. The function only sums the first column and returns the number of members. This result is incorrect.

The iterative version returns an incomplete result because it returns its predecessor when it encounters the first case that does not meet the condition of a stable cartel. The Graph (Fig. 5) was generated using the iterative function, which means that it represents the distribution of the smallest cartels.

The discrepancy between the results of these two versions of the function shows the space in which the coefficients of the second and third companies from vector β are located. This is the area where the Nash equilibrium is 2. This is illustrated in Figure 7. The graphs are not precise, as they were plotted using triangulation and on the basis of a dot cloud.

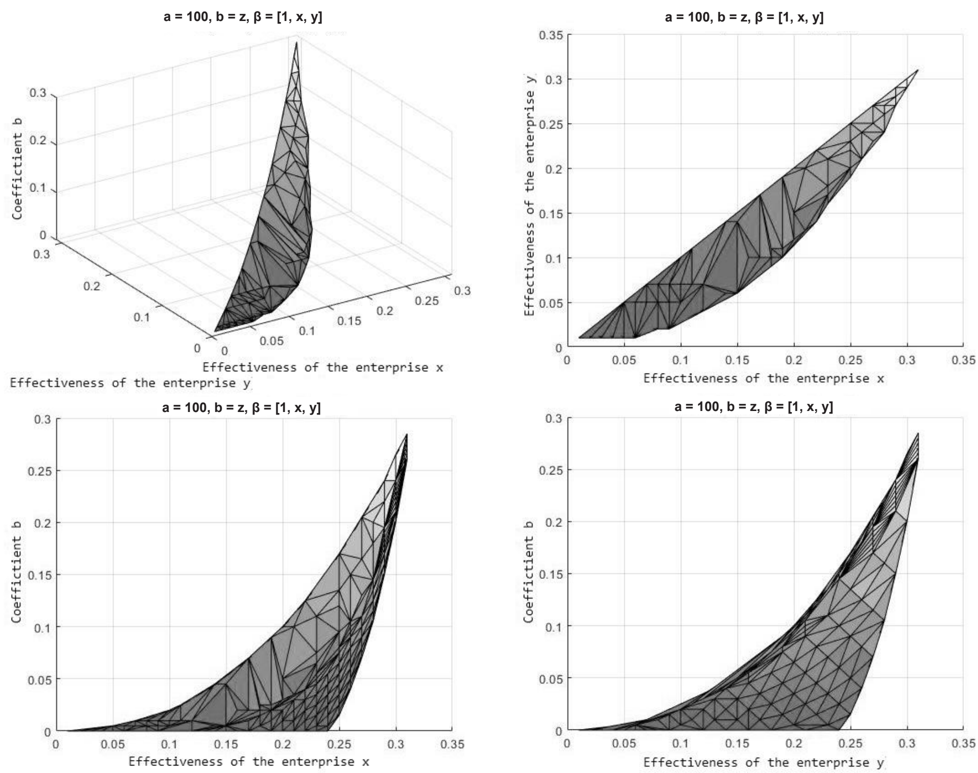
Figure 6.

Comparison of function results



Source: Result of comparing the script counting all cartel members to the script counting the first member encountered. Sample source numerical values taken from (Prokop, 2011, Table 1) or also sampled within the intervals between these values, with a step of 0.01.

Figure 7.
More than one Nash equilibrium in the β parameter space



Source: Extracting Nash equilibrium greater than 1 for 3 companies from the results of the script counting all cartel members. Sample source numerical values taken from (Prokop, 2011, Table 1) or also sampled within the intervals between these values, with a step of 0.01.

5.2. The percentage distribution of cartels

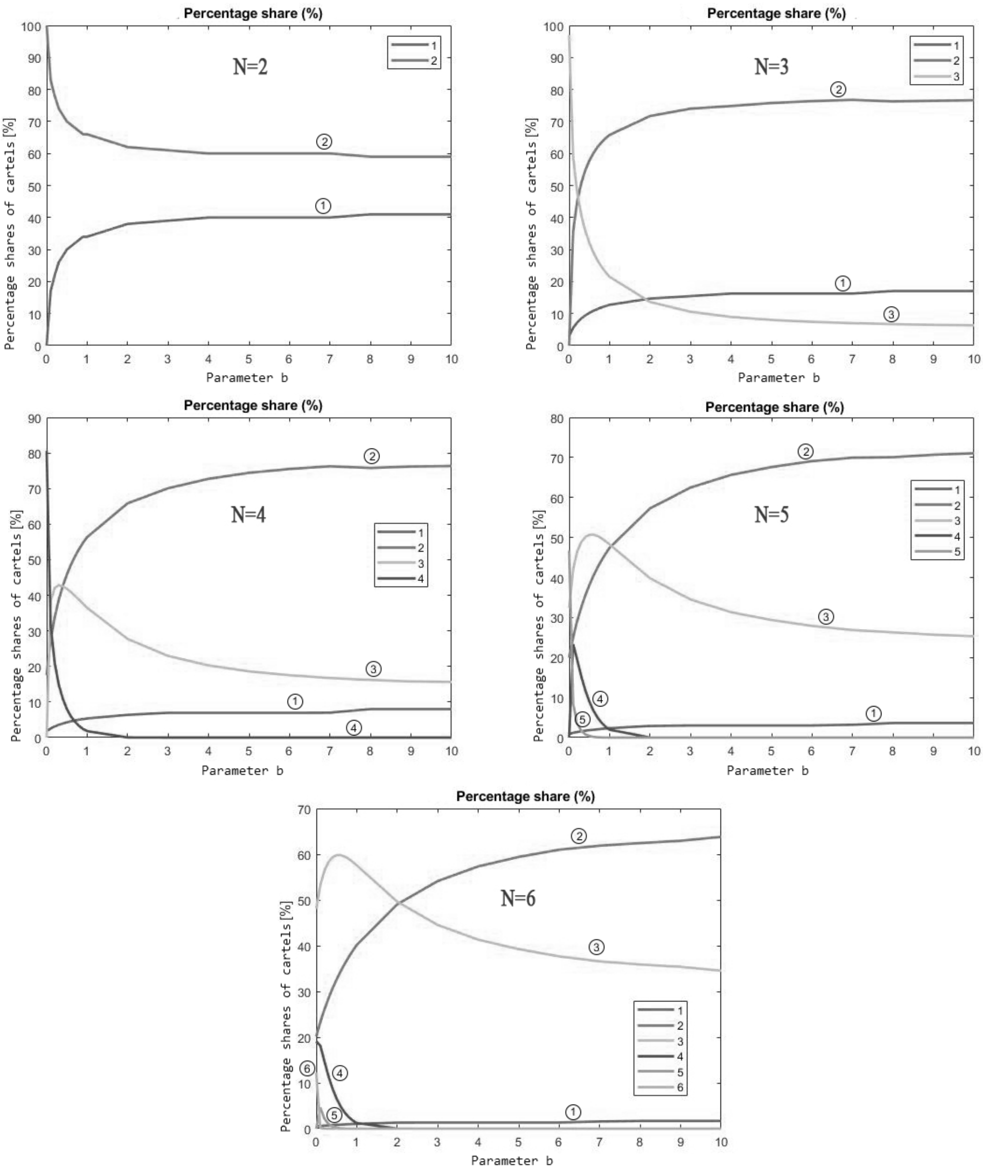
Each line is marked with a number corresponding to the size of the cartel. As stated above, these graphs are generated for the smallest number of members, which means that Nash's equilibrium has not been taken into account. By changing the variable N specified at the beginning of the range [2, 6], it is possible to determine for what number of companies the percentage of members in a given population will be generated. Figure 8 presents the results.

Figure 8 shows the odds of cartelisation with a given number of members at a given parameter and demand function 'b'. As can be seen, the lower the directional coefficient, the larger the cartels. Cartels consisting of 2 or 3 members dominate. Looking more closely, Selten's finding has been confirmed (empirically) once again. Despite parameter 'b' approaching 0, cartels of 6 members represent a minimal percentage.

In addition, it is revealed that the more companies are analysed, the harder it is to obtain a stable cartel of more than 3 companies. Fig. 8 has additional graphs showing the data source for generating graphs and how to interpret them.

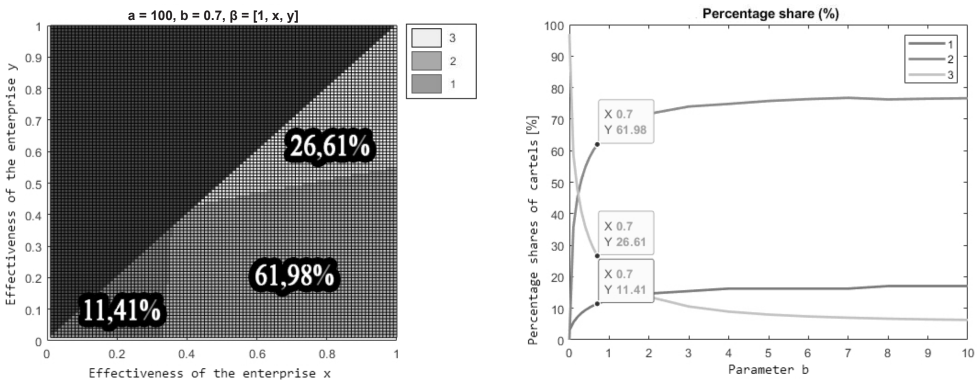
Figure 8.

The percentage of cartels in a given population



Source: Comparison of the chances of a cartel to emerge calculated from the script counting cartel members. Sample source numerical values taken from (Prokop, 2011, Table 1) or also sampled within the intervals between these values, with a step of 0.01.

Figure 9.
Interpretation of Figure 8



Source: Script calculating cartel members, interpretation of results. Sample source numerical values taken from (Prokop, 2011, Table 1) or also sampled within the intervals between these values, with a step of 0.01.

This approach to illustrating the data allows for a less precise, but easy to understand, presentation of how cartels are distributed in multidimensional spaces. The graph on the left of Fig. 9 shows the cartels for parameter b = 0.7, and the one on the right, the percentage representation of the cartels.

6. Discussion

Knowledge can spill over between organizations, so individual companies have a state (degree) of knowledge that may change. For example, it depends on whether one or more competitors have new knowledge (relative decrease in knowledge) or the company itself acquires or discovers it (increase in knowledge). Knowledge, such as the technology used in production, manufacturing, services, is a cost factor. There are therefore incentives for businesses, as well as business organisations, to support innovation, which, in the form of financial streams or tax exemptions, is more likely to be achieved at the level of the economy as a whole.

Table 3 summarises the previous scenarios:

Table 3.
The surrogate of simulation results from this work

Market event	Description	Simulation effect
Sharing of know-how within the cartel	cartel members increase their cost parameters	no observed effect on the stability of the cartel
Investment in R&D within the cartel	cartel members increase their cost parameters	in some cases, stability may be impaired

Market event	Description	Simulation effect
Discovery or acquisition of innovative knowledge	cartel members increase cost parameters by a fixed amount	no observed effect on the stability of the cartel
New business knowledge on the market	all companies increase cost parameters by a fixed amount	in some cases, stability may be impaired
Expiration of exclusive rights outside a cartel	all cost parameters except one increased by a fixed amount	no observed effect on the stability of the cartel
Expiration of exclusive rights inside a cartel	all cost parameters except one increased by a fixed amount	in some cases, stability may be impaired

Source: own study. The brief summary of the results described in chapter 3.3.

As stated above, changing the distribution of knowledge held among companies in a branch can sometimes bring about the elimination of cartels, despite the diversity of companies and previous research results. These or similar events often affect the costs of selected companies and sometimes cause stable cartels to become unstable. In general, it can be concluded that, since these scenarios appear (albeit irregularly), in the case of many existing cartels – from the perspective of their economy of operation and profit maximisation – they significantly reduce their stability.[1]

Prokop (1999) pointed out that anti-monopoly policy is in principle unnecessary, since cartels composed of companies operating in an industry where the cost parameters (and functions) are identical (homogeneous cartels) are unstable over time. However, he later explored the subject further (Prokop, 2011) and examined what would happen if this condition were not met. His additional analyses and simulations showed that unfortunately, a stable cartel is always created.

As the main conclusion of this work, the authors consider some suggestions concerning cartels, and possibly clusters of companies. This proposal may be treated as a suggestion for the establishment or maintenance of economic policies that foster innovation. Implementing, maintaining, or intensifying policies that foster innovation by supporting non-associated and associated companies, as well as the science sector, benefit the economy in two ways. Apart from direct economic benefits, including new, better, cheaper products or services, higher employment, more rewarding jobs, and increased exports, the chances of stable cartels being formed, including within the framework of existing cluster organizations, are reduced.

In addition, having already started working with the correct function, the percentage of cartels of given sizes was examined. The dependency was studied against the ‘b’ parameter of the demand function. The graphs show that a low ‘b’ coefficient promotes the formation of large cartels, which is logical, as very slowly falling demand does not favour competition.

[1] Although numerical analyses only show that unstable cartels are increasing, it is possible to imagine sequences of events following the flow of *know-how* where, with different sets of cost parameters, cartels decrease their numbers each time.

Summary

The scale of cluster formation and its economic importance on a macroeconomic scale (but not only) seem to be growing. These structures generally facilitate the acquisition of competitive advantages and internationalization of business for SMEs. On the other hand, there are increasing threats of competitive collusion, including through the development of ICT, and also on a global scale. Economic policy should therefore focus on promoting innovation, in particular technology clusters and/or R&D investment, but also on tackling the emergence of market-unfriendly alliances.

Cartels tend to stabilise if modelled with an apparatus (Prokop, 2011), which is economically quite simple, but at the same time convincing. This creates threats and the effects are felt by everyone: employees of companies outside the cartel, consumers, states. The fight against cartels is difficult and often requires international cooperation and extensive investigative measures. In addition, the relevant institutions (OCCP) have limited resources and budgets as one of hundreds of government agencies. It would therefore be desirable for there to be an 'anti-cartel invisible hand of the market', which, according to the principles of economics, addresses or even eliminates this problem.

Given the existence of certain market events linked to know-how flows, the stability of heterogeneous cartels is not a foregone conclusion. These events are both common and typical. Therefore, even considered in the medium term, the probability that they will impact (within a selected industry) an allegedly existing cartel would seem high. For this reason, pro-innovation policy, especially when dedicated to promoting (e.g. through subsidies) innovations created among groups of companies, can significantly reduce cartelisation.

The results obtained in the present paper show that supporting innovation plays a dual role in the economy, viz.:

1. it has a positive effect on economic development and thus social development;
2. it reduces the scale, frequency and negative impact of cartels.

Hence, it can be concluded that stable heterogeneous cartels are not completely stable; since industries with R&D operations are periodically 'bombarded' by new events related to know-how flows (it should be added that there are often legal issues related to IP within such industries). Therefore, it can be expected that the preservation of stable cartels will become a suboptimal solution over time, and they will consequently be broken up. However, as industrial policy almost always has a pro-innovation component, it virtually guarantees stable competitive collusion.

The conclusions in this paper are formulated in the context of the stability of heterogeneous 'R&D cartels' and in the form of an additional, important justification for pro-innovation policy. This places it within the realm of normative economics with positive economics elements (Kołodko, 2014).

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